The University of Nottingham

SCHOOL OF EDUCATION

AN EXPLORATORY STUDY OF PALESTINIAN SCIENCE TEACHERS' VIEWS OF THE NATURE OF SCIENCE

By

MOUSA M. M. KHALDI, BSc., MEd.

Thesis submitted to the University of Nottingham in fulfilment of the degree of Doctor of Philosophy

July, 2010

Abstract

This mixed methods study investigates Palestinian science teachers' views of the nature of science (NOS), with an in-depth exploration of the nature, causes and context of these views, and the possible reasons why teachers hold such views. The research provides suggestions of possible ways to improve Palestinian science teachers' views of NOS, and the factors within the Palestinian context that might either facilitate or hamper efforts to promote teachers' understanding of NOS.

Quantitative data were collected during the first phase of the study from a sample of 277 teachers working in three areas in Palestine. Twelve teachers were randomly selected for the second qualitative phase. In line with the regional and global literature, the results of the closed NOS survey, the open-ended questionnaire and the individual semi-structured interviews revealed that Palestinian science teachers hold relatively naïve, traditional views of most of the main tenets of NOS.

During the qualitative phase, a series of semi-structured interviews was also carried out with ten Palestinian academics to explore in depth their views and suggestions concerning the nature, causes and context of teachers' views of NOS. They identified possible factors responsible for this apparent naïveté in teachers' views and suggested ways to improve their understanding of NOS. The analysis of academics' responses revealed eight main factors that might explain the naïveté of teachers' views of NOS: Palestinian socio-cultural background, education policy, teachers' own personal values, teaching approaches at school and university levels, science textbooks, teacher training programmes, educational supervision and school resources.

Possible ways to improve teachers' views of NOS could be grouped in six main areas: tertiary science teaching and teacher preparation programmes, teaching as a well-resourced profession, Palestinian science textbooks, education supervision and in-service teacher training,

educational leadership and administration system, and public scientific literacy and critical awareness.

Finally, there is a consideration of the possible implications of these findings for teaching and teacher education in Palestine, for policy making bodies in the Ministry of Education and Higher Education, for methodology, and for future research in the area.

Acknowledgments

No human can accomplish a single work and ascribe it exclusively to their own doing. In all achievements, there are always clear impressions other than those of their owners which point toward the supervision, advice, constructive criticism, or approbation of others.

As I have completed my thesis, first and foremost, it is my pleasure to express my sincere thanks and deep appreciation to my supervisor, Dr. Sue McCarthy, whose insight, valuable guidance, and moral support have been of great significance throughout this work. Without her continued assistance and orientation, this work could not have materialised.

My thanks and gratitude go to Dr. Peter Gates for his support and thoughtful consideration of my research. In addition, I wish to thank Professor John Morgan, Dr. Len Newton and Professor Simon McGrath, from the School of Education for their encouragement and valuable intellectual support. I am also grateful to the support staff in the School, especially Mrs. Jackie Stevenson, Mr. Sanjay Sharma and Ms. Jane Restorick for their incredible efforts to facilitate the work.

I would also like to express my deep appreciation to my colleagues in the PhD programme for their wonderful co-operation and critical friendship over our four years stay in Nottingham. Special thanks go to my colleagues and friends back in Palestine, Nadir Wahbeh, Safi Safi and Wael Kishek, for their advice and contributions to my thesis.

Last but not least, I wish to express my deepest gratitude to my beloved family who gave me every support and encouragement over this long journey. My heartful thanks go to my parents, Abu Mousa and Im Mousa, my wife Rana, my son Majd, my daughters Leen and Bana, my brothers Khaleel, Khaldi and Ali, and my sister Ezeyya. This thesis is dedicated to you for your love and support.

God bless you all.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AAAS	American Association for the Advancement of Science
MoE	Ministry of Education
MoEHE	Ministry of Education and Higher Education
NRC	National Research Council
NSES	National Science Education Standards
NSTA	National Science Teacher Association
PCK	Pedagogical Content Knowledge
PLO	Palestinian Liberation Organization
PNA	Palestinian National Authority
UNRWA	United Nations Relief and Works Agency

Chapter One—Introduction and Research Context

1.1 Research Background

The broad aims of the school science curriculum in Palestine, as in many other countries, reflect the importance of science in general, and the nature of science (NOS) in particular, in modern society (American Association for the Advancement of Science (AAAS), 1993; Driver, Leach, Millar and Scott, 1996; National Research Council (NRC), 1996; Palestinian Ministry of Education and Higher Education (MoEHE), 2008). Improving learners' understanding of NOS has shifted from being portrayed as merely beneficial, to being considered fundamental to scientific literacy (AAAS, 1990; NRC, 1996), which is accepted as one of the main goals of science education programmes in many countries (Jenkins, 1997).

It is widely accepted in the literature that the definition of the nature of science is as tentative as the definition of science itself. There is no single definition of NOS that has full support among philosophers, historians and educators of science (Abd El Khalick and Lederman, 2000b). This lack of consensus is exemplified by the range of views held by philosophers and historians, such as Feyerabend (1975), Popper (1963, 1968), Hempel (1966) and Kuhn (1962, 1977), and leaves the definition of NOS open ended (Lederman, 1992; Alters, 1997). The meaning and perceived importance of understanding NOS, rather than being stable, have developed and changed in line with the major shifts in focus in the fields of philosophy, sociology and the history of science throughout the last century (Abd El Khalick and Lederman, 2000b; El Sheikh, 2002).

In the first half of the 20th century, NOS was seen as that part of the corpus of scientific and philosophical knowledge that allowed students to think scientifically and to use science in problem solving. Dewey (1932, cited in El Sheikh, 2002) stressed the scientific way of thinking as a science educational goal to improve students' intellectual abilities. The NOS focus during this period was on "the scientific method" and on the processes of science (Hurd, 1960) where the understanding of NOS was equivalent to understanding "the scientific method". In this context, Lederman (1992) pointed out that the Central Association of Science and Math Teachers in the United States of America recommended the inclusion of teaching about scientific method and the processes of science in school level science classes during the early 1960s.

The 1950s and 1960s witnessed the emergence of the movement for reform of science curricula and science education with a greater shift towards new hypothetico-deductive inquiry-based paradigms of instruction (El Sheikh, 2002). The objective of NOS at that time was to emphasise scientific processes and inquiry (Welch, 1966). Schwab (1962) also emphasised teaching science as a process of inquiry, with the intention to develop students' understanding of NOS. Shymansky, Kyle and Alport (1983) pointed out that the new curricula in this period emphasised the nature, structure and processes of science, and also the higher cognitive skills and appreciation of science. However, according to Harris and Taylor (1983), this inquiry-based learning and curriculum suggested that the job of scientists was merely to discover nature's laws leading to a naïve view of science and a portrayal of experimentation and laboratory work as a step-wise scientific method proceeding from observation to theory. Matthews (1994) attributed the failure of this instruction to teachers' unfamiliarity with the history and philosophy of science.

Beginning in the 1970s, there was a profound shift in ways of viewing and defining NOS. As El Sheikh (2002) explains, this development was caused largely by a change in the main purpose of school science teaching towards "Science for All", leading to rigorous calls for science education to become more broadly relevant for all students, and the appearance of new philosophies of science based on new studies in the history, psychology and sociology of science. In America, the nature of scientific knowledge was characterised as being tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic and empirical (Centre of

United Science Education, 1974 cited in Liu, 2003). These nine aspects of scientific understanding remain important today.

By early 1980s, psychological and sociological factors started to appear in NOS definitions (Abd El Khalick and Lederman, 2000b). The National Science Teacher Association (NSTA) (1982) stressed the empirical and tentative nature of scientific knowledge, and the major role of theory and inquiry in science, as the main components reflecting an adequate understanding of NOS.

NOS has been characterised in a range of different ways, as detailed in Chapter 2, showing NOS to be an amalgamation of philosophy, psychology and the sociology of science. However, NOS most commonly refers to the epistemology of science, to science as a way of knowing, and to values and beliefs about how scientific knowledge develops (Lederman, 1992; McComas, 1998).

Perhaps most importantly, NOS has been defined as a critical component of scientific literacy (AAAS, 1993; DfES/QCA, 1995; NRC, 1996), with a goal of helping students to understand the basics of science in order to promote effective application of science. Abd El Khalick and Lederman (1998) argue that while there might still be debate and disagreement about specific definitions of NOS, there is a consensus among philosophers, historians, sociologists of science, scientists and science educators as to what aspects of NOS are considered critical to school education. These include the understanding that scientific knowledge is tentative, empirical and theory laden; it is the product of inference, imagination and creativity; and scientific knowledge is also socially and culturally embedded. Other accepted tenets include the distinction between observation and inference, the refutation of one universal method for doing science, and an authentic relationship between theories and laws.

As McComas (1998) and McComas and Oslon (1998) point out, these agreed salient features of NOS have been emphasised in recent curriculum and science education standards and reform movements such as the AAAS (1993), National Curriculum for Science (DfES/QCA, 1995) and NRC (1996). More recent curriculum development initiatives in England and Wales continue to reflect this pattern (DCSF, 2004, 2008). Moreover, these aspects overlap in the definitions of NOS expressed by many science educators (e.g., Rubba and Anderson, 1978; Driver et al., 1996; Abd El Khalick, 1998; Chen, 2006). They also reflect assumptions behind efforts to reform science education that relate back to, and are supported by, Kuhn's ideas (e.g., Kuhn, 1962, 1977) that shape current views of NOS. Therefore, these aspects of NOS are adopted in this study as part of the theoretical framework for investigating and analysing Palestinian science teachers' views of NOS, and the degree of sophistication they demonstrate.

1.2 Rationale and Importance of this Study

This research is underpinned by the arguments that firstly, the main goal of science education in contemporary societies is the preparation of scientifically literate people who have the knowledge, understanding, skills and attitudes to make a contribution to society and participate effectively in everyday decision-making processes; and secondly that a sophisticated understanding of NOS is a core component of scientific literacy (Jenkins, 1997; Abd El Khalick and Lederman, 2000b). Historically it has been widely accepted that for these aims to be realised, it is vital that teachers have contemporary views of NOS in order to develop a meaningful understanding of science in their learners (Kleinman, 1965, cited in Lederman, 1992; Lederman, 1992, 2007). As Liu and Lederman (2007) explain, science teachers serve as a major source of scientific knowledge and understanding. They are likely to project their own views of NOS in their classroom teaching, thus influencing their students' learning and understanding of NOS, although as Abd El Khalick and Akerson (2004) maintain, further research in this area is needed. Consequently, it should be a decisive goal for teacher preparation programmes to develop science teachers who hold contemporary views of NOS.

Much research, from different parts of the world, has considered teachers' views of NOS (Schmidt, 1967; Carey and Stauss, 1970; Pomeroy, 1993; Lakin and Wellington, 1994; Abd El Khalick and BouJaoude, 1997; Abd El Khalick and Lederman, 1998; Smith and Anderson, 1999; Dekkers, 2002; Khishfe and Abd El Khalick, 2002; Liu and Lederman, 2002; Tsai, 2002; Yalvac and Crawford, 2002; Cakir and Crawford, 2004; McCarthy and Sanders, 2007). However, to date no research has been carried out to explore in any depth Palestinian science teachers' views of NOS, the range of issues related to teachers' and learners' understandings of NOS and the possible ways of improving understanding in this area (Wahbeh, 2009).

Despite this lack of research, my strong sense is that within the academic science education community there are concerns about the quality and effectiveness of science education in schools. My own science education at a primary, secondary and tertiary level, as well as my three years work as a researcher in a Palestinian non-governmental centre for educational research, my participation in collaborative action research projects, and my work in the field of science teacher education for four years, has given me firsthand experience of Palestinian school science teaching, and has left me with a strong belief that science is not portrayed in an authentic manner.

While concerns seem to be prevalent, evidence is lacking, as my initial literature review indicated. At the heart of the initial seeds of my research planning was the belief that an informed understanding of the nature and origins of teachers' views of NOS, their origins, and related policy and practice is prerequisite for the development of appropriate school science curricula and effective teacher education programmes in Palestine. It is my hope that this research will prompt a debate within the Palestinian science education community about what and how science should be taught in Palestinian schools, and how our teachers should be educated.

Additionally, this research aims to contribute to the global literature on this topic by providing information about the Palestinian context that will enable future comparative studies, particularly as this study looks at the topic from a cultural, social and religious perspective. The study explores the relationship between teachers' views of NOS and their religious and socio-cultural beliefs in order to further understand how teachers' socio-cultural and religious beliefs and values affect their views of NOS. Therefore, the elucidation of the Palestinian position will be of significance to science educators interested in the role of culture in science education, and more specifically in the impact of teachers' socio-cultural and religious values on their understanding of NOS.

1.3 Purposes of the Study and Research Questions

This study seeks to explore and describe the nature, causes and context of Palestinian science teachers' views of NOS, and the possible reasons why they hold such views. The research also aims to provide suggestions of possible ways to improve Palestinian science teachers' views of NOS, and to elucidate the factors within the Palestinian context that might either facilitate or hamper efforts to promote teachers' understanding of NOS.

It is against this backdrop that this study seeks to investigate a reality of Palestinian science teachers' views of NOS, to place them within the continuum of global views of NOS, and to provide a foundation for research into the development of a contemporary understanding of NOS within the Palestinian education context.

In order to achieve these goals, this study was guided by the following three research questions:

1. What views of NOS are held by Palestinian science teachers?
2. According to Palestinian science education stakeholders, what factors influence science teachers' views of NOS?

3. What views do Palestinian science education stakeholders hold regarding the advancement of science teachers' views of NOS?

I would argue that these particular research questions are clear, empirically answerable and practically manageable for the researcher, with evidence accessible in principle and in practice. They build on previous research, and have significance and practical usefulness as the findings have implications for policy and practice (McIntyre, 1997).

1.4 Research Context: Education in Palestine

Palestine lies in the West of Asia between latitudes 29.30 and 33.15 N, and longitudes 24.1 and 35.40 E. Today, Palestine, comprising the West Bank and Gaza Strip, has an area of 6200 sq km and a population of 2.9 million in the West Bank and 1.5 millions in Gaza Strip. Prior to 1917, the West Bank and Gaza Strip together with what today is known as Israel, constituted historical Palestine. It had an area of 27009 sq km and was bordered by Syria and Lebanon to the north, Egypt to the south, Jordan and Syria to the east, and the Mediterranean Sea to the west. The percentage of the population who are of school age (between 6 and 18 years old) is 38 % indicating that the education sector constitutes a very large proportion of the Palestinian community. Those aspects of the educational context in Palestine that are considered relevant to this study and are reviewed here include its historical development and structure, as well as teacher education and the science curriculum.

1.4.1 A Historical Perspective

As with any country, the current education system of Palestine has been greatly affected by its historical context. Therefore, in order to understand and appreciate the current perspective, we need to have some insight into its origins and history.

It is widely accepted within the Arab context that Palestinian education has suffered greatly as a result of Israeli occupation over the last centuries (Al Haq, 2005). For many decades, Palestinians were deprived of autonomy and control of their own education. They have been schooled under many different educational systems ruled by different countries apart from their own: Ottoman rule (1869-1917), the British Mandate (1917-1948), Jordanian and Egyptian Guardianship (1948-1967) and the Israeli occupation (1967-1993) (Kabaha, 2005). This history is considered by many to have contributed to the development of an irrelevant and outdated education system in Palestine. Below is a brief overview of the decisive historical development stages and dramatic changes within Palestinian education from the Ottoman Period to the present, with special reference to teacher education and impact on the education sector.

The Ottoman Period (1869-1917): The start of Ottoman rule over Palestine in 1869 was considered the beginning of official public education in Palestine (Tibawi, 1956). The Ottomans established a very limited number of state schools in the northern districts of Palestine and the district of Jerusalem. In addition to the state schools, there existed two other types of schools: *"AlKuttab"* schools were religious in nature and focussed on teaching, reading and writing the Quran; and preaching schools were established by European-supported Christian missionaries wishing to set up schools in The Holy Land. In general, education was very weak in this era, largely because the formal language of teaching was Turkish, and teachers had limited formal education and lacked professional training (Mazawi, 1994). However, teachers enjoyed a privileged status within the community. They were engaged in the clarification of legal and religious questions through their writing and teaching (ibid).

The British Mandate (1917-1948): Tibawi (1956) explains that during this era, the education system was better organised and many state schools were established throughout the country. The education system was divided into four sequential phases: kindergarten which admitted six-year-old children for a year; lower elementary school for seven to eleven year olds; upper elementary school for twelve and thirteen year olds and secondary school for fourteen and fifteen year old children. The educational system was controlled by the British colonial administration, which saw the role of schools as to promote only the skills and knowledge required for the effective functioning and control of the government over Palestine. There was a lack of understanding of the real needs and skills of local Palestinians and therefore no attempt to educate the masses. Tibawi (1956) maintains that during this phase, Palestinian teachers participated actively in the national movement for Palestinian independence as their role became more politicised.

The Jordanian and Egyptian Guardianship (1948-1967): As Badran (1979) explains, in 1948 the State of Israel was established as the result of the Arab-Israeli war. Following the war, what remained of Palestine (the West Bank and Gaza Strip) was subject to two different education systems: Jordan assuming responsibility for the West Bank education and Egypt for Gaza Strip education. Both authorities created state school systems and implemented the same regulations for schools and teachers as they used in Jordan and Egypt. The education system they imposed was divided into three sequential phases: elementary phase for six to eleven-year-olds, preparatory phase for twelve to fourteen-year-olds, and secondary phase for fifteen to seventeen-year-olds. This era witnessed the establishment of a number of teacher education programmes and the emergence of a new sector of education for Palestinian refugees supported by the United Nations Relief and Works Agency (UNRWA). This offers nine years of free school education to Palestinian children who are registered as refugees.

The Israeli Occupation Period (1967-1994): During this period Israeli authority extended over the whole of Palestine, and the educational system fell under Israeli control, and specifically under the responsibility of the Ministry of Defence. Khaldi and Wahbeh (2002) explain that during the Israeli occupation, education reached its lowest ebb, particularly in the public schools which were largely neglected in favour of Israeli security. Teaching conditions were very difficult with very limited resources, overcrowded classrooms and irrelevant textbooks. It appeared that the

Israeli "hidden curriculum" (Vallance, 1991) aimed to fulfil only the minimum basic educational needs for the Palestinians (Kabaha, 2005). Teachers' salaries were low and in-service training was negligible (Khaldi and Wahbeh, 2002). Teachers were often unqualified and followed outdated teaching methods (Rigby, 1995). However, teachers in this period were political activists as well as educators and so contributed to the change that was to follow. This period also witnessed the establishment of the first universities in Palestine and these were under the supervision of national non-profit institutions.

The Palestinian National Authority (PNA) Phase (1994-Present):
As a result of the Oslo Agreement between the Palestinians and Israelis in 1994, the Palestinian National Authority (PNA) took responsibility for education in the West Bank and Gaza strip for the first time in more than 25 years. They established the first Ministry of Education (MoE). However, in 1996 a new Ministry was established under the name "The Ministry of Education and Higher Education and Scientific Research". It took responsibility for higher education in Palestine, while the mother ministry (Ministry of Education) continued to take responsibility for school education. In 2002, the two Ministries were merged together in one Ministry under the name "The Ministry of Education and Higher Education" (MoEHE). The Ministry immediately started building its structure by employing suitable human resource levels, and developing an operational system to take responsibility for funding and administration of public schools, where most of the school education sector became under its responsibility. This sector is currently responsible for over 76 % of schools, with 766,730 students and 38,134 teachers according to the 2007/2008 education statistics (MoEHE, 2007). The MoEHE is also responsible for part of the higher education sector. However, most existing institutions of higher education were established during the Israeli occupation by Palestinian individuals and group initiatives, mostly with the support of the Palestinian Liberation Organization (PLO), and with financial contributions from Arab countries. Although the curricula of the schools were under thorough censorship by the Israeli civil administration,

Palestinian higher education institutions were able to maintain their independence regarding educational programmes and curricula (UNESCO, 2002).

Statistics indicate that there have been general positive changes in the Palestinian educational system during the PNA phase of control between 1994 and 2000. The illiteracy rate for individuals 15 years or older in the West Bank and Gaza Strip dropped to 10.8 % compared with 13.9 % in 1997. Declines in elementary level drop-out rates, an increase in female enrolment in schools, and a decrease in the student/teacher ratio are all examples of improvements in the education sector since 1995 (Palestine Economic Policy Research Institute-MAS, 2002).

In September 2000 the education system under PNA supervision introduced for the first time in the history of the country a Palestinian school national curriculum for all subject areas. This replaced the Jordanian and Egyptian curricula that had been followed in the West Bank and Gaza Strip since 1948. In fact, Palestinians inherited an education system that had suffered severely from decades of negligence, absence of any development and a decaying infrastructure (Rihan, 2001). The MoE attempted to reform the educational system and produced a five-year development plan (2001-2005). This reform of the MoE was based on the following principles:

1. Education is a human right;
2. Education is a tool for social, economic and technical development;
3. Education is a source and a means for democracy and social values;
4. Education is a continuing life long process;
5. Education must be available to all Palestinians.

(MoE, 1999).

To improve the quality of education, the development of human resources across both primary and secondary levels was necessary. The development plan's main objectives were to improve the professional quality of teachers through in-service teacher training programmes, to develop staff administrative skills, to support the supervision system, and to strengthen cooperation between the Palestinian education sector and the international community.

However, at the exact time of the implementation of the development plan, the Second Intifada, which started in late September 2000, caused an escalation in the conflict with Israel. This had a disastrous effect on education in Palestine (Said, 2001). Many schools were forced to close because of Israeli sieges and incursions. The reoccupation of the Palestinian territories and the ensuing curfews resulted in near collapse of the education system in Palestine (Giacaman, et al., 2002; UNRWA, 2004). The MoEHE adopted several measures and developed an emergency plan to maintain the educational system. These included assigning teachers to schools in their area of residence, recruiting university students, administrators and volunteers to substitute for the sudden shortage of teachers, and relocating students to study in their local schools.

Higher education institutions also suffered severely from the outbreak of the Second Intifada. Many students and teachers were unable to get access to their universities and colleges because of the tight Israeli siege. The MoEHE also took several measures to guarantee the continuity of education in universities and colleges, including allowing students to join courses in other universities closer to their place of residence, extending the term by reducing the summer vacation, moving courses to locations outside university campuses, and using the internet as a communication tool between students and teachers (Wahbeh, 2003).

As a result of this turmoil, the MoEHE could not implement the five year education development plan. The Palestinian political and educational situation became more complicated after the Palestinian Legislative Council elections in 2006 when the Hamas Movement won the elections of the Palestinian Government, and most of the foreign donors to the MoEHE withdrew their support from, and cooperation with, the Ministry. Then in early 2008 the donors returned to support the PNA when the Fatah

Movement returned to run the Government and lead the MoEHE in the West Bank. In light of this new situation the MoEHE developed a second comprehensive five year development plan (2008-2012) with the following four main aims:

1. To increase access for school-aged children and students of all education levels and improve the ability of the education system to retain them (Access);
2. To improve the quality of teaching and learning (Quality);
3. To develop the capacity for planning and management and to improve the financial and management systems used (Management);
4. To realize a gradual conversion of the higher education sector and the technical and vocational education and training sector from a supply-oriented to a demand-oriented sector, which, accordingly, guarantees more compatibility between outputs and labour market(s) needs (Relevance).

(MoEHE, 2008:20)

Although the MoEHE is making progress in implementing this ambitious plan, the Palestinian educational system is still characterised by complicated bureaucracy, rigid centralization, over-crowded classrooms, an adversarial supervisory system, and poor educational training programmes (Wahbeh, 2003). These difficulties obviously impinge on the professional relationships inside the schools, and produce a lack of confidence, skill, and creativity among teachers. Furthermore, with the Palestinian economy in collapse, the low salaries of the teaching profession and the increase in costs of living, many teachers seek additional income through afternoon jobs. Therefore, they do not allocate time to attend afternoon training programmes offered by the MoEHE. Due to current salary scales, men are leaving the teaching profession, and women are beginning to fill their positions. It seems, as Hashweh (2001) indicates, that as a result of the very high population growth among Palestinians and the tremendous increase in student enrolment at both primary and secondary levels, the MoEHE has prioritized the building of schools and renovating existing ones rather than improving the quality of education.

1.4.2 Structure and Management of the Palestinian Education System

The current pre-university education system under the control of MoEHE consists of three stages:

1. The Pre-school Stage (Kindergarten): for children whose ages range from 4 to 5 years. This stage did not exist in the formal educational system before the MoEHE was created in 1994. However, education in kindergartens is not under government control;
2. The Basic Compulsory Stage: this stage consists of grades 1 to 10 for children whose ages range from 6 to 15 years;
3. The Secondary Non-compulsory Stage: this stage includes grades 11 and 12 for students aged 16 to 18. This stage consists of three routes: the vocational education route, the science route, and the human sciences route. This stage ends with a national general secondary certificate examination, "Tawjihi".

(MoEHE, 2008)

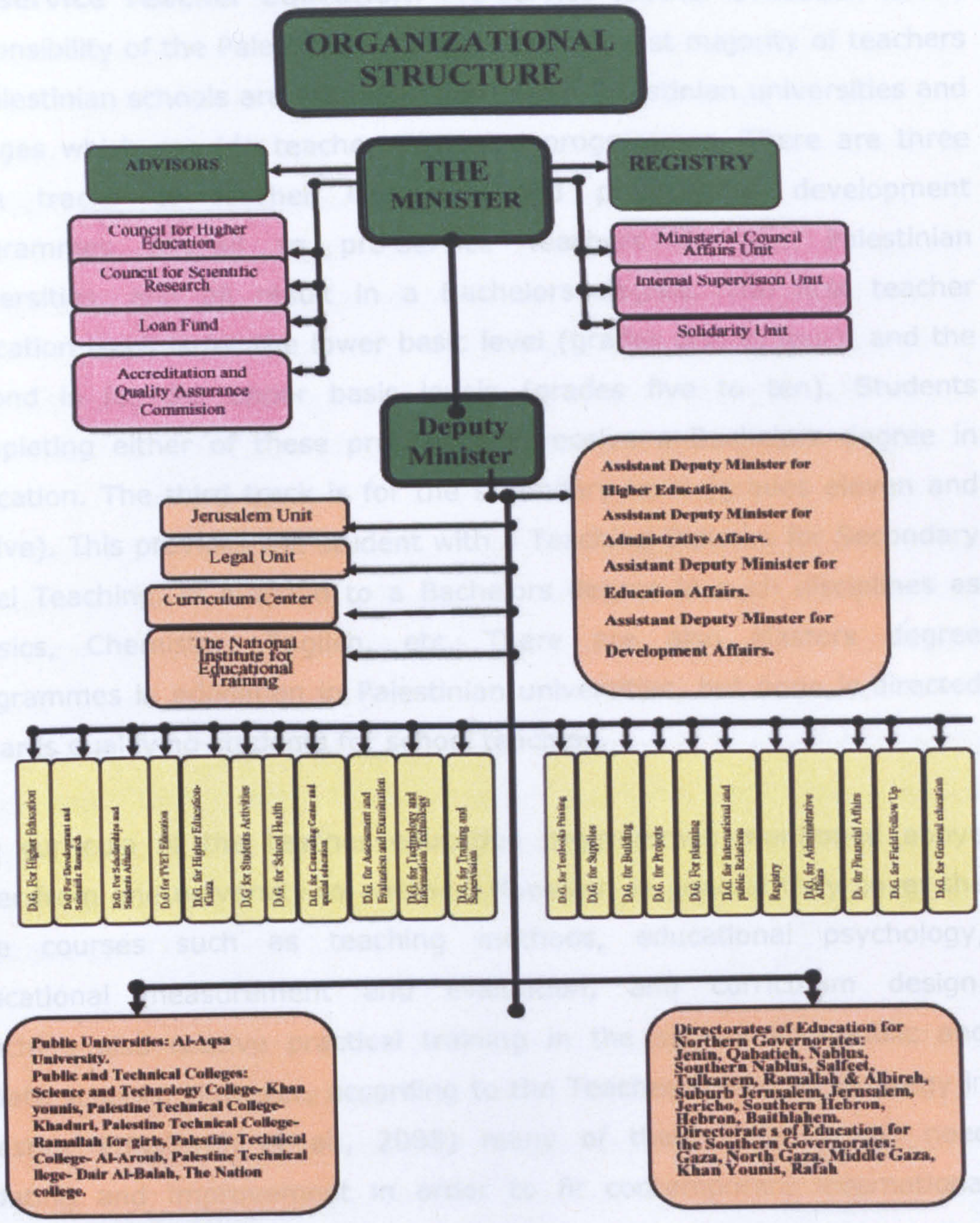
According to the Education Statistics Yearbook 2007/2008, the total number of schools and kindergartens in the West Bank and Gaza Strip in the academic year 2006/2007 was 3282, with 1164225 students and 54217 teachers (MoEHE, 2007).

There are three principal providers of school education in Palestine. The first is the governmental sector run by MoEHE. It constitutes the largest part of the school education system in Palestine. The MoEHE is responsible for most of the schools in the West Bank (76 %). It provides free compulsory and secondary education for all students. MoEHE manages the schools through eighteen directorates of education; thirteen in the West Bank and five in Gaza Strip, each run by a director general and two administrative assistants. Each directorate has partial authority over internal educational supervision and relations with the local community (See Figure 1.1 for more details on the organisational structure of MoEHE). According to the MoEHE strategic plan for 2008-2012, the

Ministry is heading towards a more decentralized system by giving more authority to those local directorates (MoEHE, 2008).
The second main provider of school education to Palestinians is the UNRWA which provides free basic education to grades 1 to 9 only for the registered refugee community in the West Bank and Gaza Strip. This sector constitutes around 13 % of the Palestinian schools, with 253,116 students and 9,279 teachers (in the scholastic year 2007/2008), and is situated mainly in refugee camps and towns where portions of the refugee population reside. UNRWA manages the schools under its supervision through four directorates of education, three in the West Bank and one in Gaza Strip.

The third provider is the private sector, which is currently responsible for about 12 % of schools providing education at all stages, enrolling about 78,111 students and 5,404 teachers (MoEHE, 2007). Although they have their own supervisory authorities for schools, UNRWA and the private sector have to follow MoEHE regulations concerning curriculum, length of the academic year and examinations.

Figure 1.1: The organisational structure of the MoEHE



Source: http://www.mohe.gov.ps/ENG/structure.html, (21 September 2009)

1.4.3 Teacher Education in Palestine

Pre-service Teacher Education: Pre-service teacher education is the responsibility of the Palestinian universities. The vast majority of teachers in Palestinian schools are graduates of the ten Palestinian universities and colleges which provide teacher education programmes. There are three main tracks of teacher education and professional development programmes offered to pre-service teachers by the Palestinian universities, and all result in a Bachelors degree. The first teacher education track is for the lower basic level (grades one to four)[1] and the second is for the upper basic levels (grades five to ten). Students completing either of these programmes receive a Bachelors degree in education. The third track is for the secondary level (grades eleven and twelve). This provides the student with a Teaching Diploma for Secondary Level Teaching, in addition to a Bachelors degree in such disciplines as Physics, Chemistry, English, etc. There are also Masters degree programmes in education in Palestinian universities, but none is directed towards qualifying students for school teaching.

The curricula of the teacher education programmes mentioned above differ from one university to another. However, in general they cover the core courses such as teaching methods, educational psychology, educational measurement and evaluation, and curriculum design. Teachers also receive practical training in the surrounding public and private schools. However, according to the Teacher Education Strategy in Palestine (Hashweh et al., 2008) many of these programmes need updating and improvement in order to fit contemporary international trends in teacher education.

In-service Teacher Education: There are currently three main providers of in-service teacher education and training programmes. The first is the

---

[1] It is worth noting here that currently there are no pre-school teacher education programmes in any Palestinian universities.

MoEHE which, as mentioned earlier, took responsibility for the pre-university education sector in 1994, and planned to reform educational programmes through its first and second five-year development plans. The main objective of the plans was to improve the professional quality of teachers through in-service teacher training programmes. All teachers, including science teachers, were enrolled in compulsory extensive developmental training sessions and workshops during and after school hours and over the summer vacation. These professional development workshops mainly focussed on contemporary teaching pedagogies such as student-centred instruction and inquiry-oriented teaching, improving teachers' content knowledge, and designing lesson plans that address the new Palestinian curriculum (Khaldi and Wahbeh, 2000; Wahbeh, 2009).

The second provider of in-service teacher education is UNRWA, which conducts several compulsory in-service intensive training courses and workshops for school teachers who work in its schools. UNRWA also created subject committees for the various fields of specializations. These committees, which consist of school supervisors from the UNRWA Educational Development Centre, and teachers from the UNRWA educational sciences colleges and schools, continue to meet regularly to work on teacher and curriculum development through training sessions (UNRWA, 2004).

The third group of providers are the non-governmental organisations (NGOs). There are around ten NGOs working on teacher education and empowerment, funded by Arab and foreign donors. Most are located in Ramallah and they provide various types of workshops and training courses in different subjects to in-service teachers.

1.4.4 The Palestinian Science Curriculum

The Palestinian education system witnessed the development of the first national Palestinian curriculum in 1998 after MoEHE assumed control of curriculum matters and established the Curriculum Development Centre in 1995. New textbooks were introduced in September 2000 for all subjects, for grades one, two, six and seven in both the West Bank and Gaza Strip, thus replacing the Jordanian and the Egyptian textbooks that were used during the period of the Israeli occupation. From 2001 to 2006, the preparation and implementation of these textbooks continued for the other grades, so that all grades were using Palestinian textbooks by the 2006/2007 scholastic year.

The Curriculum Development Centre developed a curriculum plan and identified goals for the new Palestinian science curriculum in four areas: the intellectual and national, social, cognitive, and psychological foundations. These foundations, and the goals of science teaching which originated within them, can be summarized as follows:

1. Intellectual foundation: The science curriculum seeks to reinforce faith in God, reflection on the universe, the embodiment of "good" human values and principles, to reinforce the status of mind, to promote the importance of the role of technology and science in developing society and human civilization;
2. Psychological foundation: The science curriculum takes into account the learners' needs, interests, and cognitive and physiological characteristics. It also encourages the learner to participate in activities of self-learning and group learning taking into account individual differences, and establishing rules of "comprehensive experience" in personality building;
3. Social foundations: The science curriculum should strengthen the ties between the learner and society, and enhance the individual understanding of environment and her/his ability to play an active role in preserving it, solving its problems, as fit for the Palestinian society;
4. Cognitive foundation: The science curriculum takes into account the nature of scientific knowledge, its "structure", and the relationship between science and technology. It should emphasize the importance of research and cognitive thinking.

(MoE, 1998)

The Palestinian science curriculum is embodied in science textbooks. Interestingly, for Palestinian teachers the science curriculum and science textbooks are regarded as one and the same thing. Teachers don't have access to, or refer to, a curriculum document in their teaching, just to the textbook. The curriculum documents are located only in the Curriculum Development Centre to be utilised by textbook authors and other stakeholders interested in curriculum development, but nothing to do with school teachers whose mission according to the MoEHE and Curriculum Development Centre is the implementation of the textbooks. Science textbooks are taught through subjects, each allocated a particular number of units. These subjects are: Humans, Plants, Animals and Micro-organisms, Matter and Energy, Environment, the Earth and the Universe, the Atmosphere and Meteorology, Communications, Science, Technology and Society. The general objectives of the new science curriculum according to MoEHE (1998) include the transfer of scientific knowledge to students and the promotion of scientific thinking, problem solving, innovative and critical thinking, inquiry and investigation and individual initiative. The science curriculum emphasizes the need to understand the general principles, concepts, and theories that explain the world around us.

Two recent indicators have shown that the new Palestinian science curriculum has failed to achieve the main goals announced in the foundational objectives. The first was the results of a national assessment of science in 2007/2008, implemented on a representative sample of Year 10 students, measuring basic knowledge skills (Assessment and Evaluation Department, MoEHE, 2008). The second was the 2007 Trends in International Mathematics and Science Study (TIMMS) which was conducted with about 5000 students in 150 schools in the West Bank and Gaza Strip (Assessment and Evaluation Department, MoEHE, 2007). The national assessment showed that students' average performance in science was 37 %, with only 18 % of the participants exceeding the average of 50 % success target assigned by the Ministry, indicating an overall low achievement.

The TIMSS 2007 results showed that the mean score in science was 404[2], and the international rank was 43 (out of 49 participant countries), with only 1 % of Palestinian students reaching the advanced international benchmark, while 46 % of them did not reach the low international benchmark. Of most concern is that students' mean score in TIMMS 2003 was higher than the mean score in TIMSS 2007, suggesting a decline in students' performance in science from 2003 to 2007. These results raised many questions about the effectiveness of the science curriculum and teacher education programmes. Based on these results, the MoEHE decided to review and re-evaluate the educational system as a whole, including teacher education programmes at the pre- and in-service levels, the education supervision, school management and the curricula.

It is timely therefore that this thesis explores views and origins of NOS in Palestinian school science teachers, with the long-term aim of improving the teaching and delivery of the science curriculum and teacher training programmes. It is hoped that my findings can inform this MoEHE review.

1.5 My Position in the Research

Having presented the context of the research, I feel it is important to provide my personal background and professional trajectory, in order to clarify my position in the research and consider any possible impact - positive and negative – that this might have on the research.

I am a 40-year-old, middle class devout Muslim. After completing my secondary education in a public government school, I gained my Bachelors degree in Chemistry from Birzeit University in the West Bank in 1994. I then completed a Masters Degree in Science Education at the same university. During this time I worked as a teaching assistant and then as a lecturer in the Education Department of the university until I

---

[2] TIMMS 2007 used an international score scale with a mean of 500, standard deviation of 100, advanced international benchmark of 625 or more, and a low international benchmark 400 or less.

started my PhD at the University of Nottingham in 2006. Parallel to my work as a lecturer, I was employed as a part-time researcher at an educational research centre in Ramallah for five years. During this period I worked closely with pre- and in-service school teachers through teaching and research, and had a number of publications in this field. This work as a lecturer and researcher positions me as an "insider" in my current research.

As an insider, there were both advantages and disadvantages to my research, when compared to an independent researcher (Hockey, 1993; Mercer, 2007). Being immersed in the local context, including the education system, gave me deep insight and awareness that allowed me to research the topic with sensitivity and in great depth. It also facilitated access to schools and universities, making data gathering easier.

However, a disadvantage of my position in the research was the potential for portraying a biased perspective. In addition, my existing relationships with some for the participants in the research created the potential for influencing their responses in some way. Would they give their honest views or the answers they thought I wanted to hear? Clearly these issues would present potential threats to the validity of my findings.

1.6 Organization of the Thesis

This thesis is organised in seven chapters.

Chapter One so far has introduced the study and the research background, stated the purposes of the research and the research questions, with a discussion of the rationale and importance of the study. The chapter has also presented a brief description of the structure, concern, and challenges of the Palestinian education system in its historical development so as to provide a context for the reader.

Chapter Two is a literature review and theoretical framework of the study. It investigates the concept and importance of NOS with an overview of the philosophies of science, to provide a platform for examining teachers' views of NOS, and serve as a theoretical framework for data analysis in this study. The chapter also attempts to provide an analytical review of previous studies of teacher beliefs and assessments with regard to NOS. It summarises, and offers a critical review of research done in this field, in order to situate and explain the place of this study in that body of literature.

Chapter Three explains the methodological perspectives of the study. It discusses the methodological issues and procedures involved in the research design and data collection and analysis. It justifies the mixed methods approach adopted for this study, describes the data collection instruments and their development. In addition to this, it describes the population and sample of the study, presents the data collection procedures and the phases of investigation. Furthermore, it outlines the methods and actions taken to promote the validity and reliability of the research findings, along with the mechanism and process of data analysis and considers ethical issues.

Chapter Four provides the analysis and discussion of the research findings on Palestinian science teachers' views of NOS. It presents both the quantitative and qualitative findings, compares these quantitative and qualitative findings, and discusses them in relation to the body of literature.

Chapter Five provides Palestinian academics' explanations of the causes and context of the current research findings about Palestinian teachers' views of NOS.

Chapter Six presents analyses and discusses academics' suggestions of possible ways to improve Palestinian science teachers' views of NOS, and their perspectives on factors within the Palestinian context that might either facilitate or hamper efforts to promote teachers' understanding of NOS.

Finally **Chapter Seven** spells out the conclusions and implications of the study. It provides a brief summary of the main findings, draws the conclusions of the study, with emphasis on the significance of the findings for the Palestinian context. It also provides possible implications of the study for teaching and teacher education in Palestine, for policy making bodies in MoEHE, and for methodology. Furthermore, the chapter addresses the limitations of the study, suggestions for future research in the area, and a concluding remark.

Chapter Two—Literature Review and Theoretical Framework

2.1 Introduction

The primary purpose of this chapter is threefold: to provide a theoretical framework for data collection and analysis in this study; to serve as a platform for examining teachers' views of NOS; and to investigate the concept and importance of NOS for school science. The chapter also attempts to provide an analytical review of previous studies about teacher beliefs and assessments with regard to NOS. It explores various perspectives on NOS with regard to teachers' views in particular, and science teaching in general. It offers a critical review of the research done in this field to situate and explain the place of this study in that body of literature.

First, I will explain how my theoretical framework (Figure 2.1) underpins the chapter, and demonstrate the links between the research questions, the main themes in the literature and the theoretical framework.

My research questions are drawn around three main themes. The first is about the identification of Palestinian teachers' views of NOS and the extent to which they are traditional or sophisticated. The focus of the second research question is on the explanation of the causes and context of the current teachers' views of NOS. The third considers possible ways to improve Palestinian science teachers' views of NOS.

The theoretical framework of the study has emerged from the literature, and is drawn around the research questions. Figure 2.1 below explains its basic structure involving two levels: The first and more general level is represented by the philosophies of science, with the inductivist, realist/empiricist and positivist philosophies reflecting the traditional view of NOS, historicism and social constructivism portraying a contemporary view of NOS, while the logical positivist philosophy lies on the border between the two. The second and more specific level of the theoretical framework is represented by the eight main tenets of NOS which include the empirical, inferential, creative, subjective (theory-laden), tentative and socio-cultural embedded nature of science, the myth of a single scientific method, and the epistemology and relationship between theories and laws in science.

The literature review covered five main areas, from which the theoretical framework and the methodological issues were derived, and also provided the broad reference for the interpretation of results and implications of findings. These five areas are:

1. The philosophies of science, from which the first level of the theoretical framework was derived;
2. The concept of the nature of science, from which the second level of the theoretical framework emerged;
3. The importance of understanding NOS for school science, from which the rationale and justification for the research questions for the study were distilled;
4. The research conducted around the understanding of NOS, which represents the literature around the research questions, and influences the interpretation of findings;
5. The assessment of views of NOS, which guided methodological considerations and development of research instruments.

In this chapter I start with a review of the philosophies of science that provide the first level of the theoretical framework and a platform for examining teachers' views of NOS. Then I outline a historical review of the development and characterisations of NOS concepts, and arrive at the key NOS aspects that are relevant for school education, and show a consensus among science educators and in the recent documents on science education reform. These two initial sections about the philosophies of science and the conceptualisation of NOS represent the underpinning theoretical framework for this study, as explained earlier.

In the third area of focus in this review-the importance of understanding NOS for school science-I elaborate on the importance of NOS: as a crucial component of the structure of teachers' knowledge base and their scientific literacy; as a decisive component of the public understanding of science; and for its important implications for school science and science curricula.

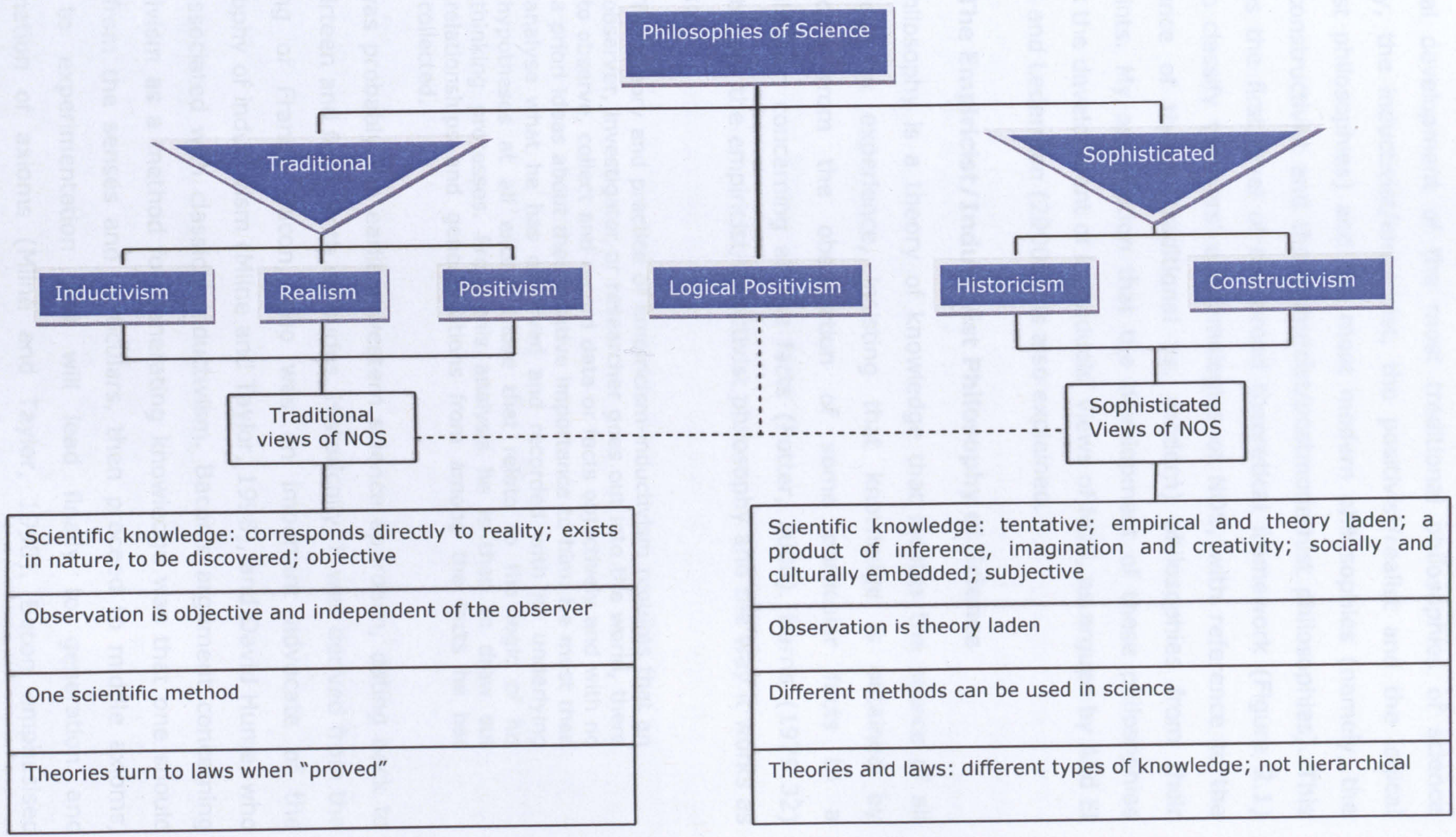
Then I review the empirical research that has been conducted about NOS. In particular, this part provides an analytical review of previous studies of the views of NOS in teachers, students and scientists, of the interplay between teachers' worldviews and their views of NOS, the relationship between teachers' beliefs about NOS and classroom practices, and of attempts to improve teachers' understanding of NOS. The discussion of my findings and recommendations for future research will be partially based on this body of literature.

The last section in this review focuses on the assessment of teachers' views of NOS. It includes an overview of the most common instruments developed and used in the literature since the 1960s. The range of methods and approaches used to explore the NOS understanding, together with their validity and reliability, provided the basis for the selection of methods and approaches used in this study.

2.2 The Philosophies of Science

The philosophy of science, in its broad sense, is "*theory concerning the nature of knowledge, the nature of the sort of activities most likely to produce knowledge and conceptions of the nature of reality*" (Potter, 2000:22). It is only fairly recent that science has been seen as a separate discipline to philosophy. It originated as a branch of natural philosophy. Science now has a life of its own, given its predictive ability in a wide range of disciplines. From the 1920s onwards, as science matured as a discipline distinct from philosophy, it developed its own philosophical framework, with the aims to describe what science is and prescribe what it should be.

Figure 2.1: Theoretical framework



In this section I survey and explain the salient characteristics and historical development of the most traditional philosophies of science (namely, the inductivist/empiricist, the positivist/realist and the logical positivist philosophies) and the most modern philosophies (namely, the social constructivist and the historicist/postmodernist philosophies). This provides the first level of the broad theoretical framework (Figure 2.1) used to classify teachers' epistemologies of NOS, with reference to the dominance of these (traditional vs. modern) philosophies from their viewpoints. My assumption that the development of these philosophies mirrors the development of individuals' views of NOS, as argued by Abd El Khalick and Lederman (2000b), is also explained.

2.2.1 The Empiricist/Inductivist Philosophy of Science

This philosophy is a theory of knowledge that locates the source of all knowledge in experience, insisting that knowledge is obtained by proceeding from the observation of some particular facts to a generalisation concerning all the facts (Potter, 2000). Harris (1979:32) characterises the empiricist/inductivist philosophy and the way it works as follows:

> The theory and practice of empiricism-inductivism requires that an observer, investigator or researcher goes out into the world, there to observe, collect and record data or facts objectively and with no a priori ideas about their relative importance to him. He must then analyse what he has observed and recorded with no underlying hypotheses at all except those that relate to the logic of his thinking processes. From this analysis he is then to draw out relationships and generalisations from among the facts he has collected.

This was probably the earliest western science approach, dating back to the thirteen and fourteenth centuries. Historically, it was derived from the thinking of Francis Bacon, who was an important advocate of the philosophy of inductivism (Milne and Taylor, 1998), and David Hume, who was associated with classical inductivism. Bacon's argument concerning inductivism as a method for generating knowledge was that one should start from the senses and particulars, then proceed to middle axioms, then to experimentation that will lead finally to generation and legitimation of axioms (Milne and Taylor, 1998). Bacon emphasised generating knowledge by observation, experimentation and inductive reasoning, but acknowledged the revealed truths of theology as part of science (Stumpf, 1966)

According to the inductivist/empiricist, science is an observational activity that establishes general laws of nature on the ground of rich supporting evidence (Joad, 1963 cited in Dibbs, 1982). Although the empiricist/ inductivist philosophy was dominant in the 17th century as the most appropriate practice in generating scientific knowledge, it could not describe what scientists actually did, or whether there exists such a process as induction. For example, Hempel (1966) opposes the narrow concept of scientific inquiry that is based on traditional inductive scientific inquiry steps. He argues that the discovery of scientific knowledge does not occur through conducting inductive reasoning procedures on data that has been previously collected.

2.2.2 The Realist Philosophy of Science

In contrast to empiricism, realism is a doctrine which claims a direct relationship between the theoretical structures of science and the actual world (Hodson, 1993a), where human observations of reality correspond exactly to an external reality that is fixed and behaves in a consistent way (Milne and Taylor, 1998). Human beings can acquire knowledge of a single reality that is independent of the knower, and this correspondence with this reality is the primary test of truth. Reality is objective and absolute, experiments conducted over time and data collected as a result can represent an unchanging reality that is objective and absolute. In fact, it is this position realism holds concerning the belief of the existence of a single reality that is independent from the knower that makes it different from all other philosophies (Cunningham and Fitzgerald, 1996).

2.2.3 The Positivist Philosophy of Science

At odds with realism, positivism denies the existence of such a thing as that which realists call absolute reality, "truth" or universality of knowledge. The positivist philosophy is a strict form of empiricism associated with Comte and his patron Saint-Simon in 19th century in

France (Poole, 1995). The basic argument of positivism is that only knowledge claims that are founded directly on experience are genuine (Abimbola, 1983). According to Saint-Simon, the history of the sciences passes through three irreversible stages, from the theological stage to the metaphysical and then to the positivist stage. Therefore, positivism is non-theistic and anti-metaphysical. It rejects the assumption that nature has some ultimate purpose or end and gives up any attempt to discover the internal or secret causes of things. On the contrary, it attempts to research facts by the observation of the constant relations between things and formulate the laws of science as the laws of constant relations among various phenomena (Stumpf, 1966).

Positivists' vision of scientific growth is derived from their view of the predictive role of scientific theory. They argue that a good theory elaborates people's knowledge and understanding by predicting phenomena that do not exist when they are originally formulated (Hempel, 1966). Thus, the prediction success of a certain theory that offers a uniform and organized explanation would gain people's confidence. Scientific growth occurs when such a successful theory offers a correction to some laws that were previously confirmed.

2.2.4 Logical Positivism

Logical positivism developed from positivism. As Poole (1995) explains, in the 1920s and 1930s a group of philosophers including Carnap, Quine, Wittgenstein, Austin, Rorty and Mach, known as the Vienna Circle, enriched and developed positivism into a wholesale theory of language. They called it logical positivism because it was a theory that the meaning of language and its conclusions were considered to follow from positivism as a matter of logic (ibid). Its main argument is based on the belief that scientific knowledge corresponds directly with reality, an assumption that reflects a naïve[3] view of NOS as Aikenhead (1987a:460) pointed out:

---

[3] Throughout this thesis words such as naive, traditional, unsophisticated, inadequate, superficial and limited, are used interchangeably.

> One vestige of logical positivism is the belief that scientific knowledge connects directly with reality, unencumbered by the vulgarity of human imagination, dogma or judgments. This ontological view is often associated with the idea that science finds absolute truth, and does so independently of the investigator's psychological and social milieu.

It also holds some other assumptions that reflect naïve views of NOS. For example, it assumes that observation remains the same during scientific revolutions, so that the new theory is an improvement over the old one (Hempel, 1966). Moreover, it assumes that scientific knowledge increases by accretion. Furthermore, it raises the necessity of developing objective criteria for the validation of scientific discoveries (Hempel, 1966) that rely on empirical investigations and the use of symbolic logic as a tool for analysis.

The aim of science, according to the logical positivist view, is to explain and predict the facts of observations by the creation of relevant theories that provide explanations and predictions. Logical Positivism places a huge significance on the validation of scientific theories and new knowledge generated. Four approaches were put forward for the purpose of the validation of scientific knowledge (Chen, 2001). The first was *verificationism*, a tradition of basing science upon what can be proved. It was derived from the philosophical works of Locke, Berkley, Hume and Russell. A statement is scientific from this perspective if, and only if, it can be verified and supported by observation or demonstrable by experimentation. On the other hand, statements which cannot be proved to be true by observation or other empirical demonstrations should be excluded from the scientific domain. For example, logical positivism excludes metaphysical propositions from science because they are not verifiable. It seems that verificationism is impractical because it needs an infinite number of positive indications to verify any supposed scientific statement. Popper found that verificationism leads to some logical dilemmas that cannot be solved.

As a result, with the progress of time, the goal of verification shifted to *justificationism*, the second approach for scientific knowledge validation according to logical positivism. In this approach, the main concern is to probe under which circumstances a given statement is valid and to confirm this validity, so that the statement is scientifically accepted as long as it has actual or positive evidence to confirm it through direct or indirect confirmation, without the need for complete verification. However, the idea of *justificationism* as a tradition for the validation of scientific knowledge was so vague that much of pseudo science might be accepted as actual science under its criteria of validation.

To decrease this concern and to solve the problem of induction, Popper (1963) formulated the principle of *falsificationism*, the third tradition for scientific knowledge validation according to logical positivism. It is based on the logic that verifying a statement or theory needs infinite positive pieces of evidence, but one negative piece of evidence is enough to falsify the theory or statement. Falsification of the theory is the most important issue to Popper, and this can be done by the deductive approach. Subsequently, Popper also said that if we cannot falsify a theory, then we should not conclude that the theory is necessarily true, but that it is temporarily acceptable. The way Popper solved the problem of induction and the result he reached (that is, science grows and develops through attempts to falsify universal statements) enabled him to set up a criterion for demarcation between science and non-science (pseudo-science). Science, as opposed to non-science, is in principle not capable of empirical verification, but rather empirical falsification. Thus, falsifiability should be taken as the demarcating criterion to distinguish science from non-science or pseudo-science (Popper, 1963).

The fourth approach for the validation of scientific knowledge, according to logical positivism, was *conventionism* (Hacking, 1983). From this perspective, theories and other knowledge are not chosen based on empirical grounds as with the three models mentioned above, but rather the choice is based on convention, according to considerations including simplicity, elegance and unifying power of explanation. However, *conventionism* with its conventional criteria for the validation of scientific theories and knowledge, was put under scrutiny, as it might be useful for the selection of scientific theories, but not for validating them (ibid).

Karl Popper and Logical Positivism in Modern Science

The Second World War was a turning point in the development of science and the philosophy of science in recent history. Modern science was dominated by several philosophical strands, one of which was a modified form of logical positivism. Karl Popper was a link between the logical positivism of the 1920s and 1930s and this modern viewpoint. Arguably, logical positivism was a specifically European movement, largely conducted in the German language and centred in Central Europe. Popper was a student of the movement in the 1920s who moved to the UK immediately before the outbreak of the Second World War. As a very long-lived English speaking philosopher, he brought his own modifications of logical positivism to English and American science, and through champions such as Peter Medawar, his views of science became central to grant-giving bodies and to educational bodies from the 1960s onwards. Below are the major contributions of Popper in this area:

Characteristics of Scientific Knowledge

Popper looks at scientific theories as descriptive theories, as they show what is being observed at a certain time in a certain place when suitable conditions for observation are met. Popper also holds the view that a certain scientific theory should have a previous metaphysical view of nature because scientific theories typically come from universal statements which are sometimes called laws of nature. It seems as if these ideas and metaphysical views share in the start up of scientific knowledge and scientific imagination in a way that leads to the appearance of a new authentic scientific theory. This means that theories are not induced from observed facts, since no one has ever observed the cited universal statement to be the case, so it can only have been imaginatively hypothesized to be part of a theory (Popper, 1963). Crucially Popper does not distinguish between hypotheses and theories. He looks at scientific concepts as ideas about natural phenomena. These concepts and scientific laws are formed by purely deductive methods.

Scientific knowledge, according to Popper, is totally objective, and the way theories are tested is also objective, and does not depend on personal beliefs.

Falsification and the Growth of Scientific Knowledge

Popper's concept of the growth of scientific knowledge rests on his principle of falsification. Popper's concept of knowledge growth does not mean more observation and experiments, but repeatedly falsifying scientific theories and replacing them with other theories that are more persuasive (Popper, 1963).

Chalmers (1980) explains the growth of scientific knowledge as seen by the falsification view. He states that science starts with problems, where hypotheses are suggested as solutions to these problems. Then these hypotheses are tested and critiqued. As a result, some hypotheses are given up and others achieve more success. These successful hypotheses are exposed to more tests. When a hypothesis that has been exposed to a large number of tests is falsified, it is then hoped to identify a new problem that requires new hypotheses followed by new testing and critiquing. In this way, the growth of scientific knowledge goes on advancing infinitely.

Logical positivism probably has the heaviest burden of cultural implications, and has been entirely and uncritically accepted by the Western scientific establishment, although a lot of evidence says science does not work like this.

2.2.5 Historicism

Historicism emerged as a response to the logical positivist view of science, when historians of science, especially Kuhn and Feyerabend, began in the 1960s to express reservations about the rigidity of the forms of science portrayed by logical positivist philosophers. They criticised the positivist model of scientific theories as being unrealistic, and not linked to the history of science. They were also sceptical about the objective standards of scientific rationality advocated by logical positivism.

Historicism basically rejects the formal logic of positivism as the primary method for analysis, but relies on the detailed study of the history of science for its analysis (Brown, 1977). This new philosophy of science approach was advocated by many contemporary philosophers including Kuhn, Feyerabend, Lakatos, Brown, Hanson and Toulmin. For the purpose of this research, historicism is sketched from the Kuhnian perspective, as in my view reflects an adequate view of the epistemology of science.

Kuhn's theory describes the history of science as a cyclic process that displays a "normal science" period within an era of accomplishment or a paradigm through which science operates within a framework. An extraordinary science period follows during which normal science faces major contradictions in relating experimental results to theories, and a crisis occurs leading to a revolution in scientific thinking. Scientists within the paradigm suddenly convert to a new way of thinking about the theories and nature, similar to a "gestalt switch" or flip, eventually resulting in a new period of normal science. Kuhn (1962) calls this overall process a paradigm shift. He introduced this notion of paradigm as an accepted set of principles by which the world is viewed. He explains that "*once a first paradigm through which to view the nature has been found, there is no such thing as research in the absence of any paradigm*" (p.79).

According to Kuhn, scientists in a particular paradigm conduct normal scientific work composed of determining significant facts, matching facts with the theory that guides the paradigm, and finally refining the articulation of the theory by determining universal constants, developing laws and principles, and finding ways to apply the paradigm to a related area of interest. Kuhn calls such practices "normal science" which is all about "mopping-up" operations where scientists are mostly dedicated to substantiating their theory and trying to solve problems that arise from anomalies. Furthermore, Kuhn asserts that at moments where there is an "anomaly," i.e., a new discovery that does not match the paradigm's theory, scientists of that paradigm are taught to work within the paradigm rules. These scientists can either see it as a "puzzle," thus devising articulations related to their theory in order to eliminate the conflict, or they can ignore such an anomaly when it persists, labelling it as such, and perceiving the failure not as resulting from the theory itself but from the failure of possessing the appropriate tools to solve the problem. Hence, as Kuhn asserts, scientists set the anomaly aside for a future generation with more developed tools.

Kuhn confronted the rationalistic view that science is always accompanied by new discoveries and thus paradigms are easily changed. Scientific discoveries within the paradigm are considered by Kuhn as just novel facts that involve an extended process of *conceptual assimilation,* which does not lead to paradigm change. More specifically, Kuhn asserts that discoveries or facts in normal science are not considered to be new at all unless the assimilation process requires a new set of rules and scientists learn to see nature in a different way.

But, how is a scientific theory abandoned and replaced by an alternative one? According to Kuhn, this kind of transition must emerge all at once, like a gestalt switch but not necessarily in an instant. It is a conversion. Kuhn describes such a transition as a choice, similar to that between two competing political institutions, i.e. a choice that should be made between two rival paradigms with *"incompatible modes of community life"*. He further asserts that this choice cannot be determined by the criteria that govern normal science or the characteristics of a good theory, i.e. accuracy, consistency, scope, simplicity and fruitfulness (Kuhn, 1977:112). The choice between two theories has to do not only with the impact of nature and logic but also with the *"techniques of persuasive argumentation effective within the quite special groups that constitute the community of scientists"* (Kuhn, 1977: 94).

Kuhn (1977:110) elaborates on this argument and explains that *"the choice scientists make between competing theories depends not only on shared criteria ... but also on idiosyncratic factors dependent on individual biography and personality"*. Kuhn calls these factors shared "norms" and "values". However, these shared values and norms, such as accuracy, consistency, and scope, are according to Kuhn ambiguous when they come to application. Two scientists could come up with different choices even with those shared values. Underneath these values are idiosyncratic factors like: "*what each scientist must consider in reaching a decision, what he may and may not consider relevant, and what he can legitimately be required to report as the basis for the choice he has made*" (p.111). According to Kuhn, standard values like accuracy, consistency, and scope work well at the beginning within the normal science, however, when it comes to theory choice, they work badly or not at all.

The above discussion suggests that a contemporary view of NOS does embody historicism.

2.2.6 Constructivism

The constructivist view is a view of knowledge and learning that portrays a sophisticated view of NOS (Duit, 1994). It is a theory of knowing that describes what makes up knowledge, and considers the processes through which knowledge is generated by learners, based on the assumption that the learners' knowledge is based on their own experiences with the nature that surrounds them (von Glaserfeld, 1989, 1995). The following quote by Simon (2000:213) describes the basic features of constructivism that reflect a modern perspective of NOS:

> Constructivism represents a major theoretical shift in what knowledge is and how knowledge is developed. This view differs from the old one in that it deliberately discards the notion that knowledge could or should be a representation of an observer-independent world-in-itself and replaces it with the demand that the conceptual constructs we call knowledge be viable in the experiential world of the knowing subject.

The most popular philosophical underpinnings of constructivism are: Piaget's genetic epistemology; the new theories of science in the 1960s and 1970s by Kuhn, Popper, Lakatos, Feyerabend and others; the new sociology of science; the postmodernist views about science; the personal theory of constructs; social constructivism; and Vygotsky's theory of language acquisition (Matthews, 1993).

Arguably, there exists a strong link between NOS and the nature of learning from the constructivist view of learning because teachers' views of NOS are constructed based on their own experiences and social relations with regards to learning and teaching science (Wertsch, 1998). Also, their practices in the classroom are mediated through their beliefs and knowledge about science and teaching in a certain context (ibid). The application of a constructivist approach to science teaching has been advocated by many science educators. It is a key to teaching and learning standards, especially in science education (Kang, 2005).

Greelan (1997) classifies the constructivist positions into six forms in terms of their epistemological and ontological positions: personal constructivism, radical constructivism, social constructivism, social constructionism, critical constructivism and contextual constructivism. In contrast, Matthews (1994) reframed this classification into two major traditions: physiological constructivism (which includes personal constructivism, radical constructivism, social constructivism and social constructionism) and sociological constructivism (which includes critical constructivism and contextual constructivism). The first tradition includes Piaget's account of learning, Vygotsky's social constructivism, and part of von Glasserfeld's work. The second tradition is oriented toward the work of Emile Durkheim, Peter Berger and, recently Edinburgh (ibid).

This study's approach is more linked to the first tradition, in particular social constructivism, since learning in science, from a modern perspective, is mostly rooted or anchored in physiological constructivism, which agrees on the idea of viewing the learners as active constructors of their knowledge (Limon, 2001).

It was the beginning of the 1970s when social constructivism materialised, when the sociology and history of science explicitly promoted the idea that science was sociologically constructed. The basic assumption of social constructivism is that scientific knowledge is socially constructed because it is created by the daily social practices of scientists. It also argues that scientific facts and beliefs are socially constructed, not truths, because what counts as facts is a matter of convention or contextual factors rather than of inherent scientific necessity (Segerstrale, 2000). According to social constructivism, scientists accept or reject a statement based on social or political factors, and not on the truthfulness of that statement. Social constructivism refuses the existence of an objective world, where knowledge is considered true relative to the social trainings, habits, and practices by which we are surrounded (ibid).

This leads us to the *socio-cultural organization of science*. From a socio-cultural perspective, science is seen as a human endeavour that looks at reality as a human and social construction, and not absolute (Segerstrale, 2000). The sociology of science is concerned with two basic aspects concerning the sociological build up of science: The first relates to the quantitative dimensions that are capable of measurement and objective analysis, like the number of people working in science, the financial costs and the quantity of knowledge produced. The second aspect which the sociology of science is concerned with is the external factors affecting science, more precisely, the relationships between science and other social, political and religious institutions. Social scientists agree on the view of science as a social institution, where the scientific activities of scientists are judged according to the following four criteria and institutional needs: universalism, communism, disinterestedness and authority (Richards, 1987). Social scientists agree that scientific knowledge grows and develops through the power of harmony between science and the institutional criteria mentioned above (ibid).

As such, we can see from the previous overview a potential parallel relationship between the historical development of the philosophies of science from traditional to modern, and the development in teachers' understanding of NOS from the traditional views towards a more sophisticated understanding of NOS. The aim is to try to get our teachers to follow that movement. In other words, we want them to move and develop in their understanding of NOS along the same track as the history followed.

We can also see from the above overview that modern science draws heavily on strands from logical positivism, historicism and social constructivism, while classical science draws on empiricism, realism and positivism. The diversity of positions of the different philosophies indicates the probability of finding a pluralism and context-dependency in teachers' views of NOS.

2.3 The Concept of the Nature of Science: What is NOS?

2.3.1 Development of the Nature of Science Conceptualisation

There is no single definition of the nature of science that has a consensus among philosophers of science, historians of science and science educators (Abd El Khalick and Lederman, 2000b). This lack of consensus on a specific NOS can be seen in the discrepancy of approaches of the most popular philosophers and historians of science, like Hempel (1966), Popper (1963, 1968), Kuhn (1962, 1977), and Feyerabend (1975) as was explained by Lederman (2007:835):

> If one considers the differences among the works of Popper(1959), Kuhn (1962), Lakatos (1970), Feyerabend (1975), Laudan (1977), and Giere (1988), it becomes quite clear that perceptions of NOS are as tentative, if not more so, than scientific knowledge itself. In short, NOS is analogous to scientific knowledge.

Other researchers agree that the definition of NOS is open ended (Alters, 1997). The meaning and objectives of NOS, rather than being stable, have developed and changed in line with the major shifts in focus in the field of philosophy, sociology, and history of science dating back to the beginning of the 20th century, where these changes in focus have, in turn, resulted in changing the ways in which science educators and science education organisations have defined NOS (Abd El Khalick and Lederman, 2000b; El Sheikh, 2002).

In the first half of the 20th century, understanding of NOS was equivalent to understanding "the scientific method" and to the ability to think scientifically and use science in problem solving. Dewey (1932 cited in El Sheikh, 2002) stressed the scientific ways of thinking as a science educational goal to improve students' intellectual abilities. Owing to the dominance of positivist theory (logical or empirical) in that period, the focus was that scientific knowledge is inducted from accurate and objective observation, so that the obtained knowledge is absolutely correct (El Sheikh, 2002). NOS focus in that period was on "the scientific method" and the processes of science (Hurd, 1960). In this context, Lederman (1992) mentioned that the Central Association of Science and Math Teachers in the United States of America recommended including the scientific method and processes of science in the teaching of science.

The 1950s and 1960s witnessed the emergence of the reform movement of science curricula and science education. In that period, students' understanding of NOS was equivalent to their understanding of the nature of scientific inquiry and the practicing of it. The objective of NOS was to emphasise scientific processes and inquiry (Welch, 1979). It was also in this period (early 1960s) when Schwab (1962) emphasised teaching science as a process of inquiry, with the intention to develop students' understanding of NOS.

Beginning in the 1970s, there was a paramount shift in viewing and defining NOS as El Sheikh (2002) explains. This development was caused largely by a change in the main purpose of school science teaching towards "science for all", and the appearance of new philosophies of science based on new studies in the history, psychology, and sociology of science . In America, the nature of scientific knowledge was characterised as being tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, and empirical (Centre of United Science Education, 1974 cited in Liu, 2003). These nine aspects of scientific understanding still remain important today.

By the 1980s, psychological and sociological factors such as the theory-laden nature of observation and the role of the social discourse in validating the scientific claims started to appear in NOS definitions (Abd El Khalick and Lederman, 2000b). The NSTA (1982) stressed the empirical and tentative nature of scientific knowledge and the major role of theory and inquiry in science as the main components that reflect an adequate understanding of NOS. In contrast, AAAS (1993) organised NOS into three basic ideas: (a) scientific world view, (b) scientific inquiry, and (c) scientific enterprise. In a third categorisation of NOS, the NSES (NRC, 1996) classified NOS into three main enduring ideas: (a) science a human endeavour, (b) nature of scientific knowledge, and (c) historical perspectives. In another approach Chiappetta, Fillman and Sethna (2002) categorised NOS into four aspects: (a) science as a body of knowledge, (b) science as a way of investigating, (c) science as a way of thinking, and (d) the interactions among science, technology, and society.

As such, NOS has been defined and characterised in different ways and from different approaches, showing NOS as an amalgamation of philosophy, psychology and sociology of science. However, NOS most commonly refers to the epistemology of science, science as a way of knowing, and the values and beliefs of how scientific knowledge develops (Lederman, 1992; McComas, 1998). McComas, Claugh and Almazroa (1998) define NOS more specifically as:

> 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 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)

Perhaps most importantly, NOS has been defined as a critical component of scientific literacy (AAAS, 1993; DfES/QCQ, 1995; NRC, 1996) where the goal is to help students understand the basics of science in order to promote an effective literacy of science. At *this* level, there is significant agreement amongst historians, philosophers and science educators on the important aspects of NOS. The existence of this level of agreement regarding the salient features of NOS has been emphasised in recent curriculum and science education standards and reform movements, such as the AAAS (1993), NRC (1996), DfES/QCA (1995, 2004), McComas (1998), and McComas and Oslon (1998).

Abd El Khalick, Bell and Lederman (1998:418) argue that there is a consensus view of NOS in certain aspects that are adequate and critical to school education. They articulate that:

> The disagreements that continue to exist among philosophers, historians, and science educators are far too abstract for K-12 students to understand and far too esoteric to be of immediate consequence to their daily lives. For example, the notion of whether there is an objective reality or only mental constructions is, perhaps, only of importance to the graduate student in philosophy. There is, however, an acceptable level of generality regarding NOS that is accessible to K-12 students and also relevant to their daily lives. It is at this level of generality that connections can be seen between students'/citizens' knowledge about science and decisions made regarding scientific claims. It is also at this level of generality that little disagreement exists among historians, philosophers, and science educators.

These aspects include the understanding that scientific knowledge is tentative, empirical, and theory laden; scientific knowledge is the product of inference, imagination and creativity, and is socially and culturally embedded. Three additional aspects include: the distinction between observation and inference, the lack of one universal method for doing science, and the relationship between theories and laws. Appendix 1, adopted from Abd El Khalick, Waters and Le (2008:838), gives a detailed characterisation and explanation of these main aspects of NOS.

These aspects of NOS are included in all explanations of NOS expressed in major science standards documents and by science education organisations (AAAS, 1993; DfES/QCA, 1995; NRC, 1996) and science educators (Rubba and Anderson, 1978; Driver et al., 1996; Abd El Khalick, 1998; Chen, 2006, among others). They also reflect the assumptions behind the new reform efforts in science education that relate to NOS that has been supported by Kuhn's ideas.

Therefore, these eight main aspects of NOS were adopted as a framework for investigating and analysing Palestinian science teachers' views about NOS, and determining the degree of sophistication they demonstrate.

2.3.2 NOS in the Structure of Teachers' Epistemological Beliefs

In recent years, research has focused mainly on studying metacognition and its processes (Schommer and Duell, 2001). The idea behind this was that students and teachers have plans for teaching and learning. They learn the implication of their plans, and monitor and reflect on the efficiency of the learning/teaching strategies they conduct (Cross and Paris, 1988). There has been a growing interest in studying teachers' beliefs of the nature of knowledge and learning (epistemological beliefs), because these beliefs constitute a powerful part of the metacognitive process (Schommer, 1994), as they seek to answer questions such as, "how do we know what we know?" (Hofer, 2002).

These epistemological beliefs of teachers' and students' either promote or hinder the teaching of thinking in schools (Schommer, 1990; Good and McCaslin, 1992). For example, beliefs that knowledge is certain, simple, handed down by authority, and that the ability to learn is innate and learning is quick, if held by teachers or students, will act negatively in the conceptual integration of knowledge (Good and McCaslin, 1992). Teachers' epistemological beliefs, also, have a major influence on their cognition and decisions, and consequently on their behaviour in the classroom. Thus, understanding the construction of teachers' beliefs is vital for the development of their professional training, and of understanding their practical behaviour in the classroom (Nespor, 1987).

Similarly, an understanding of NOS, as mentioned earlier, involves epistemological values and beliefs related to scientific knowledge and its development (Lederman, 1992). Therefore, we can see that a strong relationship and overlap exists between these two constructs - an understanding of NOS and epistemological beliefs. NOS is the science subcomponent of the broader epistemological beliefs. However, it is worth noting that to the best of my knowledge no research has been conducted to examine this relationship between teachers' and students' beliefs about NOS and their wider epistemological beliefs. There appears to be an assumption within the science education community that the effective learning and teaching of science have positive effects on the broader epistemological beliefs of learners. It seems that more research is needed in this discipline to test the validity of this assumption, and to determine exactly what effects NOS instruction has on the broader epistemological and personal beliefs of learners.

2.4 NOS and School Science

Students', and the general public's, understanding of NOS has been identified as an important educational objective of school science teaching worldwide for more than a century. It has been regarded as an important main theme in many science education reform documents (Lederman, 2007), and is still currently emphasised as an important educational objective worldwide. The main rationale behind this emphasis is that an informed understanding of NOS provides learners with the scientific literacy that would enable them to behave as informed consumers of science, who are well qualified to make relevant decisions with regard to scientific claims and data (Ochanji, 2003). In this regard, Driver et al., (1996) provide five arguments for including and teaching NOS in science education. From their view, teaching NOS is crucial to enable students to:

1. make sense of science and technology and utilise them in their daily life;
2. appreciate science and participate in decision-making processes related to science;
3. make sense of the social-cultural impact of science and the work of scientists;
4. understand the moral commitment based on the common social values;
5. facilitate a successful learning of science content.

Lederman (2007) labelled these five arguments as utilitarian, democratic, cultural, moral and science learning respectively.

In the following sub-sections, I elaborate on the importance of NOS, especially as a decisive component of the structure of teachers' knowledge base and their scientific literacy, and of the public understanding of science and for its important implications to school science and science curricula.

2.4.1 NOS in the Structure of Teachers' Knowledge Base

NOS is part of teachers' knowledge base that influences the way they teach science. To get a clear picture of this role of NOS, we need to look at the link through Shulman's (1987) model of the knowledge base for teaching, which includes two major components:

1. The practical component, which includes the processes of understanding, transformation, evaluation and reflection.
2. The logical component, which consists of seven major parts:
    - Content knowledge;
    - General pedagogical content knowledge, with special reference to classroom management strategies;
    - Pedagogical content knowledge (PCK); "a special amalgam of content and pedagogy", which includes teachers' knowledge of students' ideas, content, curriculum and evaluation processes;
    - Curriculum knowledge;
    - Knowledge of learners;
    - Knowledge of educational contexts;
    - Knowledge of educational goals, practices, values, and their philosophical and historical grounds.

Shulman (1986) points out that for a particular topic, the PCK includes knowledge of:

- What makes the topic easy or difficult to understand, including preconceptions about the topic that students bring to their studies;
- Those strategies that are most likely to be effective in re-organizing students' understanding to eliminate their misconceptions;
- A variety of effective means of representing the ideas included in the topic - analogies, illustrations, examples, explanations, and demonstrations.

He also describes the content knowledge as having two main components: The first is the substantive build up of the discipline that relates to the subject and includes the basic concepts, facts, ideas, topics and their relationships together. This also includes the understanding of the structure and the organization of the subject knowledge of the discipline. The second component is the syntactic structure of the discipline which includes the understanding of the nature of the discipline, and the manner by which the knowledge in that discipline is created and validated. We can see that NOS actually represents the syntactical component of the subject matter knowledge. In this context, following Shulman's (1987) notion of PCK, some science educators have stressed that teachers need to have what they have called nature of science pedagogical content knowledge "NOS PCK" (Abd El Khalick and Lederman 2000a, 2000b).

Building on Shulman's (1986, 1987) model of the knowledge base for teaching, Mellado (1998) differentiated the components of teachers' knowledge in two main forms: the first is a static knowledge which includes knowledge of science and the theories of science teaching methods. This knowledge refers to the body of knowledge required to learn in the initial stage of teacher education. The second component is a dynamic knowledge. It is personal and practical, and is gained from the teaching experiences and the reflection-action process. It helps teachers to reflect and reconsider their static knowledge that enables them to create a sort of pedagogical action and reasoning.

On the whole, it is clear from the above characterizations of teachers' knowledge base that NOS might be perceived as a core part of teachers' knowledge domains; with both content knowledge and PCK reflecting its decisive importance.

2.4.2 NOS and Scientific Literacy

Achieving and improving students' scientific literacy has been supported by science educators and policy makers in many countries, including Palestine (e.g., Bybee and DeBoer, 1994; Driver, et al., 1996; NRC, 1982, 1996; AAAS, 1989, 1993, 1997, 2001; DeBoer, 2000; Khaldi, 2002, 2004).

Scientific literacy is defined by Hurd (1960) as an understanding of science and its applications in society. It is defined by Atlas of Scientific Literacy (AAAS, 2001: vi):

> Knowledge and skills in science, technology, and mathematics, along with scientific habits of mind and an understanding of the nature of science and its impact on individuals and its role in society.

Scientific literacy stresses the need of the public to understand science and its impact on their lives and its influence on nearly all aspects of their lives. It aims to create the scientifically literate people who utilise their scientific literacy as an instrument to guide them for the suitable decision making that is consistent with their social and daily life by increasing their awareness of the social and political issues related to science. The issues of particular concern include the overlap between science, technology and society and the need to integrate the scientific knowledge with other forms of knowledge (Meichtry, 1993; DeBoer, 2000).

Individuals who are equipped with suitable scientific literacy can be socially active and effective; a critical decision-making ability will help them live and survive in a democratic society. To achieve this goal they should possess an adequate knowledge of the content, processes and skills of science, as well as a mature understanding of the role science plays in the different aspects of their lives (Blades, 1997; Brickhouse; 1998; DeBoer, 2000). They also need to understand the process by which scientific knowledge is generated and the factors that might play a role in its generation, development, use, and adoption. In other words, scientifically literate people should possess a functional understanding of NOS (NSTA, 1982; Driver et al., 1996).

Another related issue that overlaps with scientific literacy and composes a significant component of it is the public understanding of science, where the majority of public in any society have an interest in understanding science for personal and social reasons (Michael, 1992). According to Solomon (1997), the public need to understand science (and consequently NOS) to satisfy their individual curiosity, and to help them in the solidarity with the scientists in their society. However, the public's understanding of science, in general, focuses on factual information without much interest in conceptual explanation or theoretical issues (Michael, 1992). Public trust in scientific issues depends on the reliability and confidence of their scientists or institutions, not on their arguments or understanding of the issues (Giddens, 1990). Millar and Wynne (1988) describe the process as a transmission model, in which scientists transmit and the public receive. They claim that there are three scenarios for public reception of science; they are either rejecters, users of facts without deep explanations, or interested and curious pursuers.

It is clear from the above definition of scientific literacy that NOS is a core component of it. As a result, the best way to promote students' scientific literacy, and to improve their decision making abilities, is by teaching them NOS in schools (McComas, 1998; Turner and Sullenger, 1999). In this context, the NSES (NRC, 1996) and the AAAS project 2061 (1989) stress four key aspects of NOS as being important to achieve scientific literacy: the scientific worldview, the socio-cultural nature of science, the processes and mechanisms of the formation of scientific claims, and the authority of science in policy making.

However, in order to be able to translate these issues of NOS to classroom practice, it is a prerequisite to have teachers with strong scientific background and sophisticated understanding of NOS.

2.4.3 NOS and Scientific Inquiry

Scientific inquiry refers to the characteristics of the processes through which scientific knowledge is developed, including the conversations involved in the development, acceptance and utility of scientific knowledge (Schwartz, 2004). The NRC (1996:23) explains scientific inquiry as:

> A multifaceted activity that involves making observations; posing questions; examining books and other sources of information to

> see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternate explanations.

However, the literature lacks a concise and agreed definition of scientific inquiry, as its meaning has been debated for decades (Bybee, 2000). Nevertheless, Schwartz (2004) has characterized the general aspects of the nature of scientific inquiry that are common in recent reform documents like NRC (2000) and AAAS (1993), and are agreed by science educators (Hodson, 1998; Chinn and Malhotra 2002) and researchers (Knorr-Cetina, 1999; Dunbar, 2001). These features include:

a) multiple methods of scientific investigations;
b) multiple purposes of scientific investigations;
c) the form and role of argumentation in the development and acceptance of new knowledge;
d) recognition and handling of anomalous data;
e) sources, roles of, and distinctions between data and evidence;
f) community of practice.

This characterisation of scientific inquiry seems relevant as a basis for science education and instruction. In this context, Hodson (1998) points out that learning about science using a scientific inquiry approach involves four main phases: designing and planning, performance, reflection and recording and reporting. Fazio (2005) suggests that this inquiry-based approach to teaching aims to provide the learners with the basic scientific literacy skills for general citizenry and employment needs for their society.

Lederman (2007) distinguishes NOS from scientific inquiry. He contends that scientific inquiry is composed of various scientific processes used in a cyclical manner, where scientific processes are the activities utilised for data collection and analysis and drawing of conclusions. NOS, on the other hand, refers to the epistemological underpinnings of the activities of science and characteristics of the resulting knowledge.

From the definitions, aims, and basic features of both NOS and scientific inquiry, we can see that there are strong connections and overlap between them. Schwartz (2004:25) explains this interconnection between them:

> The conjunction between understanding the nature of scientific inquiry and understanding NOS is the perception that scientific inquiry is a creative process, driven by currently accepted theories and laws of the scientific community. The explanations of empirical evidence resulting from such inquiries are tentative and only as accurate, in an ontological sense, as the theories and laws upon which the inquiries were based. Hence, the interdependence of the nature of scientific inquiry and NOS may contribute to the intuitive appeal of using inquiry as an instructional approach to teach NOS.

Further, epistemological ideas with respect to scientific inquiry like theory-data coordination, responses to anomalous data, nature of reasoning or social construction of knowledge are best addressed to reflect the recent NOS understanding when learners are engaged in scientific inquiry activities (Chinn and Malhorta, 2002).

Moreover, it is widely accepted that the teaching of science through scientific inquiry approaches provide a rich context to deepen students' understanding of NOS (Fazio, 2005). Abd El Khalick (2001) and Shapiro (1996) found that scientific inquiry activities were key to improving NOS understanding. They recommended that scientific inquiry activities should be included in science teaching classes in an explicit and reflective manner.

However, research shows that engaging in scientific inquiry activities alone in classrooms does not necessarily lead to improvement in NOS understanding (Schwartz, Lederman and Crawford, 2004). Research also shows that a deep understanding of scientific inquiry might exist without an adequate understanding of NOS (Eick, 2000). As a result, science teachers need to possess an adequate understanding of both NOS and scientific inquiry so as to teach them effectively as integrative constructs.

2.4.4 NOS in School Science Textbooks

In this section I look at the representation of NOS in different school science textbooks, and at the need to include NOS in science textbooks in a way that improves school science teaching in general, and teachers' and students' understanding of NOS in particular.

Historically, textbooks have played a significant role in teachers' work and pupils' learning (Phillips, 2006). Despite the growing use of the Internet and other electronic media in many countries, the textbook is still the basic source of the information for the student (Radcliffe et al., 2004). Weiss (1993) pointed out that science teachers in the United States rely heavily on textbooks. For many of them it is the only resource for structuring and developing lesson plans. The International Association for Science Teaching pointed out in its 1995/1996 report that 90 % of the secondary classrooms use the school textbook as the sole source in the organisation of their teaching and the assessment of their students, and that science teachers cover 85 % of the text's content while teaching (Sanger and Greenbowe, 1999). The National Assessment of Educational Progress study in the US in 2000 pointed out that 80 % of eighth-grade science teachers reported regularly using their textbook (Radcliffe et al., 2004). More recently, Chiappetta et al., (2006) stated that more than 90 % of the teachers in secondary schools in the United States rely totally on the textbook as the sole resource in the organisation of their teaching and the assessment of their students.

Including NOS in science textbooks is very important to produce more scientifically literate citizens (Driver et al., 1996) with improved abilities to take informed decisions (McComas, 1998). It also supports the successful learning of science content (Driver et al., 1996). Furthermore, it bridges the gap between the practising scientists and school science (Sorby, 2000). Given their prominent place in the classroom, it is important that these textbooks reflect a contemporary view of NOS, and present it in an effective and balanced way.

Many studies have analyzed science textbooks to determine whether they provide a balanced presentation of the main NOS tenets. Some have used Chiappetta and Collette's (1984) framework for analysis. This framework conceptualises NOS in four main themes of scientific literacy (rather than specific NOS tenets): science as a body of knowledge, science as a way of investigating, science as a way of thinking, and science and its interaction with technology and society. According to this framework, textbooks must incorporate these themes to promote scientific literacy and a mature understanding of NOS.

Khaldi (2004) conducted a content analysis utilizing Chiappetta and Collette's (1984) framework to examine the new Palestinian science textbooks for Years 7, 8 and 9 in relation to their promotion of scientific literacy. The findings of the analysis were as follows:

a) Analysis of the scientific literacy themes in the narrative text revealed the following percentage distribution: science as a body of knowledge (73 %), the investigative nature of science (12 %), science as a way of thinking (5 %), and the interaction of science, technology and society (10 %).
b) Analysis of the specific objectives of each chapter in the textbooks revealed the following points of emphasis science as a body of knowledge (71 %), the investigative nature of science (12 %), science as a way of thinking (8 %), and the interaction of science, technology and society (12 %).
c) Analysis of the questions reveals the following points of emphasis: science as a body of knowledge (73 %), the investigative nature of science (5 %), science as a way of thinking (19 %), and the interaction of science, technology and society (2 %).
d) Analysis of the figures and illustrations reveals the following points of emphasis: science as a body of knowledge (76 %), the investigative nature of science (12 %), science as a way of thinking (5 %), and the interaction of science, technology and society (5 %).

This content analysis indicates that Palestinian science textbooks emphasize the transfer of scientific body of knowledge to students and under-represent the other three themes, which are essential for the promotion of scientific literacy and a sophisticated understanding of the nature of science.

Therefore, it cannot be claimed that the new Palestinian science textbooks can promote scientific literacy or NOS understanding. The study concluded that there is a need to reconstruct the new Palestinian science curricula and associated textbooks to develop scientific literacy by improving the balance across the four themes.

In another study of Palestinian science textbooks, Yusuf (2000) conducted an analytical evaluative content analysis on the Year 10 chemistry textbook using Chiappetta and Collette's (1984) framework. She found that the scientific literacy themes were covered in the textbook as follows: 44 % for science as a body of knowledge, 16 % for science as a way of thinking, 32 % for science as a way of investigating, and 8 % for science and its interaction with technology and society. These results showed a contrast with the recommendations of the NSTA (1982), which suggested to include scientific literacy features in science curricula with the following proportions: 43 % for science as a body of knowledge, 18 % for science as a way of thinking, 14 % for science as a way of investigating, and 25 % for science and its interaction with technology and society.

BouJaoude (1997) conducted an evaluative study of the new Lebanese science curricula using the same framework. He analysed the introductions, goals and activities and found that Lebanese curricula regarded science as a body of knowledge, and emphasised its interaction with technology and society features, while features related to science as a way of investigating, or science as a way of thinking are almost neglected. BouJaoude concluded that the Lebanese science curricula did not address scientific literacy in an effective or balanced manner. Similarly, Ali (1998), in a study of Sudanese textbooks, found a dominance of science as a body of knowledge with little focus on the other themes.

There were also several similar studies conducted in the broader international context (Garcia, 1985; Chiappetta, Fillman and Sethna, 1991, 1993; Chiappetta and Fillman, 1993a, 1993b, 2005; Phillips, 2006; Brooks, 2008), the findings of which supported the studies in Arab countries. Results of the analysis of these studies showed that textbooks, in general, inadequately addressed the four themes of scientific literacy and lack a balance of these themes, as there was a big focus on science as a body of knowledge, and ignorance of the remaining features which leads to a distorted representation of NOS.

A study by Abd El Khalick, Waters and Le (2008) was the only I identified analysing science textbooks with a direct focus on NOS. They conducted a textbook analysis in light of main tenets of NOS on 14 chemistry textbooks used in American schools. They selected the textbooks for analysis from five series, spanning one to four decades. They found that the textbooks fared poorly in their representation of NOS. They also found the representation of NOS in the textbooks over the last four decades either to be unchanged or deteriorating. In light of their findings, they stressed the need to address NOS explicitly in the American science textbooks as central targeted themes.

As such, we can see a problem and inadequacy in the way science textbooks in different countries of the world, including Palestine, address NOS and its main themes.

2.4.5 Implications for School Science

The Kuhnian and constructivist notions of knowledge generation, learning, teaching, conceptual framework and conceptual change can be employed in science education and the teaching of science.

Kuhn taught science educators how to look at NOS from a historical perspective, which was different from that of the philosophers of science such as Popper. Integration of the history and philosophy of science has been proposed by many educational bodies as an endeavour to humanize science, to enhance reasoning and critical thinking skills, and to contribute to a fuller understanding of scientific subjects.

Kuhn's ideas about theory change have played an influential role in understanding science learning and conceptual change. Researchers have highlighted the parallel between NOS and the nature of learning (Cobern, 1998). Many have argued that the conceptual change that students undergo from their intuitive understanding of the natural phenomena to the accepted scientific one resembles Kuhn's theory change through history (e.g., Hewson, 1981; Posner et al., 1982; Siegel, 1982; Vosniadou and Brewer, 1987; Driver et al., 1994). Vosniadou and Brewer (1987) argue that the development of knowledge in the child can be seen as a paradigm shift that occurs in an effort to resolve anomalies. The authors also assert that when a child is faced with major anomalies that existing conceptual structures cannot account for, a new paradigm is required, giving rise to radical restructurings. Posner et al., (1982) argue that similar to scientists "assimilation" process in Kuhnian "normal science", students use existing knowledge to comprehend the new phenomena. Furthermore, similar to the Kuhnian "paradigm shift," students must reorganize their preconceptions if they are inadequate and do not allow them to comprehend the new phenomena.

Most of the models that were established to explain conceptual change were developed by drawing on the philosophy of science and the works of Kuhn, Lakatos and Toulmin in particular (Hashweh, 1986). For example, Kuhn's model explains the conceptual change process like this: For an old concept being replaced by a new one (paradigm shift in Kuhn's model), the old one must be unsatisfactory to the learners (the crises phase), and the new one must be intelligible, believable and fruitful (new paradigm).

The constructivist view of learning and knowledge generation as seen by von Glaserfeld (1989, 1993) is based on two fundamental principles:

1. The human being is not a passive recipient of knowledge, but s/he is an active constructor of his/her knowledge. Knowledge, as von

Glaserfeld states, is created by individuals in a historical and cultural context, and is viable in relation to individual experience.

2. The function of cognition is adaptive and serves as the organizer of the experiential world, not the discovery of ontological reality.

Learners understand and interpret the world around them through the cognitive models and images they construct about the world through interaction with it. Therefore, from a constructivist point of view, knowledge is represented in the cognitive models that the learners hold while interacting with the nature that surrounds them, through which they interpret the phenomena and other actions that arrive at their cognition. Consequently, the human does not interpret the world as it is, but through those mental images (Norman, 1980). In other words, constructivism focuses on the conceptual framework the learner builds in his/her mind, rather than on the existing structure of the outside reality. This fits with Taylor's (1993:268) characterisation of constructivism as *"a view of human knowledge as a process of personal cognitive construction, or invention, undertaken by the individual who is trying, for whatever purpose, to make sense of her social or natural environment"*.

From this perspective, all theories and other elements of knowledge are subject to change in light of disconfirming observation. In fact, constructivism recommends that science teachers need to focus learners' attentions on their own conceptual frameworks, and to utilise the surrounding nature as a testing ground for the viability of their conceptions (Yalvac, 2005).

Constructivists also argue that the cognitive images humans hold are closely related to the social context they were built in. In interpreting a certain phenomenon or action, the learner recalls the cognitive image that s/he finds suitable, but the social context under which the phenomenon had happened increases the possibility of recalling a certain cognitive image, not another one (Cobb, 1994). The parallels between this view of learning and contemporary views of NOS, and particularly the relationship between the socio-context and theory development, is also clear. This relationship between the nature of science and the nature of learning has implications for how teacher educators and teachers should challenge learners' existing views in an attempt to move them to a more contemporary and acceptable understanding.

2.5 Research on Understanding[4] the Nature of Science

2.5.1 Students', Teachers' and Scientists' Views of NOS

Nearly all the research conducted to diagnose students' views and conceptions of NOS has shown that most students hold naïve, weak and inconsistent beliefs about NOS (e.g., Klopfer and Cooley, 1961; Korth, 1969; Mackay, 1971; Rubba and Anderson, 1978; Rubba, 1976; Rubba, Horner and Smith, 1978; Ayasreh, 1985; Ryan and Aikenhead, 1992; Discernna and Howse, 1998; Dekkers, 2002; El Sheikh, 2002; Khishfe and Abd El Khalick, 2002; Liu and Lederman, 2002; Lederman, 1992, 2007). For example, several studies have shown that students hold a view that scientific knowledge is absolute and fixed, and that the role of scientists is to discover this knowledge (Griffiths and Barry, 1993; Abd El Khalick and BouJaoude, 2003; Kang, Scharmann and Noh, 2004). Others have revealed that students are not aware of the exact differentiation between theories and laws (Mackay, 1971), the role of creativity and imagination of science (Mackay, 1971; Larchelle and Desautels, 1993), or the difference between observation and inference (Khishfe and Abd El Khalick, 2002). In other studies, students were found to hold inadequate conceptions of various core features of NOS such as the relationships between hypothesis, theories and laws (Bell et al., 2003; Abd El Khalick, 2006), or the nature of scientific reasoning (Tamir and Zohar, 1991).

Likewise, research conducted to assess both pre- and in-service teachers' views of NOS shows that they generally possess inadequate

[4] In this study, as in the literature around NOS, the terms understanding, views, beliefs, conceptions and perspectives are used interchangeably (Clandinin and Connelly, 1987). Although it is accepted that these terms can have different meanings, within the area of NOS it is not considered necessary to distinguish between them.

understanding of most aspects of NOS. Most hold fluid beliefs that lack coherence or consistency, and are similar to their students' beliefs (Schmidt, 1967; Carey and Stauss, 1970; Billeh and Hasan, 1975; King, 1991; Pomeroy, 1993; Lakin and Wellington, 1994; Murcia and Schibeci, 1999; Smith and Anderson, 1999; Tairab, 2001; Dekkers, 2002; Khishfe and Abd El Khalick, 2002; Liu and Lederman, 2002; Tsai, 2002; Yalvac and Crawford, 2002; Cakir and Crawford, 2004; Halai and McNicholl, 2004; Dogan and Abd El Khalick, 2008). For example, some teachers, like their students, hold a view that scientific knowledge is absolute (Lederman, 1992), others hold the positivist view of science (Pometry, 1993), others think of science as a body of knowledge (Tairab, 2001), or believe in the existence of a universal scientific method that reveals truth (Halai and McNicholl. 2004). In his comprehensive reviews of the literature related to teachers' beliefs of NOS, Lederman (1992, 2007) noted that teachers' beliefs were inadequate regardless of their academic background, academic abilities, teaching experience, or subject areas.

However, a few studies of secondary teachers' beliefs of NOS that were conducted after 1990 showed some positive findings of teachers' conceptions of NOS, with a range in their understanding from being naïve to adequate. For example, Abd El Khalick and Lederman (1998) found that secondary science teachers' beliefs of certain aspects of NOS were consistent with the contemporary conceptions of NOS, although their understanding of the social and cultural embeddedness of science, and the relationship between laws and theories was limited.

Similarly, in a study conducted in Lebanon, Abd El Khalick and BouJaoude (1997) found that half of their subjects held some adequate views of NOS, but with a lack of coherence, as the majority of them held traditional views of the theory-laden nature of observation, and the existence of a stepwise scientific method. Akerson and Hanuscin (2007) found similar results with in-service teachers' conceptions of NOS. Although many held sophisticated views of NOS, they were inconsistent with some adequate aspects of NOS such as the creative and imaginative nature of science and the reliance of science on evidence. The fact that they simultaneously held views that contradicted these sophisticated ideas indicated that their views on the whole were not well developed.

Haidar (1999) examined pre- and in-service teachers' views of NOS in the United Arab Emirates and found that teachers' views were neither definitely naïve nor contemporary. He ascribed these findings to the interaction between teachers' education and their religious worldviews, as being Islamic, they refuse some of the underlying assumptions of constructivism that reflects a modern view of NOS.

Several studies have also been conducted to assess scientists' conceptions of NOS, and to compare their beliefs with students and teachers beliefs (Behnke, 1961; Schmidt, 1967; Pomeroy, 1993; Schwartz, 2004). Findings of this line of research showed that scientists' views of NOS were inadequate and generally similar to teachers' and students' naïve views. However, a study conducted by Durke and Cossman (1976) revealed that the scientists in their study (800 scientists among university natural science faculty in the US) possess adequate views of most of NOS aspects.

I can conclude from my review that there is a broad consensus that neither students, teachers nor scientists in these studies possessed informed and accurate conceptions of NOS. The teachers lacked an understanding of the philosophical underpinnings of the subjects that they teach. This conclusion is considered particularly significant given the broad variety of assessment instruments that were used (Lederman, 2007).

Finally, to the best of my knowledge, there are no studies that have examined Palestinian school students', pre- and in-service science teachers' or scientists' conceptions of NOS.

2.5.2 The Interplay between Teachers' Worldviews and their Views of NOS

Lederman and Liu (2007) define a worldview as a set of values and beliefs held by a group of people about the nature of reality that forms their terms of reference to make sense of the world. This worldview, which consists of socially and culturally dependent beliefs, influences the way learners think about the world and defines their attitudes about nature and the possession of knowledge (Schraw, 2002). According to Jegede and Okebukola (1991), the socio-cultural environment determines to a great extent, how an individual functions, interprets and reacts to various stimuli. In this context, Pajares (1992) considers that beliefs are shaped through a process of enculturation and social construction. Thus, although knowledge is personally constructed, it is socially mediated as a result of the experiences and interaction with others in that social context (So, 2002).

Hodson (1993b) argues that different societies might define and categorize science differently due to their different aspirations and values. This argument has been supported by research which revealed that cultural beliefs and values could affect teachers' views of science (e.g., Allen and Crawley, 1998; Zimmerman and Gilbert, 1998; Dzama and Osborne, 1999; Waldrip and Taylor, 1999). Lederman and Liu, (2007) also argue that people with different worldviews may have concurrently different views about NOS.

However, several studies have shown that teachers' worldviews (especially their socio-cultural and religious beliefs) might interact with their views of NOS (Jegede and Okebukola, 1991; Allen and Crawley, 1998; Dzama and Osborne, 1999; Shumba, 1999; Cobern and Loving, 2000; Abd El Khalick and Akerson, 2004; Liu and Lederman, 2007; Mansour, 2007, 2010). Reiss (2010) argues that for people who are religious their scientific knowledge is a sub-set of their religious knowledge. This argument is consistent with the findings of Halai and McNicholl (2004), which show that Pakistani science teachers, who are religious in nature believe that all knowledge evolved from the Quran, and tend to merge science and religion. Similarly, Mansour (2010) found that the personal religious beliefs of Egyptian teachers was the main factor influencing their thinking and interpretation of science and scientific phenomena related with religion, and for most of them *"religion comes first, and science comes next"* (p.127).

However, these studies revealed contradictory findings. For example, Liu and Lederman (2007) found that the participants who held the traditional worldview (that there exists a fixed, core body of knowledge best acquired through experts via transmission and reconstruction) held sophisticated views of NOS (such as the idea that science is subjective, culturally embedded and has limits). However, Abd El Khalick and Akerson (2004) found that their American participants who held a belief that science and religion are in conflict did not show progress in their views of NOS, while those who believed that science and religion are two different ways of knowing showed improvement in their views of NOS Similarly, Ogunniye et al., (1995) and Shumba (1999) found that non-western teachers who held traditional worldviews were more inclined to have naïve views of NOS.

Considering the complexity of people's religious beliefs and their views about religion might create a complex and fluid relationship between teachers' views of NOS and their religious beliefs and depends on the religion in question. This relationship depends on the compatibility of teachers' religious views with science (whether the two are two different ways of knowing), the extent to which they avoid value judgments about both ways of knowing (Abd El Khalick and Akerson, 2004), or the extent to which they mix them together, comparing and projecting each of them on the other without being aware of that the axioms and set of rules that each of them stands on are different from the other. However, according to Reiss (2009), it is very important that teachers, whether they have religious beliefs or not, be respectful to their students' religious beliefs even if these beliefs are scientifically poor, because these religious views are the lenses through which these students see and interpret the world.

As such, it seems that the interplay between teachers' conceptions of science and their cultural values in science teaching is not clear. More empirical research is needed in this area, as Lederman and Liu (2007) emphasised. They suggest that it is very important to understand how teachers' socio-cultural values influence their ways of picturing their science discipline, so as to enable the design of a science curriculum that suits the socio-cultural context and maintains harmony with its cultural values and religious norms.

2.5.3 The Relationship between Teachers' Beliefs of NOS and Classroom Practices

Questions related to the relationships between teachers' beliefs and their classroom practices are difficult to answer, as this issue is controversial. Some studies have found a positive relationship between teachers' beliefs about NOS and their practices (Dibbs, 1982; Brickhouse, 1990; Milne and Taylor, 1995; Hashweh, 1996; Chun, 2000). Others revealed a mismatch between teachers' beliefs and their practices (Duschl and Wright, 1989; Hodson, 1993b; Lederman, 1999), while in a few cases it was found that teachers' practices were partially affected by their beliefs (Omari, 2006).

The research conducted with the aim to improve teachers' understanding of NOS was guided by an assumption that teachers' beliefs of NOS have a direct influence on their practices (Lederman and Zeidler, 1987; Lederman, 1992). However it was found that the relationship between teachers' beliefs of NOS and practices is more complex than a simple and direct relationship between beliefs and practices (Lederman and Druger, 1985; Lederman and Zeidler, 1987; Abd El Khalick and Lederman, 2000b).

There are several factors and constraints that mediate the link between teachers' beliefs and their classroom practices. These constraining factors include:

a) Curriculum: this sometimes contains misconceptions about NOS (Bentley and Garrison, 1991; Khaldi, 1998), or adopts traditional philosophical views of science like positivism, or organizes the laboratory activities based on induction (Tobin and McRobbie, 1997). With the curriculum having more power and effect on the teaching process in the classroom than the teachers' own beliefs about NOS, who in most cases do not challenge the curriculum, they teach it independently from their own views (Milne and Taylor, 1995).

b) Instruction: some teachers think the knowledge they have is the main source of their authority and power over the students, so they do not like to explain to their students that the knowledge they have is tentative.
c) Pressure to cover the content (Duschl and Wright, 1989; Hodson, 1993b; Abd El Khalick et al., 1998).
d) Weakness in classroom management and organisational skills (Lantz and Kass, 1987; Duschl and Wright, 1989; Hodson, 1993b; Lederman, 1999; Abd El Khalick et al., 1998).
e) Institutional constraints (Brickhouse and Bodner, 1992).
f) The socio-cultural context: teachers' actions are not tied solely to their personal plans, but also to the social process plans, as argued by Wertsch (1998), who recommended adopting a problematic relationship between beliefs and actions, rather than the simple assumption that beliefs direct actions.
g) Lack of teaching experience (Brickhouse and Bonder, 1992; Lederman, 1992).
h) Teachers' concerns over students' abilities and motivation (Duschl and Wright, 1989; Brickhouse and Bodner, 1992; Abd El Khalick, et al., 1998; Lederman, 1999).
i) Poor pre-service teacher training (Matthews, 1994; Mellado, 1997; Hand, 1999).

It seems clear from these studies that although possessing adequate beliefs of NOS is a necessary condition, it is not sufficient for teachers to translate their beliefs of NOS into classroom practices. There seems to be multiple frames of reference, powers, and authorities that guide teachers' actions and practices (Tobin et al., 1994).

2.5.4 Improving Teachers' Understanding of NOS

The growing body of research (as reviewed so far) showed that teachers lacked contemporary conceptions, or mature understanding, of NOS. This led the research and interventions to be geared toward improving teachers' understanding of NOS and science education (Lederman, 2007). Teachers could not be expected to teach properly what they do not possess or understand reasonably themselves (Lederman, 1992). As a result, researchers and science educators gave more attention to improve science teachers' understanding of NOS. However, there has been a change in focus of the core NOS issues to be taught. For example, in early 1900s the focus was on the scientific method and then on the scientific processes and inquiry by 1960s (Lederman, 2007). Nowadays, NOS is taught as a basic element of scientific literacy as considered by reform movements (AAAS, 1989, 1997; NRC, 1996, 2000).

Two main approaches of instruction to teach NOS were proposed by science educators to achieve the goal of improving teachers' understanding of NOS; namely an implicit and explicit approach (Abd El Khalick and Lederman, 2000a). The implicit instruction approach assumes that a proper delivery of the scientific content and its processes will lead to a mature understanding of NOS (Tremebath, 1972; Rowe, 1974; Gabel, Rubba and Franz, 1977; Lawson, 1982). Advocates of this approach assume that learning about NOS will result as a 'by-product' through the engagement of the learner in the various inquiries and scientific activities and investigations (Tremebath, 1972; Barufaldi, Bethel and Lamb, 1977; Riley, 1979).

However, most of the implicit instruction approach research carried out to improve teachers' understanding of NOS were not successful in enhancing participants' understanding (Tremebath, 1972; Barufaldi, Bethel and Lamb, 1977; Riley, 1979; Scharman and Harris, 1992). The failure of these, and other initiatives, might be related to the misconception held by those scholars that these who participate in scientific based activities and inquiry will automatically learn and understand NOS. At a broader level, research shows that pre- or in-service learning of science content did not seem to contribute in improving teacher's understanding of science (Carey and Stauss, 1970; Billeh and Hasan, 1975).

On the other hand, the explicit instruction approach assumes that NOS should be taught specifically, with predetermined aims and content, in the same way as any other cognitive learning outcome. Teachers should plan specifically how to teach and assess NOS, and provide an environment for the students to reflect on their experiences within a conceptual framework that explains NOS features (Abd EL Khalick et al., 2000). This explicit approach has been advocated by recent reform movements (AAAS, 1993; NRC, 1996), which called to include NOS in school teaching content as a core component of scientific literacy that students should possess. Empirical research carried out in this discipline found that the explicit approach was more effective than the implicit approach to improve teachers' understanding about NOS (Lederman and Druger, 1985; Lederman, 1986; Rydler, Leach and Driver, 1999; Abd El Khalick and Lederman, 2000b; Khishfe and Abd El Khalick, 2002; Sorenson, McCarthy and Newton, 2010; Abd El Khalick and Akerson, 2009). In this context, Abd El Khalick and Akerson (2009) argue that the explicit approach is more effective when it is reflective, where the learners are provided with structured opportunities to reflect on their learning of NOS, and where a framework considering learning as conceptual change is adopted.

Many of the science educators and researchers who adopted and advocated the explicit approach to improve teachers' understanding in their research utilised relevant elements from the philosophy and history of science in their teaching gearing to improve teachers' conceptions of various aspects of NOS (Carey and Stauss, 1968; Billeh and Hasan, 1975; Ongunniyi, 1983; Gess-Newsome, 2002).

The context for explicit teaching of NOS was conceptualised by Khishfe and Lederman (2006) as integrated and non-integrated. In the integrated approach, NOS is explicitly instructed by being embedded within the science content. Some researchers had adopted this approach and integrated NOS features within their science content. Klopfer and Cooley (1963), Solomon, Duveen, Scot and McCarthy (1992) and Wahbeh (2009) utilized some elements from the history of science to teach NOS to their students in an integrated manner. Their results showed an improvement in their students' conceptions of some features of NOS.

In the non-integrated approach, NOS is instructed separately without relation to the regular science content in classes where the aim is to improve learners' conceptions of NOS through inquiry and NOS direct activities. This approach was carried out by researchers to improve the learners' understanding of NOS (Durkee, 1974; Carey et al., 1989; Liu and Lederman, 2002). Nevertheless, little improvement was achieved in the participants' views of NOS after these studies were implemented. Bell and Matkins (2003) and Khishfe and Lederman (2006, 2007) found no significant difference between the integrated versus non-integrated approach on the improvement of the learners' views of NOS, as both led to improvement in the participants' views of NOS.

Therefore, it is not yet possible to argue whether the integrated or the non-integrated approach is more effective in general. A more critical appraisal of the effectiveness of the various efforts to enhance teachers' views of NOS in light of their competence to enable the teachers to express adequate views of NOS to their students are needed.

2.6 Assessment of Views of NOS

Over the last fifty years, a range of different approaches have been utilised for the assessment of teachers' beliefs of NOS. These approaches have mirrored the changes that have occurred in the method design of teacher beliefs research because of the paradigm shift from the positivist quantitative research in the 1960s to more qualitative research approaches in the mid-1980s (Richardson, 1996; Lederman, Wade and Bell, 1998). Many assessment instruments have been developed since the 1950s with a primary focus on ideas related to NOS. Some of these instruments were considered to have a poor validity, while others were considered to be valid and reliable (Lederman, 2007).

This section includes an overview of the most common instruments developed and used in the literature since the 1960s which possess a reasonable degree of validity and reliability. For a comprehensive review of the various instruments developed in this discipline, refer to Munby (1983), Lederman, Wade and Bell (1998), Lederman, Abd El Khalick and Schwartz (2002) and Lederman (2007).

The review focuses mainly on the structure, comprehensiveness, range of sources and perspectives, ease of administration, length, suitability for large scale studies, reliability, and the depth that the instruments can demonstrate teachers' beliefs of NOS. The rationale for including this detail about each instrument is that it raises methodological issues and provides the context for the instruments used and developed in this study.

Test of Understanding Science (TOUS) by Cooley and Klopfer (1961): a quantitative instrument of 60 multiple choice items with four alternatives for each item. It measures participants' understanding of science with four scores; an overall score and three subscale scores that measure understanding about the scientific enterprise, the scientist and the methods and aims of science respectively. However, its content validity is questionable since some of its items go beyond the scope of NOS concepts. They are more about the job of the scientists and their institutions. Another problem is that TOUS lacks comprehensiveness in covering all aspects of NOS. Therefore, Lederman et al., (1998) recommended that TOUS was inappropriate to be used alone as a comprehensive instrument for research conducted to study participants' conceptions of NOS.

Science Process Inventory (SPI) by Welch (1966): a 135-item test with an agree/disagree response format. It was developed to assess teachers' and students' understanding of NOS, with particular focus on aspects related to the processes by which the scientific knowledge is obtained. It is a rather comprehensive instrument that covers various aspects of NOS, and the values and assumptions related to it. However, it is too long, and its agree/disagree response format leaves participants no choice for a neutral or no comment response.

Wisconsin Inventory of Science Processes (WISP) in 1967: was developed by the scientific literacy research group at the University of Wisconsin. It is a quantitative instrument that consists of 93 items with an agree/disagree response format. WISP was originally developed to assess high school students' concepts of NOS in the United States. It was widely used by researchers as a valid and comprehensive instrument for NOS assessment. However, WISP was designed to give only one overall score without the possibility to give details.

Nature of Science Scale (NOSS) by Kimbal (1968): a 29-item test with three response alternatives (agree, neutral, disagree). It was developed for the purpose of comparing the views of science teachers and scientists. NOSS gives only one total score for the respondent's view of science, which makes it difficult to get a detailed description of the participants' understanding of the various aspects of NOS.

Nature of Science Test (NOST) by Billeh and Hasan (1975): a 60-items test with five alternatives from strongly agree to strongly disagree. It covers four major aspects of NOS: the processes, products, assumptions and ethics of science. Again, NOST lacks any subscale, which limits its efficiency as a thorough assessment instrument.

Nature of Science Knowledge Scale (NSKS) by Rubba (1976): a 48-items test with a five-choice response format. It was originally developed to assess secondary students' understanding of NOS. It covers six main aspects of NOS: the amorality, creativity, developmental, parsimonious, testability and unity dimensions of NOS. Its validity and reliability were established for each aspect separately. However, Lederman et al., (1998) criticized its validity for having some identical pairs of items in some subscales that would result in a higher reliability estimate than the actual one.

Views on Science-Technology-Society (VOSTS) by Aikenhead, Ryan and Fleming (1987): a 114-items test with multiple choice response format. It was developed to assess participants' understanding of NOS, the nature of technology and the interaction between science, technology and society. The multiple choice alternatives for the VOSTS items were empirically derived from students' open-ended responses where they were asked about their position on NOS and STS issues. Thus, the various alternatives in each item were student-generated.

VOSTS is considered to be an empirically based instrument with a high degree of validity in the Canadian context (Ryan and Aikenhead, 1992; Lederman et al., 2002; Chen, 2006). However, the validity of VOSTS might be problematic out of the Canadian context, as some of the items were related to the Canadian society and cultural values.

Nature of Science Survey by Lederman and O'Malley (1990): a qualitative open-ended format survey consisting of seven open-ended items. It was developed to assess high school students' views of the tentative NOS. It was designed to be used in conjunction with follow-up individual interviews. The purpose of using the interviews was to validate the researchers' interpretations of the participant answers, and to provide an in-depth description of the participants' views of NOS. It was the first valid attempt to use open-ended questionnaires followed by interviews to assess students' views of NOS, although it has problems in the wording and overlap of some items. Abd El Khalick and Lederman (2002) considered this open-ended questionnaire as the first form of the Views of NOS instrument (VNOS-A).

Critical Incidents by Nott and Wellington (1995): a technique of assessing teachers' understanding of NOS that depends basically on confronting teachers with some scenarios of actual classroom events and asking them questions about the ways in which they would respond. Nott and Wellington assumed that teachers' response to these questions (that is, their practice) reflects their beliefs relating to NOS. This assumption has not had significant support in the literature.

Views of Nature of Science (VNOS) by Lederman and Abd El Khalick (1998): the original form of this instrument was the Nature of Science Survey developed by Lederman and O'Malley (1990). Abd El Khalick called it (VNOS-A) and considered it the first form of the VNOS open-ended questionnaire. In 1998, Lederman and Abd El Khalick revised, modified and expanded the VNOS-A questionnaire twice to improve its validity generating VNOS-B and then VNOS-C[5] (Lederman et al., 2002). VNOS-C consists of ten open ended questions (Appendix 3) accompanied by a follow up interview (Appendix 4) that covers the various aspects of NOS, namely: the empirical nature of scientific knowledge, the theory-laden nature of scientific knowledge, the social and cultural embeddedness of scientific knowledge, the myth of "the scientific method", the tentative nature of scientific knowledge, scientific theories and laws, the creative and imaginative nature of scientific knowledge and observation, inference and theoretical entities in science.

VNOS-C was face and content validated by a panel of three science educators, a historian of science, and a scientist. It was also content validated by comparing and contrasting participants' NOS profiles that were obtained from the questionnaires and the corresponding interview transcripts, where the views of NOS of the participants revealed from both were found to be very similar (Abd El Khalick, 1998, 2001). The use of VNOS-C has been widely reported in the literature, and it is considered the most popular paper and pencil tool to assess NOS qualitatively (e.g., Abd El Khalick and Lederman, 2000a, 2000b; Akerson et al., 2000; Abd El Khalick, 2001; Moss, Abrams and Robb, 2001; Schwartz and Lederman, 2002, 2006; Akerson and Abd El Khalick, 2003; Lederman and Lederman, 2004, 2006).

---

[5] Modifications to VNOS-C are still being made by current researchers to fit specific studies assessing NOS. For example, another two forms of VNOS were developed: VNOS-D by Lederman and Khishfe (2002) and VNOS-E by Lederman and Ko (2004). They differ from VNOS-C in length and complexity of language used to improve suitability for high school and very young students.

It seems that such open ended questionnaires accompanied by follow up interviews are very influential and can be considered valid to yield meaningful and trustworthy outcomes of small scale assessments of stakeholders' views of NOS (Liang, 2009). Consequently, VNOS-C was selected as the most appropriate assessment instrument for the second phase investigation of teachers' views on NOS in this thesis as will be explained in detail in Chapter 3.

Views on Science and Education (VOSE) by Chen (2006): a standardized assessment tool designed to measure adults, college students, and pre-service and in-service teachers' concepts and understanding of NOS and related teaching attitudes. It consists of 15 main questions and 85 items, where each main question is followed by a number of items each reflecting a certain philosophical position. It covers the various aspects of NOS that are widely discussed in the literature (e.g., Good et al., 2000; Lederman, Abd El Khalick and Schwartz, 2002; Schwartz and Lederman, 2002). These include the tentativeness and validation of scientific knowledge, socio-cultural issues, role of imagination, epistemology of theories and laws, nature of observation, scientific method, and subjectivity and objectivity.

VOSE also includes five questions to measure participant teachers' attitudes towards teaching various issues in NOS: teaching about the tentativeness of scientific knowledge, the nature of observation, the scientific method, the relationship between theories and laws, and the subjectivity embedded in science.

VOSE was developed in three stages. In the first stage, the author conducted a search of the related literature to select NOS aspects to be included in the questionnaire. Following the literature review, she determined the content and format of the questionnaire through a pilot study. Open-ended data were collected from interviews with some pre-service secondary science teachers. These data and the problems raised from the pilot were taken into consideration in the development of VOSE items.

In the second stage, the researcher developed and tested the questionnaire's items. Some of the items were revised from "views of science, technology, and society" (VOSTS) developed by Aikenhead and Ryan (1992). Others were generated from recent literature and from the responses and statements emerged from the pilot study in phase one above. These items were then reviewed by a panel of experts for the purpose of validation. Moreover, some students were interviewed with these items to check content clarity.

In the third stage, the final test, which consisted of 15 questions and 85 items, was administered to 302 junior and senior students. Some of the students were re-tested and then interviewed to ensure the reliability and validity of the test.

The development, validation, analysis and suitability for large scale assessments of VOSE (Chen, 2006) led me to believe that it is a comprehensive, valid and reliable instrument to assess teachers' views of NOS and their attitudes toward teaching about NOS. The strength of VOSE as an assessment instrument lies in the fact that it has multiple sources and was empirically based, constructed from learners' perspectives with a focused domain of measurement that can be managed and analysed easily, especially in large-scale assessments. It was judged to be suitable to use those parts of VOSE that assess participants' views of NOS, which consist of 10 questions and 55 items, for the first quantitative phase of my study that is detailed in Chapter 3 that follows (Appendix 2).

Student Understanding of Science and Scientific Inquiry (SUSSI) by Liang et al., (2008): a standardized assessment instrument having a blend of five-point scale Likert-type items and open-ended questions, that was developed to gain a rich and deep understanding of the pre- and in-service teachers' views of how the scientific knowledge develops. It covers six main themes; tentativeness of scientific knowledge, observation and inferences, creativity and imagination in science, social and cultural embeddedness in science, scientific theories and laws, and methodology in scientific investigations. Each theme is represented by four Likert items that involve the most common naïve views and contemporary views of the targeted theme, and an open ended question (Liang et al., 2008). The items of SUSSI were built mainly from existing empirical studies and other literature, especially VOSE, VOSTS, VNOSE and VNOS-C. The authors modified existing items from these instruments and the literature, and analysed the data they got from different sources such as the Likert items, the open ended questions and the follow up interviews to insure the trustworthiness of SUSSI. They also examined its face and content validity through a panel of nine experts.

It seems that the combined quantitative and qualitative methods utilised in the development of this instrument has enhanced its validity and reliability, and made it feasible to be utilised for small and big scale studies that allows for large scale national and international comparisons of stakeholders' views of NOS. However, it is not sensitive enough to probe the stakeholders' cultural or religious impact on their views of NOS (Liang et al., 2009). It had not yet been developed when I carried out my research.

2.7 Quantitative Versus Qualitative Assessment of Views of NOS

Referring back to the most widely used assessment tools to assess students' and teachers' beliefs of NOS in the literature aforementioned, one can see that most of them, especially those from the 1960s to the 1980s, were quantitatively based. This trend might be interpreted as relating to the tendency of most researchers to develop user-friendly instruments that can be handled and analysed easily. The other factor was that behaviourism was the dominant paradigm from the 1960s until the 1980s. It was therefore natural that the focus was on quantitative methodologies. However, with the shift of interest in cognition in the 1980s, some qualitative approaches to assess the beliefs of NOS emerged (Richardson, 1996).

Quantitative approaches using surveys with items of forced choice alternatives were criticized for different reasons, for example, for the understanding of beliefs, researchers need to make inferences of the participants' underlying conditions. These inferences could not be made via information obtained from closed questionnaires with forced alternatives (Pajares, 1992). These instruments were ineffective to detect the participants' interpretations, or their underlying reasons for choosing a certain answer. Their ability to probe the beliefs of NOS of the subjects was limited to labelling their beliefs as adequate or inadequate, but they failed to describe these beliefs. Moreover, Aikenhead, Fleming, and Ryan (1987) criticised the construct and the validity of the forced choice quantitative instruments, in that the developers of these instruments assume that participants recognize and understand the instrument items in a manner similar to their understanding. Another concern for Alters (1997) was that most of these instruments were developed from the perspectives of the expert and tended to over simplify and over generalize the views of NOS. Abd El Khalick and BouJaoude (1997) pointed out that some participants might have combinations of views that could not be easily detected in a multiple choice response format. Munby (1983) added that sometimes the developers' desires and biases were implied in the multiple choice instrument, and hence responses generated from it were not necessarily the participants' actual beliefs.

Such criticisms and concerns of the convergent quantitative approaches caused a shift toward more qualitative, open-ended approaches for more in-depth description and analysis of individuals' beliefs of NOS. As mentioned, the most popular open-ended questionnaire developed was VNOS-C. Some other open-ended instruments were developed like "the images of science probe" by Driver, Leach, Miller, and Scot (1996), "small group discussions" by Solomon (1992), and "situated-inquiry interview" by Welzel and Roth (1998).

Nonetheless, qualitative open-ended approaches are not without their own weaknesses. It is sometimes very difficult for researchers to get the intended information from each participant, since it is unlikely that all would address a certain concept related to NOS as expected, especially some questions do not deal directly with the related issues or concepts. Another concern is that this approach needs a lot of time and effort in administering and analysing, and is therefore ineffective for large scale assessments.

In fact, I would say that the most fundamental factor in selecting the data collection instrument to be utilised in research is its potential to achieve its aims. For some purposes, quantitative instruments are the best, while in other cases open-ended qualitative instruments are more suitable. Interestingly, Lederman (2007) and Abd El Khalick and Lederman (2000b), in their critical review of literature, show that findings in several research projects on students' and teachers' conceptions of NOS were consistent in their findings regardless of the assessment instruments, whether quantitative or qualitative, used in each research project.

2.8 Summary

In this chapter I have presented the underpinning theoretical framework and background literature for this study, and focussed on research relating to various perspectives on NOS with regard to teachers' views in particular, and science teaching in general, where I provided an analytical review of previous studies about teacher beliefs and assessments with regard to NOS in five main areas:

- Philosophies of science and what is understood by science, including an overview of the salient characteristics of the most traditional philosophies of science (namely, the inductivist/empiricist, the positivist/realist and the logical positivist philosophies) and the most modern ones (namely, the social constructivist and the historicist/postmodernist philosophies).
- The concept of the nature of science including the historical development of NOS conceptualisation. The review revealed that there exist many definitions of NOS that vary from one philosopher to another and from one science educator to another. However, according

to the international reform documents in science education, there exist eight main aspects of NOS that are relevant for school science teaching. These include the empirical, tentative, and subjective nature of scientific knowledge, the social and cultural embeddedness of science, the myth of a single scientific method, the role of imagination in generating scientific knowledge, and the epistemology of, and relationship between, theories and laws in science.

- Nature of science and school science, with a focus on the importance of understanding NOS, especially for being a decisive component of the structure of teachers' knowledge base and their scientific literacy, and for its important implications for school science and science curricula.

- Research conducted around the understanding of NOS including students', teachers' and scientists' views of NOS, the interplay between teachers' worldviews and their views of NOS, the relationship between teachers' beliefs of NOS and classroom practices, and improving teachers' understanding of NOS. The review shows that many students, science teachers and scientists do not possess an adequate understanding of NOS. Instructional strategies that explicitly address NOS outcomes have had some success.

- Assessment of views of NOS, including an overview of the most common instruments developed and used in the literature since the 1960s, which possess a reasonable degree of validity and reliability. The review revealed the tendency to move from convergent quantitative approaches toward more qualitative, open-ended approaches for more in-depth description and analysis of individuals' views of NOS.

Through this literature review it became clear that my study could make a significant contribution in the field by generating data that could facilitate an understanding of Palestinian teachers' views of NOS, the reasons why they hold such beliefs and the possible ways to move their understanding of this very fundamental topic forward.

Chapter Three—Research Methodology and Design

3.1 Introduction

The main purpose of this study was to investigate teachers' views of the nature of science (NOS) and to explain these views in the context of Palestinian education. The study was exploratory in nature and employed a descriptive research design. Following a justification of the research methodology, this chapter discusses the methodological issues and procedures involved in the research design and data collection and analysis.

This chapter consists of ten sections beginning with Section 3.1 which provides an introduction to the chapter. Section 3.2 addresses the philosophical underpinnings of the research through a discussion of the main educational research paradigms: the quantitative/positivist, qualitative/interpretivist, and mixed methods paradigms. Section 3.3 explains and justifies the mixed methodology approach adopted for this study, followed by Section 3.4 which gives an overview and description of the data collection instruments (methods) and their development, including a discussion of the literature on questionnaires and semi-structured interviews and their relevance to this investigation. The population and sample of the study, and the sample selection process for the participants for both the quantitative and qualitative phases of the research is addressed in Section 3.5, followed by a presentation of the data collection procedures and the phases of investigation in Section 3.6. Section 3.7 is devoted to a brief outline of the meanings of validity and reliability, and the methods and actions taken to strengthen the validity and reliability of the research findings. Section 3.8 outlines the mechanism of data analysis of both the quantitative and qualitative data while Section 3.9 considers the ethical issues, including the researchers responsibilities to the participants, and the actions carried out to overcome the fundamental ethical challenges. Finally, Section 3.10 provides a summary of the main points of the chapter.

Figure 3.1 outlines the methodological sequence including the phases of investigation, and a schedule of data collection and analysis.

Figure 3.1: Overview of the methodological sequence

Phase 1: Research plan • Initial thoughts and questions for the research • Literature review and reading about the topic
Phase 2: Quantitative data collection • Instrument selection (closed questionnaire) and adaptation • Selection of participants • Administration of the instrument • Analysis of quantitative data, **leading to shift in research focus and reframing of the research questions**
Phase 3: Qualitative data collection • Design and development of instruments: open-ended questionnaire and interviews • Random selection of 12 participants from Phase 2 for an open-ended questionnaire and follow up interview. • Administration of semi-structured interviews with 10 academics and 6 education officials
Phase 4: Data analysis • Analysis of qualitative data from teachers and other stakeholders • Merging of quantitative and qualitative data of teachers' views of NOS • Generating profiles of stakeholders' explanations and recommendations concerning teachers' views of NOS
Phase 5: Interpretation of the data • Findings and conclusions • New knowledge/understanding • Answering of research questions

3.2 Philosophical Underpinnings of the Research

Before I describe and discuss the specific methods I utilised in this research, I will briefly present the general philosophical underpinnings of the research where I clarify the ontological and epistemological positions I adopted, and explain the selection and relevance of a mixed methods approach as a design for this study.

There are two principle paradigms[6] in educational research: the positivist paradigm and the interpretivist paradigm. The positivist paradigm is "*modelled on the natural sciences with emphasis on empirical, quantifiable observations which lend themselves to analysis by means of mathematical tools*" (Husen, 1997:17). It recognises an objective reality with an objectivist conception of social reality, not dependent on the researcher, who tends to remain objectively separated from the subject matter. It uses empirical research to test hypothetical generalizations and often employs a deductive approach (Fenstenmacher, 1986; Bryman, 2001). Quantitative research provides data through the use of quantified measuring instruments like questionnaires, and structured interviews which possess a reasonable degree of validity and reliability (Galton, Simon and Croll, 1980). These techniques are utilised frequently in educational research, especially in experiments and surveys. They can easily access features like biographies, views, opinions and attitudes from large populations (Lunn, 2000). Its strength lies in its accessibility to statistical analysis that allow for the generalisabilty of findings.

In contrast, the interpretivist paradigm is modelled in the social sciences and emphasises an understanding of the subjects' perspectives, processes, and the contextual components in which the research takes place (Husen, 1997). This paradigm is based on researching a phenomenon in its natural conditions as a direct source of data, where the researcher is a primary data gathering instrument. Qualitative data are more descriptive, where words, objects and pictures are used, rather than numbers. Researchers who adopt this paradigm are more often concerned with the process; not merely the results. They analyse their data inductively, not looking for the data to approve or refute a certain hypothesis that was formulated before the beginning of the study, rather they try to develop general norms or theories through the aggregating and linking of partial information and data although the researcher may

[6] A paradigm is a world view or a belief system that "*includes criteria according to which one selects and defines problems for inquiry and how one approaches them theoretically and methodologically*" (Husen, 1997:17).

know roughly in advance what s/he is looking for (Strauss and Corbin, 1990; Miles and Huberman, 1994).

Researchers who work exclusively within the qualitative paradigm argue that it is not acceptable to utilise the same methodologies to study natural objects and human beings, because human beings are continuously changing, and give meaning and interpretation to the situation of research (Glaser and Strauss, 1967; Strauss and Corbin, 1998). The paradigm's epistemological position stands on the view that reality is subjective and socially constructed (Bryman, 2001) accompanied by an ontological view that the social phenomena that are researched are not separated from those involved in the construction (Gubrium and Hostein, 1997). Qualitative interpretivist research is crucial for looking at unexplored deep features that might have a cultural or social nature. In the educational context, this type of research is helpful in getting to the deep structure and conceptualisation of the participants' knowledge or beliefs, especially in areas like teachers' beliefs or views where these views are in most cases complex and influenced by the context (Lunn, 2000).

Creswell (2003) suggests that there are three further distinctive features and differences between the two paradigms that should be taken into consideration when selecting either (or both) of them as a research paradigm (Creswell, 2003). The first difference relates to the research questions being asked. In quantitative research, the research questions are predetermined, while qualitative researchers start with broad views or impressions which then lead to the main research questions. The same is true for the research instruments in both approaches. The second difference concerns sample size. Quantitative approaches are suitable for large sample sizes of participants, and can provide a generalisable view of the issue under investigation, whereas qualitative approaches are only relevant with a small number of participants when there is a need to get to a deep understanding of the phenomena under investigation, without an objective of large scale generalisation. The third difference relates to the role of the researcher. In quantitative investigations the researcher is an objective outsider, but within a qualitative design the researcher is part of the design and map of the research.

However, although these paradigms differ in terms of epistemology, ontology and data analysis, a great body of recent research argue in favour of a mixed methods approach utilising both in order to take advantage of their points of strength relative to the purpose of the research study (Solomon, 1992; Layder, 1993; Robson, 1993; Miles and Huberman, 1994; Hammersley, 1995; 1998; Strauss and Corbin, 1998; Tashakkori and Teddlie, 1998; Cohen and Manion, 2000; Bryman, 2001; Creswell, 2003). These researchers argue that the crucial issue when planning a research project is to utilise the best way to answer the research questions (Hammersley, 1992).

The mixed methods approach contains elements of both quantitative and qualitative approaches in its research methodology (Tashakkori and Teddlie, 1998). It contains quantitative and qualitative research techniques, methods, theories, data sources and language to research the same problem in a single study (Patton, 1980; Johnson and Onwueghuzie, 2004). Creswell and Clark (2006:5) describe the mixed methods research as:

> ... a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analyzing, and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone.

This approach was also supported by Robson (1993:xi) who stated that *"several methods of inquiry are likely to be better than any single one in shedding light on an issue"*, because they allow researchers to generate rich and reliable data, and enhance the validity of their research findings. In a similar manner, Creswell and Clark (2006) justified the employment of a mixed methods research in addressing research problems contending that it has strengths that offset the weaknesses of both qualitative and quantitative research; provides more comprehensive evidence for studying a research problem and encourages the use of multiple worldviews or paradigms.

A mixed methods approach stands on pragmatism as a philosophical position and holds both objective and subjective points of view, accepts external reality and chooses expectations that best produce the desired outcomes (Tashakkori and Teddlie, 1998). The major tenets of pragmatism that make it very suitable as a paradigm for a mixed methods approach lie in its concept of quantitative and qualitative methods as compatible enabling researchers to use both in their research, and in its orientation toward "what works" in practice (Creswell and Clark, 2006). In this regard, Brewer and Hunter (1989, cited in Tashakkori and Teddlie, 1998:12) argue that:

> The pragmatism of employing multiple research methods to study the same general problem by posing different specific questions has some pragmatic implications for social theory. Rather than being wed to a particular theoretical style, and its most compatible method, one might instead combine methods that would encourage or even require integration of different theoretical perspectives to interpret the data.

This approach which focuses on the advantages and fields of strength of each of them has been supported by many researchers who believe that it is expansive, creative, inclusive and complementary. They argue that using this approach, when appropriate, will generate a deeper analysis of the researched subject and a higher degree of confidence in the findings than either the qualitative or quantitative approach can do alone (Patton, 1990; Strauss and Corbin, 1990; Miles and Huberman, 1994; Cohen and Manion, 2000; Bryman, 2001, 2006; Creswell, 2003, 2006; Johnson and Onwuegbuzie, 2004).

3.3 The Selected Methodology: An Explanatory Mixed Methods Design

Research methodology refers to the nature of a research design and methods. It is made up of the research techniques and procedures which researchers utilize to answer their research questions and to meet the aims of their study. This methodology develops from the researcher's ontological and epistemological assumptions, as clarified by Sarantakos (2005), who mentioned that the research methodology is a strategy that translates the ontological and epistemological assumptions of the researcher into guidelines that show him/her how research is to be conducted and managed.

To answer my research questions and meet the aims of my study, I have chosen an explanatory mixed methods design (Creswell and Clark, 2006). It is a two-phase design that starts with the collection and analysis of quantitative data, followed by qualitative data collection and analysis. It is used when a researcher needs qualitative data to explain or build upon quantitative findings.

In this study, beginning with a quantitative phase allowed me access to the views of a large sample of Palestinian teachers from a wide geographical area thereby increasing the validity of my findings. This first phase also guided the selection of a sample of twelve teachers for the second qualitative phase. Here it was depth, coherence, comprehensiveness, that were obtained from data concerning teachers' views of NOS. This explanatory mixed methods approach enabled me to triangulate the quantitative data about teachers' views of NOS I obtained from the first phase with the qualitative data gathered in the second phase of the study, that enabled for deep exploration of teachers' views of NOS. I argue that such a rich and reliable data could not be achieved using quantitative methods alone. In the second phase, academics and other education officials were interviewed with the aim of explaining why Palestinian science teachers hold such views of NOS, and for their insights and opinions on how to improve teachers' views of NOS within the Palestinian context.

Keeping in mind the necessity for a researcher to be aware of the influence of philosophy on approaches of research (Guba and Lincoln, 1982), and in order to make use of the strengths of most of the paradigms in accordance with the rigour of the research, this research is underpinned by a pragmatist ontological position of the nature of reality, and an interpretivist epistemology of the nature of knowledge and its creation by holding an assumption that knowledge is experiential, personal and subjective (Herbert, 1990). This mixed methods approach fits best with the ontological assumptions of pragmatism and the epistemological assumptions of interpretivism (Murphy et al., 1998; Creswell, 2003). It is this philosophical stance (pragmatism) with its balanced and pluralistic position to mixed methods research that enables it to fit together the insights provided by qualitative and quantitative approaches into a workable solution (Johnson and Onwueghuzie, 2004).

Utilising a pragmatist paradigm allowed me to answer my research-specific questions by aiming for a very thorough analysis and careful explanations of the research topics. Moreover, this paradigm/approach combines both quantitative and qualitative methodologies in the same study uniting their strengths for answering the research questions which could not be achieved using a quantitative or qualitative methodology alone. Furthermore, it allowed me to triangulate the quantitative and qualitative data from the questionnaire and interviews in an attempt to provide valid and reliable results with a reasonable degree of confidence, and enabled me to avoid bias as much as was possible.

In the following section I discuss the instruments developed for data collection: closed and open-ended questionnaires and a series of semi-structured interviews.

3.4 Data Collection Techniques

I used a closed questionnaire to collect the quantitative data, and an open-ended questionnaire and five versions of semi-structured interviews to collect the qualitative data. These questionnaires and interviews are described below in terms of their source, development, structure and suitability for this study.

3.4.1 Questionnaires

Questionnaires are widely used in social sciences to collect data concerning participants' perceptions, tendencies, beliefs, values, motivations, future plans, etc. (Anderson, 1998). I used questionnaires in this research because they were useful and efficient for my time and effort (Robson, 1993) given that the population of my study was very large and distributed on a relatively sizeable geographical area in the West Bank of Palestine (Bell, 1999; Bryman, 2001). Moreover, I found questionnaires to be relatively low cost techniques that were suitable for gathering broad and in-depth informational data concerning teachers' views of NOS (Robson, 1993; Cohen and Manion, 2000) that would enable me to characterise their views. Furthermore, following Anderson (1998), I think, if handled properly, they give sufficient and accurate quantitative and qualitative data.

A Closed Questionnaire

A closed forced responses questionnaire (Appendix 2) was adapted from the "Views on Science and Education" (VOSE) questionnaire developed in Taiwan by Chen (2006). VOSE is a standardized quantitative assessment instrument that was designed to measure adults, college students, and pre- and in-service teachers' concepts and understanding of NOS and related teaching attitudes. It consists of 15 main questions and 85 items, where each main question is followed by a number of items each reflecting a particular philosophical position. It covers the various aspects of NOS that are widely discussed in the literature to date (e.g., Good et al., 2000; Lederman, Abd El Khalick and Schwartz, 2002; Schwartz and Lederman, 2002). These include the tentativeness and validation of scientific knowledge, socio-cultural issues, role of imagination, epistemology of theories and laws, nature of observation, scientific method, and subjectivity and objectivity. VOSE also includes five questions to measure participant teachers' attitudes towards teaching some aspects of NOS, which mainly covers teaching about: the tentativeness of scientific knowledge, the nature of observation, the scientific method, the relationship between theories and laws, and the subjectivity embedded in science.

VOSE was developed in three stages. In the first stage, Chen conducted a literature search to select the NOS aspects to be included in the questionnaire. She then determined the content and format of the questionnaire through a pilot study. The second stage consisted of testing the questionnaire items. Some of the items were revised from "Views of Science, Technology, and Society" (VOSTS) developed by Aikenhead and Ryan (1992), while others were generated from the recent literature or from the responses and statements emerging from the pilot study in stage 1 above. These items were then reviewed by a panel of experts for the purpose of validation. Moreover, some students were interviewed with these items to check content clarity. In the third stage, the final questionnaire, which consisted of 15 questions and 85 items, was administered to 302 pre-service secondary science junior and senior students. Some of the students were retested and interviewed following the retest to establish the reliability and validity of the test.

The development and analysis of VOSE (Chen, 2006) led me to believe that it is a comprehensive, valid and reliable instrument to assess teachers' views of NOS and their attitudes toward teaching about NOS. The strength of VOSE as a standardised assessment instrument lies in its development from multiple sources, it is empirically based, and it was constructed from learners' perspectives with a simple measurement scale that can be administered and analysed easily, especially in large-scale assessments (Chen, 2006). It was judged to be suitable to use those parts of VOSE that assess participants' views of NOS, which consist of 10 questions and 55 items (Appendix 2). The remaining five questions were not relevant, as they assess teachers' attitudes towards teaching NOS which is beyond the scope of this study.

For use in my study, the selected questions were translated into Arabic and adapted slightly to fit the Palestinian context. For example, the term God in the original questionnaire was replaced by "Allah", and an expression that described a scientist as a "devoted Christian" was replaced to describe him as a religious person, so as to avoid any bias to a particular religion. Some words and concepts, such as tentativeness and conscience, cannot be literally translated to Arabic without losing some of the flavour of the original text. Therefore, the literal Arabic translation was modified in some parts to improve clarity of expression taking care not to alter the meaning. The questionnaire was then validated by seven Palestinian science educators who were all academics and experts in science education and the field of NOS, and was then piloted on 35 science teachers. Relevant modifications were carried out on the questionnaire in light of the validators' comments. All the comments obtained from the validators were around the Arabic expressions used, without any change to the essence of the original content or format of the original questionnaire. Afterwards, a test-retest with the 35 teachers was carried out; the instrument achieved a 0.84 correlation coefficient. The questionnaire was then distributed to a representative sample of 537 science teachers within the West Bank, of whom 277 (55.4 %) completed it. Across the whole sample, a Cronbach alpha value of 0.81 was achieved, indicating a reasonable internal consistency and reliability of the instrument.

A Qualitative Open-Ended Questionnaire

The purpose of utilising an open-ended questionnaire was to allow for detailed description and explanations of teachers' views and understanding of NOS and its main tenets. It allowed the respondents to express their own views and understanding of the issues and tenets related to NOS freely, without imposing any particular predetermined views.

In this study, ten of the twelve questions in the open-ended questionnaire were taken from Views of Nature of Science-form C (VNOS-C) developed by Abd El Khalick (1998) with two additional questions utilised. VNOS-C consists of ten open-ended questions that cover the various aspects of NOS mentioned earlier. VNOS was originally developed by Lederman and O'Malley (1990) as an open-ended questionnaire, and included seven open-ended questions. Abd El Khalick (1998) revised it by adopting some items, modifying others, and adding new items. He established the face and content validity of VNOS-C through having it examined by a panel of three science educators, a historian of science, and a scientist.

I was confident that VNOS-C, which was widely used and highly regarded in the field, was appropriate for this phase of the study as a valid and reliable instrument widely used in the literature with a good reputation. However, two questions were added to VNOS-C (Items 11 and 12 in Appendix 3) in order to explore in more detail the cultural, social and religious influences on teachers' views of NOS in the research context of Palestine. I think these questions added to the comprehensiveness and validity of the original VNOS-C questionnaire within the Palestinian context, although the VNOS-C questionnaire was face and content validated in previous research by its author and others (Lederman and O'Malley, 1990; Abd El Khalick, Bell and Lederman, 1998; Abd El Khalick et al., 2001; Liu and Lederman, 2007).

This questionnaire formed the basis of the follow-up interview discussed in the following section. Here, the participants were interviewed after completing the questionnaire to establish validity of item interpretation and responses, and to further probe participants' views of NOS (Lederman et al., 2002).

3.4.2 Semi-Structured Interviews

Interviews are ideal for allowing in-depth understanding of teachers' views, ideas, perceptions, and their conceptions of teaching (Gao and Watkins, 2002). They enable the researcher to determine the participants' views from their explanations, terminology, judgements, body language, emotional reflections, etc. (Patton, 1990; Cohen and Manion, 2000). This was the case in this research where the interviews were very helpful in characterising and analysing teachers' views of NOS in-depth, the reality and causes of these views, and also the possible ways to improve them.

While, there are several ways in which the interview can be used as a research technique, in this study, it is used in conjunction with other methods to answer the research questions (Cohen and Manion, 2000).

In this study, I judged the semi-structured interview format to be most appropriate for getting to the heart of science teachers' views of NOS. It enabled me to guide the interview, in order to facilitate in-depth probing. The semi-structured format allowed me to ask any relevant unplanned questions in response to the interviewee's answers, and change or add questions during the interview (Bryman, 2004). As Driver (1995) and Robson (1993) suggest, I found that this flexible instrument gave me sufficient freedom to tailor the interview to my research goals.

Interview Development Phase

The data collection for this research involved interviews with different participants for different purposes. For the purpose of answering my research questions, five versions of semi-structured interviews were developed. Below is a brief description of these interview schedules.

1. ***A follow-up interview*** (Appendix 4) was conducted with teachers who responded to the open-ended questionnaire. The main aims of this follow-up interview were to validate participants' answers to the open-ended questionnaire, to probe their answers in more depth, and to explore the rationale for their written statements (Leach et al., 2000). It was also designed to elicit the source of teachers' views. The interview consisted of three main parts. The first part aimed to check the clarity of the respondents' answers, follow up on any missing or incomplete data, and clarify any discrepancies in their responses across the questions. The second part (adopted from Abd El Khalick, 2006) consisted of follow-up questions to the different scenarios of naïve responses that might have been obtained on each item of VNOS-C. These questions, when used, required respondents with naïve views to comment on, and consider any conflicts in their answers to the questionnaire items. The third part consisted of five additional open-

ended questions that aimed to encourage teachers to expand on their views in an attempt to reveal the kernel.

2. ***Semi-structured interviews*** were conducted with academics (Appendix 5). These interviews consisted of gathering biographical data about the academics, and posing ten main questions to them. The aim was to explore their understanding and opinions of the reasons why teachers hold such traditional views of NOS. They were also intended to investigate the academics' opinions and views of the possible ways and mechanisms for improving teachers' views of NOS within the Palestinian context, and the possible factors that might exist which could support or impede the development process.
3. ***Semi-structured interviews*** were conducted with science textbook authors (Appendix 6). These interviews consisted of gathering biographical data on the respondents and posing eight questions to them. The aim was to establish whether textbook authors contributed to the formation of the views of NOS held by the teachers, and if so, to what extent they sought to look at the way textbooks were designed, and the degree to which the authors were in position to include NOS appropriately within the curriculum. Authors were also asked how the science textbooks could be improved in their presentation of NOS, and what factors might facilitate or hinder this process.
4. ***Semi-structured interviews*** were conducted with science education supervisors (Appendix 7). After gathering biographical data, ten questions were asked in an effort to explore the role teachers' supervisors and the education supervision system play in the development of teachers' views of NOS; whether the supervisors are helpful in this regard; and whether they are in a position to effectively develop teachers understanding of NOS.
5. ***Semi-structured interviews*** were conducted with in-service teacher trainers (Appendix 8). These interviews consisted of gathering biographical data and posing nine questions to the trainers to explore how NOS is addressed in in-service teacher training programmes and the degree of attention they pay to this topic in their training, and whether they are in a position to do this job professionally. They were also asked about the role teacher training might play in improving

teachers' understanding of NOS, and the possible facilitating or hampering factors they might face in trying to achieve this goal.

3.5 Sample Selection

Careful sample selection was vital in both the quantitative and qualitative phases of this research. As Miles and Huberman (1994) point out, this is crucial for data analysis, generalisation of findings and the quality and confidentiality of the conclusions drawn from the research. The sample sizes were influenced by the aims of the research and the nature of the population (Cohen and Manion, 2000). Here follows a description of the sample selection process for the quantitative and qualitative phases of this research and its impact on the research findings.

3.5.1 Quantitative Phase

The initial aim of the quantitative phase of data collection was to broadly diagnose Palestinian science teachers' views of NOS, with the aim of selecting the ten teachers with the most sophisticated views and the ten teachers with the most naïve or traditional views of NOS. The intention was then to explore in the next phase the relationship between the views of NOS and the classroom practice of these teachers at the extremes of the continuum.

Thus, a broad and large sample was needed for this initial phase to facilitate effective selection for the second phase. To achieve this goal, the total number of science teachers in the public sector in the West Bank, which represents the population of the study, was obtained from the MoEHE. This population of 1470 teachers was distributed across 13 districts. In order to cover this broad geographical region, I selected the central district of Ramallah and randomly selected one district from the north and one south of Ramallah. The questionnaire was distributed through the teacher directorate offices to all 537 science teachers in these three districts as at the beginning of the 2007/2008 academic year. A response was received from 277 teachers (55.4 %) who varied in gender, length of teaching experience, geographical location within the West Bank, field of study, degree and teaching qualification. Table 3.1 shows the basic characteristics of this sample of teachers.

Table 3.1: Characteristics of the sample of teachers (n = 277)

Gender	Male (No/Percentage)		Female (No/Percentage)		No response	
	135 (48.7 %)		142 (51.3 %)		0	
Teaching qualification	Qualified		Not qualified		No response	
	150 (54.2 %)		124 (44.8 %)		4 (1 %)	
Field of study	Physics	Chemistry	Biology	General science	Lower elementary	No response
	42 (15.2 %)	73 (26.4 %)	66 (23.8 %)	65 (23.5 %)	13 (4.7 %)	18 (6.5 %)
Degree	Diploma		Bachelor		Master	No response
	38 (13.7 %)		206 (74.4 %)		31 (11.2 %)	2 (0.7 %)
Geographical location	Ramallah		Jerusalem		Qalqelieh	No response
	99 (35.7 %)		64 (23.1 %)		113 (40.8 %)	1 (0.3 %)
Experience	<1 yr	1-5 yrs	6-10 yrs	11-15 yrs	>15 yrs	No response
	42 (15.2 %)	118 (42.6 %)	64 (23.1 %)	22 (7.9 %)	27 (9.7 %)	4 (1.4 %)

The large sample size, relatively high response rate and rich diversity revealed by the biographical data allowed me to assume that this sample offered a broad picture of teachers' views of NOS within the population, from which teachers for the follow-up qualitative phase could then be successfully identified.

3.5.2 Qualitative Phase

Unexpectedly, the analysis of the data collected from the first phase failed to identify teachers with any level of sophistication to their views of NOS. This compelled me to modify my research focus, as the range of beliefs held was insufficient to allow a comparative investigation into the relationship between teachers with sophisticated and naïve views, and their classroom practices. Because the quantitative phase revealed that this sample of teachers held traditional views about science, it was judged appropriate and significant to explore in depth the nature, causes and context of teachers' views of NOS. Consequently the five populations of the second phase were:

1. the 277 in-service science teachers who filled the closed questionnaire in the first phase;
2. Palestinian academics who were involved in science teacher education;
3. science textbook authors;
4. MoEHE teacher trainers;
5. MoEHE school supervisors.

The sample of the first population, in-service science teachers, was selected using a simple random sampling technique (Cohen and Manion, 1985) from the body of teachers (277) who filled out the closed questionnaire in the first quantitative phase carried out in Palestine in autumn of 2007.

Fourteen teachers[7] were selected for the open-ended questionnaire and the follow-up interviews. Two of them expressed their unwillingness to participate in a follow-up interview. As a result, a decision was taken to exclude them from the study. Table 3.2 shows the basic demographic characteristics of the twelve teachers who participated in this qualitative phase, while Table 3.3 gives more biographical and background information on each of them.

As shown in these two tables, there was great diversity in the participants' backgrounds and, given the random nature of the sample, is considered an adequate representation of science teachers in the West Bank.

[7] In fact, the plan was to follow up with 12 teachers. However, when I approached MoEHE to select 12 teachers from the cohort of the 537 who completed the questionnaire, they advised me to select two or three additional teachers in case some of them retired or resigned after data collection in the previous academic year.

Table 3.2: The characteristics of the participant teachers

Gender	Male		Female		
	5		7		
Religion	Islam		Christianity		
	10		2		
Teaching qualification	Qualified		Not qualified		
	8		4		
Field of study	Physics	Chemistry	Biology	General science	Lower elementary
	2	2	3	4	1
Degree	Diploma		Bachelor		Masters
	3		7		2
Geographical location	Ramallah		Jerusalem		Qalqelieh
	5		4		3
Experience	<1 yr	1-5 yrs	6-10 yrs	11-15 yrs	>15 yrs
	2	5	2	1	2

Table 3.3: Biographical and background data of the participant teachers

	Gender	Degree	Specialisation	Teaching qualification	Geographical location	Experience (years)	Religion
T1	Female	Bachelor	Chemistry	No	Ramallah	8	Islam
T2	Male	Diploma	General Science	Yes	Ramallah	2	Islam
T3	Female	Diploma	General Science	Yes	Qalqelieh	18	Islam
T4	Male	Bachelor	Physics	No	Jerusalem	1	Islam
T5	Female	Bachelor	Biology	Yes	Qalqelieh	4	Islam
T6	Female	Bachelor	Lower Elementary	Yes	Jerusalem	1	Islam
T7	Female	Bachelor	Biology	Yes	Jerusalem	3	Islam
T8	Male	Bachelor	Physics	No	Qalqelieh	7	Christian
T9	Female	Masters	Biology	Yes	Ramallah	2	Islam
T10	Male	Diploma	General Science	No	Jerusalem	23	Islam
T11	Female	Diploma	General Science	Yes	Ramallah	13	Christian
T12	Male	Masters	Chemistry	Yes	Ramallah	4	Islam

The sample of the second population, academics involved in teacher education from the main Palestinian universities and teacher training research centres, was selected according to the criterion-based sampling technique recommended by Holloway (1997). Here, the researcher identified certain criteria on which the selection of the sample is based. The criteria for my sample selection firstly, that participants were Palestinian professionals who were experts or researchers in the field of

NOS or the philosophy of science, and secondly that they were involved in science teacher education in Palestine. The purpose behind these criteria was to ensure that rich and rigorous information about the topic could be obtained. Using these criteria it was a difficult task to find suitable academics within the relatively small Palestinian community. My decision to include ten academics in this sample was informed by the widespread acceptance within the educational research community that the richness of the data makes up for the relatively small sample size (ibid).

This second group consisted of eight males and two females. Six have a PhD in science education, one a PhD in curriculum design, one a PhD in the philosophy of science, one a PhD in physics (with publications on NOS), and one was in his final year of PhD study in science education when this study was conducted. Seven members of the group were science education lecturers at the Bachelors degree level in four universities in the West Bank, another one was a physics lecturer, and the remaining two were researchers in two non-governmental teacher education research institutions that work with in-service science teachers to promote teacher empowerment and professional development. Table 3.4 shows the basic biographical and background data of the individual participant academics.

The two science textbook authors were selected in different ways: one was randomly selected (TA2), while the other (TA1) was purposefully selected. He was the coordinator of the national team of science textbook authors who shared in developing the broad aims of the science curriculum (curriculum document).

The sample of the fourth group, the MoEHE teacher trainers, was also selected in different ways: one was randomly selected (TT2), while the other (TT1) was purposefully selected. He was the director of in-service science teacher training in MoEHE.

Finally the sample of the fifth group, two MoEHE school supervisors (S1) and (S2), was randomly selected, using a simple random sampling technique.

Table 3.4: Biographical and background data of the participant academics

	Gender	Degree	Source of last degree	Discipline	Religion	Experience (years)	Involved in teacher education	Conducted research in NOS
A1	Male	PhD	Germany	Science Education	Islam	8	Yes	Yes
A2	Female	PhD	U.S.A	Curriculum Design	Islam	35	Yes	No
A3	Male	MED	Palestine	Science Education	Islam	4	Yes	Yes
A4	Female	PhD	Jordan	Science Education	Islam	5	Yes	Yes
A5	Male	PhD	Holland	Science Education	Islam	10	Yes	Yes
A6	Male	PhD	U.S.A	Physics	Christian	30	Yes	No
A7	Male	PhD	U.S.A	Science Education	Islam	6	Yes	No
A8	Male	PhD	U.S.A	Philosophy of Science	Islam	25	Yes	Yes
A9	Male	PhD	U.S.A	Science Education	Islam	13	Yes	Yes
A10	Male	PhD	Jordan	Science Education	Christian	20	Yes	Yes

3.6 Data Collection

This section summarises sequentially, the key steps in the quantitative and qualitative phases of this study.

3.6.1 Quantitative Data Collection Phase

The following is the sequence of the main steps followed in the first phase of data collection which was quantitative in nature:

1. A closed questionnaire to assess teachers' views of NOS was selected and adapted. This questionnaire was translated to Arabic, and checked for validity and reliability.
2. The questionnaire was piloted on 35 science teachers in July 2007, after the researcher received permission from the Palestinian MoEHE.
3. Three of the teachers who completed the questionnaire were interviewed to test the clarity of the questionnaire. Slight modifications were made to the questionnaire in light of these interviews.
4. A retest with the same group of teachers was conducted three weeks later.

5. In early September 2007, at the beginning of the academic year, 550 copies were distributed to school teachers in 200 public schools in the north, middle and east of the West Bank. I distributed the questionnaire to the teachers through the education directorate offices in these three districts who also took responsibility to collect the completed questionnaires from school teachers.
6. I personally visited the three education directorate offices a week later to collect the questionnaires: 277 out of 537 were collected. The questionnaires were then analysed, and fourteen of the teachers who responded to the questionnaire were randomly selected for the second qualitative phase of the study.
7. Quantitative data obtained from the closed survey concerning teachers' views of NOS were analysed, described and presented in Chapter 4 that follows.

3.6.2 Qualitative Data Collection Phase

Qualitative data collection was the focus of the second phase of the research project. It included the following main steps:

1. An open-ended questionnaire was developed to explore an in-depth assessment of teachers' views of NOS, and questions for semi-structured interviews to be conducted with school teachers, academics, MoEHE school supervisors, MoEHE in-service teacher trainers and science textbook authors were developed and validated.
2. A request for permission to administer the open-ended questionnaire and conduct interviews was sent to the MoEHE in early September 2008. Permission was granted by the Ministry at the end of September 2008.
3. A pilot study with two teachers was carried out to test the open-ended questionnaire and follow-up interview questions with them. The semi-structured interview to be conducted on the academics was piloted on one academic.
4. The necessary modifications of the instruments were done in light of the findings from the pilot study.
5. The open-ended questionnaire and follow-up interviews were conducted with twelve teachers, after which the academics,

supervisors, in-service trainers and textbook authors were interviewed. All interviews were digitally recorded. This process was carried out between the 5th October and the 20th November 2008.

6. All qualitative data were then analysed. Teachers' views of NOS obtained from the quantitative and qualitative phases were merged, characterised and explained.

3.7 Validity and Reliability

While mindful of the significance of carefully establishing the validity and reliability of the research methods when conducting both the qualitative and quantitative phases of this research, I also recognise that reliability and validity have a variety of meanings in different research paradigms and methodologies (Cohen and Manion, 2000). The most important of these for the current research, which is situated largely within the pragmatic paradigm, are the external and internal validity and reliability.

Internal validity refers to the accuracy of the results obtained from the related research, and whether it represents reality (Verma and Malick, 1999). In my research, internal validity refers to the correspondence of the views of NOS in the minds of the teachers and those reported in this study. External validity refers to the applicability of the research findings in contexts other than where the research was carried out, in other words, the degree of generalisability of the findings (Creswell, 2003). In my research external validity refers to the degree to which the results concerning teachers' views of NOS can be generalised to all science teachers in the public sector in Palestine.

On the other hand, internal reliability refers to the extent to which different researchers, given the data and results of analysis would match them together in the same way ending up with the same conclusions. While external reliability refers the extent to which a different researcher would get the same findings if they were to analyse the same data (Lunn, 2000). In my research external reliability refers to the degree to which there was an agreement between my analysis of teachers' views of NOS and another researcher's analysis of the same data.

In this research, several sequential steps during the development and implementation of the instruments, as well as the analysis and interpretation of them, were taken into consideration to strengthen and corroborate its validity and reliability for both the quantitative and qualitative phases.

Quantitative Phase

The validity and reliability of the closed questionnaire that was adapted for this study were tested and corroborated during the development of the original instrument by Chen (2006). However, given the translation process and the minor changes that were deemed necessary, the following steps were taken in this study to further ensure its validity and reliability:

1. The Arabic translation of the questionnaire was validated by a panel of seven science educators who are experts in the field of NOS and enrolled in teacher education programmes. Some minor adaptations were carried out on the Arabic version in light of their comments as explained in an earlier section.
2. It was then piloted on a random sample of 35 (out of 120) science teachers who were gathered to preview and correct the secondary school national exam (Tawjihi) papers organised by the MoEHE in June/July 2007. I distributed my questionnaire randomly to 35 of them and collected them on the same day. It is important to note that teachers who participate in the exam correction process are usually selected randomly from the whole body of school teachers by the Measurement and Assessment Unit in the MoEHE, and can thus be considered as a representative sample of science teachers in the West Bank.
3. A test-retest of the closed questionnaire was conducted with another group of 40 teachers selected randomly from the cohort of 120 teachers above and yielded a 0.84 correlation coefficient.

4. When conducted on the actual sample of 277 teachers, the closed questionnaire yielded a 0.81 overall internal consistency using Cronbach's alpha coefficient, and a range between -0.18 to 0.85 for the items addressing each of the eight main tenets of NOS investigated in this study, as shown in Table 3.5a below. Given the small number of items used to investigate some of the tenets of NOS, Cronbach's alpha scores for the data when grouped in this way were adequate. Two tenets, Tentativeness and the Nature of Observation, however, failed to give satisfactory Cronbach's alpha scores.

One explanation of this, apparently because of internal confusion in the way in which respondents answered these questions. For example, for the nature of observation tenet, the overall Cronbach's alpha score was strongly negatively correlated, indicating a negative covariance between responses. Upon inspection of the data and removal of Items 8.1, 8.2 and 8.5, the Cronbach's alpha score was boosted to 0.568, which is considered satisfactory. Tentativeness presented a different problem, because it was based on only three items in the first place. Two of the items contributing to this aspect reflected the cumulative and evolutionary nature of science development (Items 4.2 and 4.3), while Item 4.1 reflected a revolutionary view of the development of science. Omitting the latter item removed the negative covariance (Cronbach's alpha = 0.33), allowing this data to be included in the study. It seems likely that teachers believe in the accumulative and evolutionary view of science knowledge development, and do not see the revolutionary perspective as an opposing view. These items were also omitted from the "Subjectivity and Objectivity" tenet necessitating a revised calculation of Cronbach's alpha and the mean for this issue also (Table 3.5b).

After these modifications the overall consistency as measured by Cronbach's alpha was 0.74 for 51 items and 228 responses. On the whole, this overall value is acceptable, but the internal consistency values for the subgroups are fairly low. According to Erladson et al., (1993 cited in Chen, 2006) this is to be expected, because the original questionnaire was empirically developed from qualitative data derived from interviews.

Table 3.5a: Cronbach's alpha test of internal consistency for questions addressing NOS tenets

Tenet of NOS	Cronbach's alpha	Total number of responses	Total number of items contributing to score
Scientific Method	0.413	270	6
Validation	0.515	266	7
Socio-cultural issues	0.451	263	7
Imagination	0.852	269	4
Epistemology	0.721	252	15
Subjectivity and objectivity	0.593	234	34
Tentativeness	-0.183	276	3
Nature of observation	0.338	272	5

Table 3.5b: Revised results for the three tenets affected by questions subsequently excluded from the total data set

Tenet of NOS	Cronbach's alpha	Total number of responses	Total number of items contributing to score
Tentativeness	0.333	276	2
Nature of Observation	0.568	273	2
Subjectivity and Objectivity	0.611	235	31

It is difficult, therefore, to apply conventional concepts of validity and reliability, especially as the items were developed from respondents' interview transcripts, rather than from the researcher's presumption of consistent answers. The important point is that teachers' views of the eight aspects of NOS are not independent but interrelated, so the overall internal consistency of the questionnaire gives an idea of reliability even if the correlations for each aspect are relatively low.

Having said that, I am confident that the above steps helped improve the validity of my quantitative data, in accordance with Cohen and Manion (2000) who contested that careful sampling, and appropriate instrumentation and statistical treatments of data would improve quantitative data validity and trustworthiness.

Qualitative Phase

1. The open-ended questionnaire to assess teachers' views of NOS (Appendix 3) and respective follow-up interviews (Appendix 4) were piloted with two teachers before being administered to the sample. A follow-up interview was conducted with each respondent after they completed the questionnaire, which acted as a respondent validation (Bryman, 2001), as it provided valuable feedback about the clarity of the items and how the respondents interpreted them. Moreover, the piloting of the questionnaire and follow-up interviews helped me to focus my questions more closely and remove possible sources of ambiguity, and consequently increased their validity and feasibility (Morrison, 1993). However, the questionnaire used in this study (with very minor modifications as mentioned earlier in this chapter) was adapted from VNOS-C developed by Abd El Khalick (1998) and, as such, its content, construct and face validity were tested in previous research (Bell and Lederman, 1998; Abd El Khalick and Bell, 1999; Abd El Khalick et al., 2001; Liu and Lederman, 2001).
2. Similarly, the semi-structured interview with the academics (Appendix 5) was piloted on one academic before the final version of the interview was conducted with the sample.
3. Respondent validation (Bryman, 2001) was established for this phase by providing the interviewees with the transcripts of their responses, so as to confirm that the findings drawn from the interview data matched the participants' views. After I transcribed the interviews, I personally revisited the interviewees and asked them to read the transcripts of their interview, which sometimes led to further discussion and validation. This technique was helpful to promote the validity of the research findings by minimizing the possibility of misinterpretation of the interview data.
4. To ensure the external reliability of the main instrument (the adapted version of VNOS-C), I asked a colleague who is an expert in the field of NOS to analyse the data obtained from four respondents on VNOS-C. I then compared and contrasted my analysis with his analysis, and found that the agreement between my analysis and his was around 85 %. In the cases when we had differences in our analyses, we resolved these

discrepancies and reached consensus by revisiting the data and further discussion. I also asked him to check my translation of all the quotations I took from the interviews and included in my thesis (peer validation). Again in the cases when we had differences in the translation, we resolved these discrepancies and reached consensus by revisiting the original quotes in Arabic.

A General Method Utilised for Promoting Validity and Reliability: Triangulation

Triangulation involves gathering data from different sources and methods to shed more light on the theme or the issue under investigation (Creswell, 1998). According to Coolican (1999:470) *"triangulation means comparing different views of the same thing"*. There are four main types of triangulation according to Branen (1992): multiple methods, multiple researchers, multiple data sets and multiple theories. In this study, I utilised a multiple methods approach by using of two or more methods of data collection (Cohen and Manion, 2000) for the purpose of data collection and corroboration of validity and reliability of the results. I used both quantitative and qualitative methodologies, thus triangulating the closed questionnaire, the open-ended questionnaire and the interviews (methodological triangulation). I looked for consistency between the different groups of interviewees (data source triangulation) regarding the same issues of explaining teachers' views of NOS, and the possible ways to improve these views (Hammersley and Atkinson, 1995).

Having said that, I think that the triangulation and respondent validation procedures I have utilised have increased the internal validity and credibility (Bryman, 2001) of this research and minimized as much as possible the bias and subjectivity of the researcher (Rubin and Rubin, 1995). I am aware though that it is not possible to achieve complete objectivity and disinterestedness in any research as argued by Stauss and Corbin (1967), and support the view that validity and trustworthiness should be seen as a matter of degree rather than an absolute state (Gronlund, 1981).

3.8 Data Analysis Strategies

The present study used both quantitative and qualitative research frameworks in the analysis of the collected data. The analysis of NOS data collected was guided by a reform-based framework of the conceptions of the tenets and aspects of NOS deemed important and accessible to school education and appropriate for a scientifically literate person (Abd El Khalick, 1998). These include: the understanding that scientific knowledge is tentative, empirical and theory laden; scientific knowledge is the product of inference, imagination, and creativity, and is socially and culturally embedded; the distinction between observation and inference; the lack of one universal method for doing science; and the relationship between theories and laws (Appendix 1 gives a detailed characterisation and explanation of these tenets of NOS). These predetermined tenets of NOS served as a theoretical framework to guide the instruments development and initial coding of data obtained from the questionnaire and interviews as will be explained in the following sections, which outline the procedure for data analysis in both phases of this study.

3.8.1 Quantitative Data Analysis

The quantitative analysis was applied to the data obtained from the closed questionnaire in phase one of data collection which was suitable for descriptive statistical analysis that is numerical in nature. After data had been collected in September-October 2007, the quantified responses were coded using a Likert ranking scale from 1 (strongly disagree, reflecting the least sophisticated view) to 5 (strongly agree, the most sophisticated view). The scores of items that reflect traditional views (2.3, 2.4, 3.3-3.5, 5.1, 5.2, 6.1, 6.2, 7.1, 7.2, 8.3, 8.4, 9.1, 9.2, 9.6, 10.5, 10.6, and 10.9) were reversed before being treated identically with other items on the questionnaire. The data were analysed using SPSS (Kinnear and Gray, 2006). The statistical analysis of the items centred on the following eight tenets of NOS:

NOS Tenet	Items
Tentativeness	4.1-4.3
Validation of Scientific Knowledge	1.1, 1.3, 1.4-1.8
Socio-cultural Issues	2.1-2.4, 10.2, 10.3, 10.5
Imagination	3.1-3.3, 3.5
Epistemology of Theories and Laws	5.1-5.6, 6.1- 6.5, 7.1- 7.4
Nature of Observation	8.1-8.5
Scientific Method	9.1-9.6
Subjectivity and Objectivity	1.1-1.8, 2.1- 2.4, 3.1-3.3, 3.5, 5.2, 6.2, 8.1, 8.2, 8.3-8.5, 9.1, 9.2, 9.4, 10.1-10.5, 10.7-10.9

Mean scores were calculated for all of these aspects following the same way of analysis conducted by the developer of the original questionnaire (Chen, 2006). However, the analysis of data generated in this way might be problematic because calculating the mean scores of the tenets assumes that Likert scale is an interval scale which is subject of disagreement (Wright and Masters, 1982; Dennis and Dormody, 1994). Though many people just treated Likert scale as interval scales rather than ordinal ones, especially twenty years ago, there are more people in psychology who think that one should treat Likert scale as ordinal data where data can be summarised using mode and median, not mean values. Others argue that each individual Likert item can be considered as ordinal in nature, but the Likert scale that sums up the responses of several Likert items that are internally consistent might be considered as interval.

In this study, though it might be problematic to treat this data as interval using mean and standard deviation, to use modes and medians assuming the scale as ordinal is also equally problematic and would lose some of the richness of the information. Therefore I have decided to follow Chen (2006) summarising and describing data obtained for the main tenets of NOS using mean values and standard deviations because these tenets are coming from the literature where they have been constructed, tested and validated by Chen and others, and are internally consistent. I would argue that given the fact that people are fairly stable in their beliefs and are not going to have beliefs that change and shift widely within each tenet, averaging the items of each tenet to obtain the mean tenet score for each teacher is justified.

There was an inherent difficulty, however, in interpreting mean values in terms of the Likert scale from which they were derived. The mathematical mean of the 1 - 5 Likert scale is 3, which qualitatively in this study was expressed as a "neutral" response. However, while responses such as "agree", "strongly agree", "disagree" and "strongly disagree" can be interpreted in a straightforward manner in terms of the questions posed, "neutral" cannot. A neutral response, in terms of understanding of NOS, can best be interpreted as that the respondent did not understand the question, or did not have an opinion, either through lack of knowledge or lack of commitment. I feel that this "neutral" response is best interpreted as indicating a fairly unsophisticated view of NOS. As a result, I have adopted the convention of regarding a mean score of 1 - 2.5 as representing naïve/traditional/unsophisticated views of NOS, while a score of 3.5 - 5 can be considered a sophisticated viewpoint. Individuals scoring between 2.5 and 3.5 I interpret as borderline, although it could be argued that these also include predominantly naïve viewpoints.

3.8.2 Qualitative Data Analysis

The qualitative analysis was applied to the data gathered from the open-ended questionnaire, follow-up interviews, and the series of the semi-structured interviews that were non-numerical in nature. These data were collected in the second phase of data collection in October-November 2008, to elaborate and triangulate the quantitative data, and to add to its richness, depth and detail.

The procedure for analysing teachers' views of NOS obtained from the adapted VNOS-C and follow-up interviews involved three main steps (Hewson and Hewson, 1989) designed to generate profiles of the teachers' views of NOS as associated with the eight targeted tenets of NOS given above. The first step was the coding of the data after being transcribed[8]. The NOS-related codes, based on the eight tenets of theoretical framework outlined earlier, were: the empirical nature of scientific knowledge, the theory-laden nature of scientific knowledge, the social and cultural embeddedness of scientific knowledge, the myth of the scientific method, the tentative nature of scientific knowledge, epistemology of theories and laws, the creative and imaginative nature of scientific knowledge and the observation, inference and theoretical entities in science.

The second step was the theme (category) generation which involved a systematic organisation of the data into groupings that were comparable and similar (Rose and Sullivan, 1996:232). This involved analysing the stakeholders' statements regarding each of the NOS main tenets and grouping them together. The third, and final, step involved statement generation, by summarising the respondent's detailed answers in a couple of sentences, or phrasal statements where appropriate. Here, each participant was treated as a separate case, where the data collected from the adapted VNOS-C and the follow-up interviews were utilised to create a provisional outline of each participant's views of the eight tenets. These outlines were used for generating patterns and categories. Quotations that represented examples of similar underlying issues or concepts were chosen and added as examples of each category.

Teachers' emergent views, as described and portrayed in relation to each of the NOS tenets, were compared with the contemporary science education literature and reform documents on the topic to determine and identify their views on each aspect of NOS as either naïve, borderline or informed. A naïve view of a certain tenet of NOS indicates that the participant lacks an adequate/contemporary understanding of this tenet. A borderline view indicates that the participant holds somewhat informed

---

[8] The transcription and analysis of all interviews were done in Arabic to avoid losing the exact meaning of the participants' ideas and information in the translation process. However, the parts selected as quotations were translated into English later in the write up process, and a colleague confirmed the accuracy of my translation.

views of the tenet, but these views are often inconsistent and conflicting, or s/he is unable to justify and explain his/her view of the tenet clearly. An informed view of a certain tenet is indicated by the correspondence of the subject's views with those in contemporary science education documents, and the possession of an adequate and consistent understanding of the views that relate to that tenet.

The analysis process used to construct profiles of the participants' views of NOS was conducted on a tenet-by-tenet basis because the participants do not necessarily have comprehensive and coherent views across all the tenets of NOS (Abd El Khalick, 1998). The analysed quantitative and qualitative data of teachers' views of NOS were then combined to answer the first research question, with the qualitative data adding depth and detail to the quantitative results (Patton, 1987).

Similarly, analysing the interview transcripts of the academics, supervisors, teacher trainers and textbook authors involved two main steps. In the first step, the participants' responses to the semi-structured interviews (Appendices 4, 5, 6, 7, 8) were transcribed and coded. The coding of the data involved combining detailed information contained in their responses in light of four main themes used as a general framework for the analysis process:

1. explanation of teachers' naïveté of NOS;
2. ways of improving teachers' views of NOS;
3. factors supporting the development of teachers' views of NOS;
4. factors hampering the development of teachers' views of NOS.

The coding and categorisation of the responses led to the creation of a number of categories and sub-categories that allowed for a simpler description of the data, and facilitated a smoother analysis of the data and drawing of conclusions. In the next step the data from all the interviews regarding the first theme explaining the inadequacy of teachers' views of NOS were pulled together into main categories, where the set of transcripts were treated as a whole for the purpose of developing the main categories. I searched for patterns in each category in order to make comparisons and summaries of the patterns. I examined the quotations that appeared to represent examples of similar underlying categories or sub-categories.

As a result, eight main categories emerged from the data as explanations of the naïveté of teachers' views of NOS. These categories were:

1. science textbooks;
2. structure and policies of the education system in Palestine;
3. the Palestinian socio-cultural background;
4. teachers' own personal values;
5. teaching approaches at school and university levels;
6. teacher training programmes;
7. educational supervision;
8. school resources.

Within each of these eight categories, a number of aspects and issues were identified and reported in Chapter 5.

The analysis of data related to themes 2, 3 and 4 generated six main categories of possible approaches recommended by the stakeholders to improve teachers' views of NOS. The categories that emerged were:

1. tertiary science teaching and teacher preparation programmes ;
2. teaching as a well-resourced profession;
3. Palestinian science textbooks;
4. education supervision and in-service teacher training;
5. educational leadership and administration system;
6. public scientific literacy and critical social awareness.

Chapter 6 presents findings emanating from the analysis of these three themes.

3.9 Ethical Considerations

Ethical considerations relate to the researcher's commitment not to harm the participants by any means, and to respect their values, rights, needs and privacy (Verma and Malick, 1999). They include issues that the researcher should take into consideration which are related to the standards of behaviour expected of the researcher, such as accessibility, consent and voluntary participation, anonymity, confidentiality and any negative consequences that occur after the data has been collected (Kvale, 1996).

I have closely adhered to the ethical considerations characterised above, and have been responsible in my behaviour towards the participants. I sought and gained approval of the research ethics committee of the University of Nottingham in order to conduct my research. I received permission of the MoEHE before I contacted the participants to avoid putting them at any risk. I informed all the participants about the goals of the research and how I was going to use the data, as well as how I was going to keep and guarantee their anonymity, privacy and confidentiality, which I did indeed maintain throughout the research process. I also explained to them that their participation was voluntary and they could withdraw at any point. Two of the teachers who completed the closed questionnaire and were selected for follow-up interviews did not want to be interviewed and withdrew from the second phase of data collection with no pressure from me to participate. In cases where two of the teachers and one of the teacher trainers interviewees were not happy about me digitally recording the interview, I followed their wishes and relied on written notes from the interview.

I tried to minimise the negative psychological effects that might have resulted from the discussion with the teachers about their understanding of NOS, especially in the cases where teachers held naïve views of NOS. I wanted to avoid humiliation, as supported by Sapsford and Abbot's (1998) argument that subjects of the study should be protected from harm as much as possible. I explained that this naïve understanding of NOS is a global trend and not exclusive to Palestinian teachers. I also explained this to my contacts in MoEHE in order to insure that the research findings did not affect the teachers negatively in their relations with their supervisors or other personnel within the Ministry. After the interview with each teacher, I pointed out the areas of naïveté in their responses, and explained a more current and informed position on NOS.

Anonymity and confidentiality were guaranteed in the presentation of the research findings by making responses anonymous and giving all participants pseudonyms. Furthermore, after I finished the interviews and transcribed them, I sent the interview transcripts to all participants to confirm the information I got from them was accurate. In conclusion, I am confident that the procedures I adopted ensured that the key ethical requirements were met.

3.10 Summary

This chapter presented the methodology and design of this research, starting with the philosophical underpinnings of the research. It clarified my ontological and epistemological positions and situated my research within the larger debate of quantitative, qualitative and mixed methods approaches, before explaining the relevance of an explanatory mixed methods design for my study. The chapter described and discussed in detail the research design, the data collection techniques, the sample selection, and the phases of investigation. The steps that were taken into consideration with regards to the preparation, implementation and the analysis of the research instruments to improve the validity and reliability of the study for both the quantitative and qualitative phases were then presented. Finally, the chapter outlined the procedure for data analysis of both the quantitative and qualitative data, and discussed the ethical considerations of the research.

Having discussed the paradigms and methods adopted in this research, the next chapter reports and discusses the research findings of both the quantitative and qualitative phases concerning teachers' views of NOS.

Chapter Four—Research Findings: Teachers' Views of NOS

4.1 Introduction

The initial approach of this study was to conduct a quantitative survey of Palestinian science teachers' views of the nature of science (NOS), in order to identify sub-groups of individuals holding naïve and sophisticated views, which could be utilised for further research about their practice. This quantitative phase was not designed to test views in depth, but to identify teachers at the extremes of the range of views of NOS. However, the initial findings of this quantitative phase revealed that the range was narrow, and it was impossible to find teachers with sophisticated views across all the tenets of NOS. This led to a refocusing of the second phase of the project towards an in-depth exploration of Palestinian science teachers' views of NOS and the possible reasons why they hold such views. Here a qualitative approach was used.

This chapter reports the results of both research phases, and treats these data as a single whole. To summarise the methods used to explore teachers' views of NOS (and detailed in Chapter 3), quantitative data were collected during the first phase of the study in August and September 2007, from a sample of 277 teachers out of a total of 537 working within the three areas of Palestine chosen for consideration. Based on this sample, a random sub-sample of 12 teachers were involved in the qualitative phase from October to November 2008.

The quantitative survey was adapted from the "Views on Science and Education" (VOSE) questionnaire developed by Chen (2006) to include eight main aspects of NOS, namely tentativeness and validation of scientific knowledge, socio-cultural issues, role of imagination, epistemology of theories and laws, nature of observation, scientific method, and subjectivity and objectivity. The qualitative approach also covered eight aspects, however two differ slightly as justified in Chapter

2, these being the validation of scientific method and the inferential nature of science.

The present chapter is organised into four main sections. The first presents the quantitative findings, while the second analyses qualitatively the selected twelve teachers' views. The third section compares these quantitative and qualitative findings, and triangulates results from VNOS-C and the follow-up interviews with the quantitative results of the closed questionnaire to increase the validity and reliability of the study. The chapter ends with a discussion and conclusion of the findings.

4.2 Quantitative Findings of Teachers' Views of NOS

This section reports the first phase of an investigation into the views of Palestinian science teachers of the nature of science. The VOSE questionnaire for evaluating views of NOS, translated into Arabic, and adapted to fit within the Palestinian educational context, was validated by seven Palestinian science educators and academics, and in 2007 piloted on 35 science teachers before it was distributed to 537 teachers of which 277 (55.4 %) completed it. The total number of science teachers in the West Bank is circa 1500 (MoEHE, 2007), all working under the same conditions within a centralised administrative system teaching the same curriculum, and receiving the same quality of training and supervision. The 277 respondents therefore represent approximately 20 % of the total number of science teachers in the West Bank and their diversity of backgrounds and experience (see Section 3.5.1 in Chapter 3) suggest that this is an entirely representative sample. It is therefore reasonable to assume that this sample offered a broad picture of teachers' views of NOS within the population, and was not biased relative to the total teacher population.

What follows is a descriptive presentation of the findings from this survey. The overall summary statistics, with the average scale score, minimum, maximum and standard deviation for each subset (tenet), on a scale of 1 - 5, of NOS items are given in Table 4.1

Table 4.1: Descriptive statistics of teachers' mean scores on NOS issues measured

NOS Issue	Number of respondees	Number of items	Min	Max	Mean	Std. Deviation
Total (all issues)	277	51	1.90	3.36	2.84	0.24
Tentativeness	277	2	1.5	5	3.44	0.55
Nature of observation	276	2	1	5	2.61	0.62
Epistemology of theories and laws	277	15	1.18	4.00	2.53	0.49
Scientific method	277	6	1.33	5.00	2.34	0.46
Use of imagination	276	4	1.00	5.00	2.99	0.67
Validation of knowledge	276	7	1.33	4.29	2.57	0.45
Subjectivity and objectivity	277	31	1.82	3.54	2.88	0.28
Socio-cultural issues	277	7	2.00	4.38	3.36	0.44

As explained in Section 3.8.1 in Chapter 3, I have adopted the convention of regarding a mean score of 1 - 2.5 as representing naïve/traditional/unsophisticated views of NOS, while a score of 3.5 - 5 can be considered a sophisticated/informed viewpoint. Individuals scoring between 2.5 and 3.5 I interpret as borderline, although it could be argued that these also include predominantly naïve viewpoints. Similar boundaries of naïve and sophisticated viewpoints were also used by Cobern and Loving (2002). Using this classification it is clear, as Table 4.1 shows, that in general the sample hold naïve or borderline views, as no mean for the eight tenets was above 3.5. More sophisticated statistical analysis depends on the Likert scale responses being more or less normally distributed around the mean. An inspection of the distributions of mean scores for each of the eight tenets shown in Figure 4.1 reveals that most were symmetrically distributed around the midpoint of the Likert scale. Nevertheless, the data could not be treated as normally distributed variables, because they fall between ordinal and interval level measurement, and because of the arbitrary upper and lower boundaries of 1 and 5. The effect of multiple items sets in smoothing the distribution and reducing its range of mean responses is clearly seen in the distribution of mean scores of the subjectivity/objectivity in science with

34 items contributing to the tenet. The distribution of mean scores relating to the use of imagination in science was clearly not symmetrically distributed, and could be interpreted as being bi- or tri-modal (Figure 4.1). For these reasons, the teachers within the sample were reclassified according to the score boundaries listed above into "naïve", "borderline" or "sophisticated" for each of the eight tenets, and the proportion of teachers in each category is presented in Table 4.2 below.

Table 4.2: Percentages of teachers with naïve, borderline and informed views of NOS

NOS Issue	% Naïve Views (mean score 1-2.5)	% Borderline Views (mean score 2.51-3.5)	% Sophisticated Views (mean score 3.51-5)
Total (all issues)	9.8	90.2	0.0
Tentativeness	16.2	45.8	37.9
Nature of observation	56.2	33	10.9
Epistemology of theories and laws	48	49.8	2.2
Scientific method	71.5	27.4	1.1
Use of imagination	33	33	34.1
Validation of knowledge	46.7	48.2	5.1
Subjectivity and objectivity	10.8	88.4	0.7
Socio-cultural issues	4.0	57.0	39.0

Having established that the quantitative dataset was representative of Palestinian science teachers' views, and that there were no obvious biases due to gender, religion, teaching qualification, field of study, degree, geographical location or experience, as indicated from the frequency tables of the variables, the following is a brief summary of the results in terms of relative sophistication or naïveté:

The least sophisticated views related to issues of scientific method, the epistemology of scientific theories and laws, the validation of scientific knowledge, and the nature of observation. The relatively less traditional views were associated with subjectivity/objectivity and the use of imagination. The two tenets where most respondents held sophisticated views were socio-cultural embeddedness and the tentativeness of scientific knowledge.

It is worth noting that an initial glance at the above summary and at Table 4.2 would suggest a fairly positive picture concerning teachers' views of NOS. However, caution must be raised in this interpretation for the following reasons:

First, as noted in Section 3.8.1 in Chapter 3, means of Likert scale scores do not translate directly into any of the categories which make up the initial Likert questionnaire. This is a particular issue with the VOSE survey, where individual tenets are probed by a number of questions and sub-questions, making it difficult to assign boundaries to individual tenets. Second, tenets of NOS vary in the number of items involved and are the subject of multiple items in VOSE. Thus "the scientific method" is probed by only six items, whereas, at the other extreme "subjectivity and objectivity" is probed by 31 items. It is a property of such datasets that the more items contributing to an aggregate score, the more the score will tend towards the mean. Thus for example, when all NOS issues are aggregated (51 items), more than 90 % of the sample hold borderline views (Table 4.2). On the other hand, for "the scientific method", with only six items, only 27 % were borderline. This grouping of questions leads to a significant tendency of the dataset to aggregate around the mean (Coolican, 2004).

As a result of these difficulties, it is impossible to assign a priori boundary values for naïve, borderline or sophisticated views. I have therefore chosen to use the range 2.5 - 3.5 as indicative of a borderline views, in other words, a more stringent definition than that of the arithmetic mean.

4.2.1 Naïve Views

A spectrum of views was observed in relation to each of the eight tenets of NOS. However, in general, although up to one third of individual respondents gave sophisticated replies in three of the issues, overall, the answers received were clustered at the naïve/traditional end of the spectrum. The least contemporary, most traditional views were in understanding of the scientific method, epistemology of scientific theories and laws, and validation of scientific knowledge, and the nature of observation.

Examining teachers' responses to the Likert items in detail for each issue reveals that they held the least contemporary views in issues relating to **"the scientific method"** (71.5 % held naïve views for this tenet). Item 9.1 reveals that 97.1 % of the sample held naïve views, believing that there is a step-by-step scientific method that most scientists follow in their research because it guarantees reliable results. Nevertheless, 11.2 % agreed that sometimes knowledge could be discovered accidentally without following a particular "scientific method" (Item 9.5).

Views relating to **the epistemology of scientific theories and laws** were also primarily traditional, with an average of 2.54 and 48 % of the sample holding naïve views. Most individuals (259 out of the 277 respondents) according to Item 5.1 felt that theories and laws are natural phenomena embedded in nature and which scientists discover, rather than being descriptive devices for the natural world. Their responses also reflect a belief that when a theory is proved it becomes a law, as scientific laws are usually supported by more evidence (Item 7.2). Nevertheless, 24 % of the sample demonstrated somewhat more sophisticated belief that theories and laws are different forms of ideas (Item 7.4).

The third least traditional view related to **the validation of scientific knowledge** with an average of 2.58. In this case 46.7 % of the sample held naïve views. The majority did not accept that scientific knowledge and theories might be chosen according to conventions such as their simplicity or the good reputation of the scientists. However, 56.7 % of the sample held a more informed view about evaluating theories according to the available empirical evidence (Item 1.8).

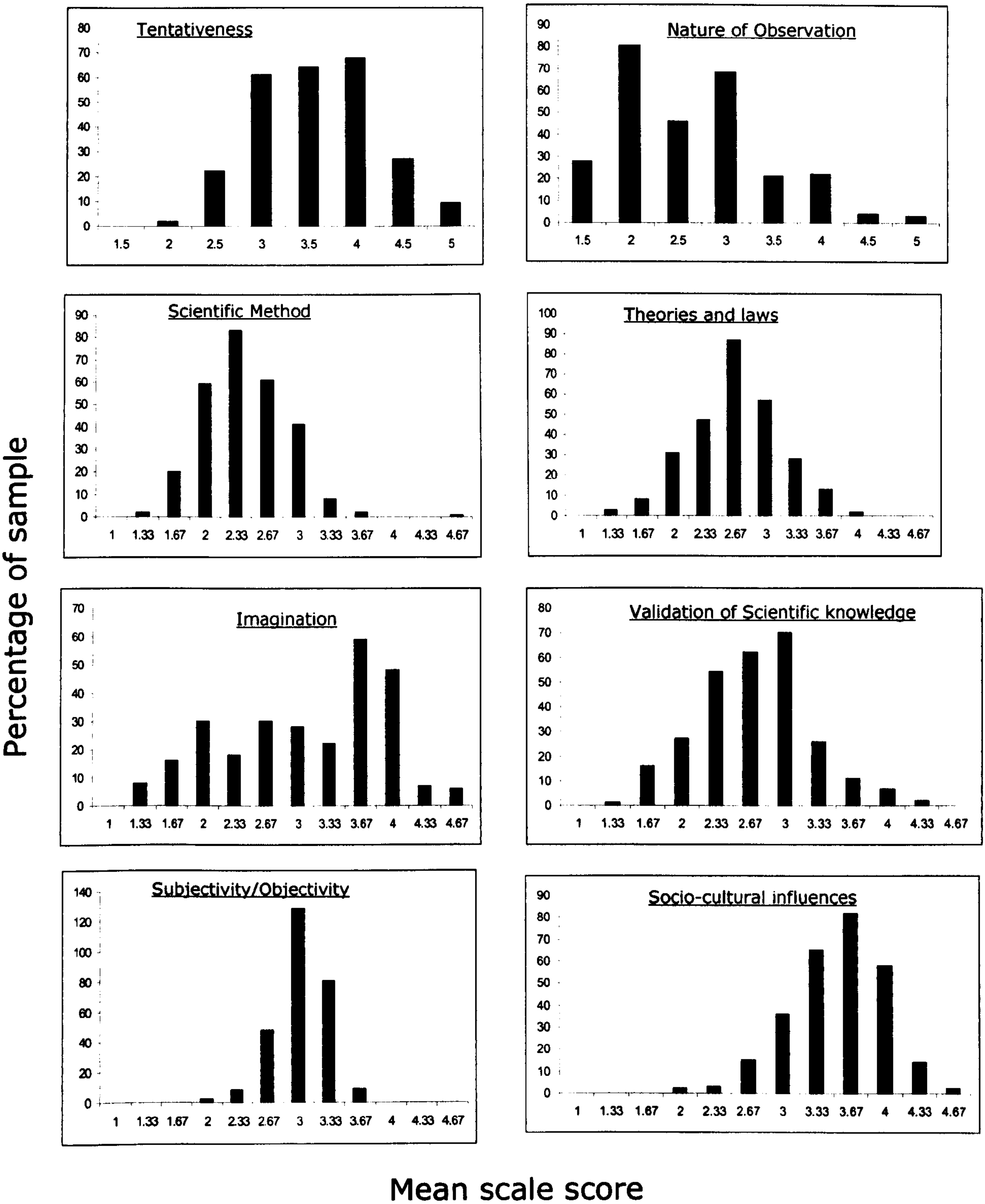
The fourth issue within this category was that relating to the **nature of observation**, with most of the teachers (79.4 %) believing that observations are facts and that different researchers always make the same observations because it reflects what is seen in nature.

However, some views within this category were slightly less traditional. For example, within views reflecting the **use of imagination** (average 2.99; 33 % holding naïve views), almost half of the teachers (48.8 %) felt that scientists use imagination in one way or another when they do their research, and 54.5 % considered imagination to be a basic source of creativity. Nevertheless, overall beliefs for this tenet were fairly traditional, with 39.7 % of the sample feeling that imagination was not consistent with the logic of science (Item 3.3), and 60 % believing that imagination lacked reliability. The second issue of NOS within this category where teachers held slightly more informed views was that related to **subjectivity and objectivity** of science. For this issue, with an average of 2.88, 10.8 % of the sample held naïve views. Although they portrayed the objective positivist view of science in most of the items related to this issue, they held some informed views in a few of them. For example, 40 % of them agreed with the parsimonious view that scientists accept simple theories and avoid complex ones (Item 1.4).

4.2.2 Borderline Views

The two tenets of NOS about which teachers appeared most informed related to the **socio-cultural influences** and to the **tentativeness** of scientific knowledge. I labelled these beliefs as "borderline", reflecting a combination of naïve and contemporary views (see Tables 4.1 and 4.2). Nevertheless, the percentage of teachers holding sophisticated views about these two aspects of NOS was only about a third. For **socio-cultural issues**, a substantial portion of 158 teachers agreed that culture and society influence the development of science. For example, 60.3 % agreed that research approaches are influenced by the social and cultural values in a society (Item 2.1) and 78.3 % supported the idea that scientists should consider both the importance of and socio-cultural values when conducting research (Item 10.2). Nevertheless, a substantial minority (18.8 %) held the view that it is possible to conduct successful research in isolation of social values (Item 10.5).

Figure 4.1: Frequency distributions of mean scale scores for NOS tenets using the VOSE questionnaire (n=277)



For **tentativeness of scientific knowledge,** with an average of 3.45, and only 16.2 % of the sample holding naïve views, it is clear that most of the teachers held views lying somewhere between completely naïve and contemporary. However, it is significant that 37.9 % of the sample held sophisticated views for this tenet. In response to specific items, 47.6 % of the sample believed in evolutionary change of scientific theories (Item 4.3), while 65 % of the sample believed that science progresses through accumulative processes, so that the old theories are still preserved (Item 4.2).

4.2.4 Summary of Quantitative Findings

The data revealed that the views of this sample of Palestinian science teachers are relatively unsophisticated in most of the aspects of NOS that were considered in this analysis, with mean scores for most aspects below or close to 3, the overall midpoint of the scale. Only views on the importance of socio-cultural embeddedness and the tentative nature of scientific knowledge gave mean scores which were higher than 3, representing a mix between traditional and more sophisticated views.

Based on the findings of the quantitative survey, it became apparent that it would be impossible to identify teachers with sophisticated views across all tenets of NOS analysed, or even with views that could broadly be classified as informed. The reasons why this might have been so will be discussed in detail in Chapter 5. Therefore a comparison of practices of teachers with sophisticated and unsophisticated views was impossible. Rather, it was judged appropriate and significant to explore in depth the nature, causes and context of these views of NOS. Therefore, it was decided to refocus the study to try to identify the factors responsible for this apparent naïveté in teachers' views of NOS across the sample of Palestinian science teachers. To this end, a sample of twelve teachers was randomly selected from the body of teachers (277) who completed the closed questionnaire for further analysis by questionnaire and interview in the following year. Their responses to the open ended questionnaire (VNOS-C) and the follow-up interviews were transcribed, coded, collapsed into categories, and then organised and grouped to generate description profiles of their views of NOS. Please refer to Chapter 3 for detailed methodology and sample selection.

4.3 Qualitative Findings of Teachers' Views of NOS

This section presents a qualitative characterisation of teachers' views of NOS. Eight tenets of NOS were pursued in this study as the framework of the qualitative analysis (Abd El Khalick, 1998; Lederman et al., 2002). These aspects include the empirical, inferential, creative, subjective (theory-laden), tentative and socio-cultural embedded nature of science, the myth of a single scientific method, and the epistemology and relationship between theories and laws in science. See Chapter 2 and Appendix 1 for a detailed description and characterisation of these tenets, and Chapter 3 for details of the qualitative analysis. In summary, each participant was initially treated as a separate case, where the data collected from VNOS-C and the follow-up interviews were used to generate profiles of participants' views for each tenet. These outlines were used to generate patterns and categories which then informed the next phase of analysis at the group and tenet level.

Teachers' emergent views, as described and portrayed in relation to each of the NOS tenets, were compared with the contemporary science education literature and reform documents on the topic to determine and identify their views on each aspect of NOS as either naïve, borderline or informed. A naïve view of a certain tenet of NOS indicates that the participant has a traditional view and/or lacks an adequate/contemporary understanding of this tenet. A borderline view indicates that the participant holds somewhat informed views of the tenet, but these views are often inconsistent and conflicting, or s/he is unable to justify and explain his/her view of the tenet. An informed view of a certain tenet is indicated by the correspondence of the subject's views with those in contemporary science education documents and research, and the possession of an adequate and consistent understanding of the views that relate to that tenet.

The analysis process used to construct profiles of the participants' views of NOS was conducted on a tenet-by-tenet basis because the participants do not necessarily have comprehensive and coherent views across all the tenets of NOS (Abd El Khalick, 1998).

The following sections present teachers' views of NOS and its eight tenets. An overview of the nature and significance of these tenets is provided in Chapter 2.

4.3.1 The Empirical Nature of Scientific Knowledge

The construction of scientific knowledge is at least partially based on empirical evidence that is derived from observations of the natural world. This empirical evidence is crucial in science, and accounts for its objectivity. It provides validity in the search for interpretations and predictions that attempt to generate a comprehensive understanding of the natural world, and enables a greater control (AAAS, 1990; NSTA, 2000). However, observations are theory laden, meaning they are not only dependent on human senses, but are filtered through their perceptual apparatuses which are based upon their theoretical presuppositions and frameworks (Abd El Khalick, 1998). Although empirical evidence is very important as a basis for the construction of valid and reliable scientific knowledge, scientists do not always have direct access to natural phenomena. Much of the scientific knowledge and claims are not always directly testable by empirical evidence. Therefore science processes often rely on inferences and other theoretical entities. Scientific knowledge includes scientific theories and inferences which are not limited to the empirical evidence (Bloom, 2008).

There were several opportunities in the questionnaire and the interview for the participants to reveal their views of the empirical nature of scientific knowledge, particularly Questions 1, 2, 3, 5, 6 and 8. Through the analysis of this tenet, two main categories emerged:

(a) science is a discipline that is based solely on hard data and tangible measurable facts and evidence to prove it;

(b) science relies on direct and indirect evidence.

When views were deemed not to fall clearly into one of these categories, the benefit of doubt was given and views falling between naïve and borderline were classed as borderline, and views falling between borderline and informed were deemed to be informed.

(a) Science is a discipline that is based solely on hard data and tangible measurable facts and evidence.

This category, at a general level, represents the view of all but one of the participants (T12). These eleven participants stressed the empirical nature of science, and its reliance on tangible, measurable data and direct evidence. However, their understanding of the empirical nature as indicated from their responses means directly observable and hard physical evidence. They did not mention any role of scientific inferences, imagination, creativity, or any human elements as evidence supporting scientific claims. They equated scientific inquiry only to experimental proof, and saw the role of evidence as to "prove" scientific claims. In their response to the first question on how they differentiate between science and other disciplines, these eleven respondents all stressed the empirical nature of science and its reliance on hard data as crucial factors characterising science. This is explained by the following quotation taken from T8 response to Question 1:

> Science differs from other disciplines because it is based on laws, theories, facts and principles that rely on scientific experiments and direct observations. But other disciplines like religion depend on faith and cannot be proved ... Arts and Aesthetics are mental intuition and constructs that are difficult to defend because they do not stand on hard evidence like in the case of science.

These teachers also differentiated science from non-science explaining that science involves content and process, and the process stands on observable and measurable empirical experiments. In this context T3 responded:

> Science is a context and a process. This process should follow the scientific method to arrive at valid and reliable knowledge, thus starting from observation to experimentation, to concrete findings, to assessment, to conclusions arriving at new scientific claims.

Additionally, seven participants differentiated science from non-science in that science is an objective discipline. They ascribed its objectivity to the direct evidence and hard data on which it stands, as T3 explained:

> This physical evidence that science stands on, which depends on hard experiments and direct observations, grants science its great objectivity, away from the human biases or opinions that characterizes other disciplines, except religion.

T3, T4 and T10 attributed the socio-cultural free nature of science to its dependence on hard observable evidence that accounts for its universality and freedom from any personal or social impact or interpretations.

In their response to the questions relating to the extinction of dinosaurs, structure of atoms and classification of species, these participants did not indicate any role of inferences, imagination or creativity in their explanations. Rather, they offered direct observable experiments and data. This response from T2 supports this view:

> Scientists are very certain of the structure of the atom because they could see it through the electronic microscope ... They are certain of their classification of the species through their observation of the similar characters between the creatures that are classified under the same species.

The view that the role of evidence is to prove scientific claims was very obvious from the responses to Question 3, where all 11 respondents stressed the necessity of empirical experimentation in the development and approval of scientific knowledge. They pointed out that the physical evidence scientists get via empirical experimentation is crucial for reaching the truth concerning any scientific claim. For example, it is clear from the following quotation by T10 that she would not acknowledge any piece of knowledge as being scientific, unless it has been "proven" experimentally:

> There are two types of science, theoretical science that is based on theoretical entities that cannot be tested experimentally. This type of science is provisional and not constant. It is more like a hypothesis that we cannot rely on as evidence to verify this type as a concrete and reliable science. The other type is the practical science that has been derived from experimental results. This type of science is reliable and proved. Empirical experimentation is the soul of scientific research and science production.

T5 differentiated science from non-science by the ability to prove science by tangible evidence from experimental data, while other sciences are based on mental entities or faith. T4 defined the experiment as "*any way or tool that utilizes observation to approach and get true scientific knowledge*". T5 adopted a similar position saying:

> One of my primary goals of teaching science is to enable my students to do as many experiments as they can to prove scientific claims such as laws, generalizations and principles, so that they will become convinced and persuaded of these elements of science.

The above responses strongly support that this group of teachers did not demonstrate an understanding of the empirical nature of science in general, nor the relationship between evidence and scientific claims, whether supportive or affirmative. Consequently, this group views of this tenet were classified as naïve.

(b) Science relies on direct and indirect evidence to support its claims

This category represents the view of only one participant (T12). This quotation reveals the richness of his description of science:

> Science is a human endeavour that is socially and culturally embedded. It is empirical in nature and constructed from a mixture of inferences, imagination and non-sensory creativities. It is based on a methodology or a process that relies on the integration of empiricism (senses) and cognition. Scientific knowledge develops by empirical experiments and logical inference, or by inferences from observation, without a need for empirical experiments, sometimes. For example, Newton arrived at his laws by mental inferences without direct empirical evidence.

This view of NOS is informed suggesting that this participant holds a sophisticated view as purported by the science education literature previously mentioned.

In summary, it can be concluded that eleven of the twelve participants, (T1-T11) who were represented by category (a) above, hold a naïve view of this tenet of NOS, while only one participant (T12) holds an informed view. No borderline views were identified.

4.3.2 Inference and Conceptual Inventions in Science

Science is based on both observation and inference, where observations can be measured and tested by the senses directly, while inferences are statements about phenomena that cannot be directly measured. They are interpretations of observations and conclusions drawn based on the data accessed from the observations. As Abd El Khalick (1998) says, inferences deal with non-observable natural phenomena that are not accessible to the senses where the scientific knowledge about them can be measured by their effects or manifestations. These theoretical entities are inferred explanations leading to the generation of hypothesis, theories, laws and models based on inference through direct or indirect evidence. He explains that science includes a lot of theoretical entities and terms that are not directly observable such as the structure of the atom, the concept of the species in biology, gravity, magnetic field, and the particle nature of light, which constitute a significant component of science. Students should understand that these theoretical entities are based on inferences and indirect evidence (Abd El Khalick, 1998).

Questions 6 and 7 of the questionnaire were designed to explore teachers' views of this tenet. These two questions were utilised to probe whether teachers believe that the construct of the atom (Question 6) or the characterisation of the species (Question 7) are based on indirect evidence and inference, or they think that scientists have developed these constructs relying on direct observation. Teachers were also asked about the evidence the scientists used, and how certain they are concerning the structure of the atom and the concept of the species. Teachers' views of the inference and "conceptual inventions" (Ryan and Aikenhead, 1992) in science as indicated mainly from their responses to Questions 6 and 7 of the questionnaire, and indirectly from Questions 8 and 11 have been classified into two main emergent categories:

(a) Conceptual inventions such as theories, laws and models are copies of reality that scientists have direct access to, and are certain about.

(b) Conceptual inventions such as theories, laws and models are theoretical constructs determined via inference from direct or indirect evidence.

(a) Conceptual inventions such as theories, laws and models are copies of reality that scientists have direct access to, and are certain about

This view was held by eleven out of the twelve of the participants. They believe that conceptual inventions are copies of reality, the same as any other observable scientific phenomena. Scientists are seen having direct access to them through observation or relevant experiments that provide scientists with enough evidence to be certain of them and their validity. Without this concrete and direct evidence, these entities are only speculations that cannot be accepted as part of the formal scientific knowledge. They attempted to describe the role of observation and direct evidence, without including inference as part of the process. All of them agreed that scientists are certain about the structure of the atom and the classification of species because they have resulted from empirical experiments that gave concrete evidence.

Some of the participants in this group gave specific responses of the evidence and experiments scientists have used, while others gave general responses. For instance, T1 was very clear in her belief that scientists have direct access to them. It is clear from the following quotes from her responses to Questions 6 and 7 concerning the structure of the atom and the characterisation of the species that she emphasises experimentation to the exclusion of inference which in this particular field of science was absolutely paramount:

> This structure has resulted from a great effort of experiments scientists have done to reach this conclusion like Faraday's experiments in electrical analysis, Rutherford's experiments, Millikan's experiments on the structure of the atom, electrical discharge experiments, and the use of the mass spectrophotometer and the electrical discharge tubes.

Concerning the concept of species she added:

> I think scientists are quite sure of this classification because they arrived at this classification after doing a lot of experiments and observation on animals, from which they could identify the characteristics of each species and their shared features with special focus on their ability to produce new generations that are fertile. I think this characterisation is a scientific fact nowadays.

T3, also, believes that scientists are certain about the structure of the atom and the concept of species. However her response was more general:

> Scientists are certain because they all have agreed on the structure of the atom and the classification of species, and because this structure and classification have not undergone any change since a long time ago, which indicates a sort of validity for them.

Three of the participants in this group expressed their lack of understanding of how scientists have arrived at the structure of the atom and the classification of the species. Nevertheless, they said they have full trust and confidence in scientists that make them believe that these constructs are true and represent reality.

Another group of three participants hold the view that scientists have visually seen the atom through the electronic microscope, and this is why they are certain about its structure. While, another teacher (T5), expressed her wishes that one day in the future scientists will be able to invent a super electronic microscope that will enable people to see the atom and hopefully its components clearly, instead of relying on the electrical discharge experiments that are being used to date, and might not be as accurate as visualising it directly through such a microscope when possible:

> Such a super electronic microscope, if being developed, will provide us with valuable information concerning the exact structure of the atom and its components, that might change the current mental image we hold of the structure of the atom that is coming from relatively poor empirical experiments like nuclear reactions.

In response to Question 11 about the issues teachers would like to impart to their students through teaching, one of the participants, T7, replied:

> There is a lot of garbage knowledge we see every day in the media or newspapers that claim to be scientific knowledge, without any concrete evidence to support, they just rely on statistics or correlations between numbers. Some of them are so critical and dangerous when they relate to human health or security. So, I always stress to my students not to accept any new knowledge unless they are convinced it has empirical evidence, or is supported by a concrete observation that relates to it directly.

As demonstrated above, teachers in this group do not have sophisticated views, or awareness, of the relevance or use of indirect evidence and inference to arrive at conceptual inventions in science. They also do not distinguish between observation and inference in science, and appear ignorant of the notion of inference. As such, it is clear that this group of teachers (T1 - T11) do not hold views on this tenet that are in agreement with those recommended by the contemporary literature and science educators. Consequently, their views on this aspect were classified as naïve.

(b) Conceptual inventions such as theories, laws and models are theoretical constructs determined via inference from direct or indirect evidence

This view was held by only one participant (T12) who embraced a view that science relies on both direct evidence from observation and indirect evidence from inference. In his response to Question 1 of the questionnaire, which asked the participants to define science and how they differentiate between it and other disciplines, he responded:

> Science relies on a methodology that integrates the empiricism through the senses, and the rationalism through the inference in one workable station that gives it its power and trustworthiness over the other disciplines. ... Science has an empirical nature, and is also a mixture of inferences, imagination, and non-sensory creativities.

He explained the disagreement between scientists' interpretations of the dinosaur's extinction in question eight:

> These explanations are the results of inferences from mental entities and might not be real, where the scientist's brain plays a major role in developing and completing the picture of the issue in his/her mind.

Concerning the structure of the atom and the concept of the species, he demonstrated that these are abstract constructs and mental images that scientists have identified through indirect evidence by inference, using their own imagination and creativity. He thinks that scientists are fairly sure and certain about them, to the best of their knowledge, to date, but they might change in the future. As such, we can conclude that this participant conveys an informed and current view of this aspect of NOS.

In summary, 11 out of the 12 teachers (T1-T11) hold a naïve view of the inference and conceptual inventions in science ignoring or rejecting any role of inference in the construct or the development of scientific knowledge. However, one participant, T12, holds an informed view of this tenet, embracing a view that science relies on both direct evidence from observation and indirect evidence from inference, and that theoretical entities are models determined via inference from indirect evidence. It is worth noting here that it was not possible to classify any of the participants as having a borderline view of this tenet.

4.3.3 Imagination and Creativity in Science

The creation and advancement of scientific knowledge depends on empirical evidence from observations of natural phenomena, where logic plays a crucial role in the scientific process. Nonetheless, it is currently accepted that this process partially relies on scientists' imagination and creativity that are consistent with the available evidence (AAAS, 1990; Abd El Khalick, 1998). It is widely accepted that imagination and creativity play a crucial role in scientific inquiries and investigations. They are involved in the interpretation and inventions of explanations, and are essential for the creation of new ideas. Scientists use their imagination and creativity coupled with their pre-knowledge, logic and inferences in all stages of their investigations and generation of scientific knowledge (Abd El Khalick, 1998; Abd El Khalick, Bell and Lederman, 1998; Chen, 2006).

Teachers' views of this aspect of NOS were explored explicitly through Question 10 of the questionnaire, and implicitly by looking at their answers to various questions in the questionnaire, such as Questions 1, 3, 6, 7, 8 and 11. Their responses have been classified into three main emergent categories:

(a) No existence of imagination or creativity in science because science is a reliable discipline.

(b) Existence of imagination/creativity in certain stages of scientific inquiry and knowledge generation.

(c) Existence of imagination/creativity in all stages of scientific inquiry and knowledge generation.

(a) No existence of imagination or creativity in science because science is a reliable discipline

This view was held by eight out of twelve of the participants. This group of teachers (T1- T3, T6-T8, T10, T11) do not believe in the existence of any kind of imagination or creativity in science or scientists' work. They conveyed that imagination and creativity lack reliability, and are not consistent with the logical principles of science, as they cannot be defendable. However, they justified their rejection of the existence or use of imagination/creativity in different ways. For example, T8 and T10 think that there is only one truth for any scientific phenomenon that is discovered following the scientific method, thus leaving no room for imagination or creativity:

> How can we accept creativity and imagination in producing new knowledge when we know that creativity and imagination are very personal, and scientists differ enormously in them, and there is only one truth (T8).

In a similar manner, T2 and T3 rejected imagination and creativity because they deemed that scientific knowledge can only be proved by empirical evidence through relevant experiments and observation, and following the scientific method:

> We cannot claim that a new piece of scientific knowledge is correct, unless we obtain it empirically, where the success of the experiment lies in its ability to prove the new knowledge. So to be successful, this experiment has to follow the universal standardised scientific method that does not have any place for imagination or creativity within its standardised steps (T3).

This need for a "standardised" scientific method to arrive at new knowledge was also stressed by T7 and T11 who stated that even if they could accept the existence of imagination/creativity in science, they could not rely on them, or defend them as sources that might lead to new correct knowledge.

T1 and T6 ascribed their rejection to the existence or use of imagination/creativity in science to their religious beliefs. They feel that a deep and free imagination, sometimes, causes "religious troubles" and might lead a person to think on certain issues that are prohibited for a Muslim to reflect on, for example, thinking creatively, or allowing for unlimited imagination in Darwinism, or in metaphysical matters. In response to a question about the main difference between her as a Muslim and another atheist science teacher in dealing with science or teaching it, T1 explained the impact of her personal religious understanding on her view of the imaginative/creative nature of science, and the possible negative effect of her understanding of religion on her potential creative and imaginative abilities:

> As a Muslim, my thoughts of all aspects of life including science are defined by a frame that is bounded and restricted by religious standards and borders that I cannot exceed or go beyond. For example, I cannot reflect on the origin of the creatures or their destination because it is out of my business. Everything and all creatures are created by Allah and at the end they will return back to Him after death for Judgment. These boundaries in thinking for religious considerations might hinder creativity or imagination, but I am totally happy with them. I think Allah's satisfaction on me is more important than being a creative thinker ... For non-believers, though they have no restrictions on what to think, or on how to think of matters or imagine them, I do not think this will add much to their imaginative or creative skills as long as they are trying to be creative in issues that are out of their business. I am quite sure their imaginative or creative trials on such issues will not lead to anything stunning.

These eight teachers also believe that imagination/creativity contradict objectivity, and might include a lot of biases because they are more personal and open ended, *"imagination is a very personal issue that lacks the minimum limit of objectivity"* (T8). As seen from their responses, it can be concluded that this group of participants hold a naïve view of this aspect of NOS.

(b) Existence of imagination/creativity in certain stages of scientific inquiry and knowledge generation

This view was held by three of the participants, T4, T5, and T9. They believe in the existence and use of imagination and creativity in scientific inquiry in certain stages of the creation and development of scientific knowledge. However, they hold inconsistent views concerning this tenet with relation to other related aspects of NOS such as the inferential nature of science and the myth of one scientific method. T5 and T9 believe that scientists use imagination/creativity in the early stages of scientific investigations, hypothesis creation, planning and design after observation. However, in data collection, analysis and the drawing of results and explanations there is no creativity or imagination, because as T5 explains, "*scientists have to be objective*".

In contrast, T4 believes that creativity and imagination take place after data collection and analysis when scientists use their imagination/creativity in drawing the explanations for their findings and conclusions that might lead to the creation of new knowledge, or in applying the findings to daily life issues. T4 presented the Human Genome Map as an example in support of his belief in using imagination/creativity after data collection. He stated:

> After scientists established the Genome project, and after they collected their data, they started thinking and imagining what was going to happen after that, and how they will benefit from the map in the short and long term, such as having full control of human beings' traits, solving some diseases that relate to heredity, and understanding the mechanisms of these diseases. Some of these ambitions and aims have not been achieved yet, but they are gradually working on them.

Although this group believe in the existence and use of imagination and creativity in certain stages of scientific imagination/creativity, still they believe in a single universal scientific method and deny the inferential nature of science which indicates an inconsistency in their views of this aspect of NOS with other related aspects. As such, this group were classified as holding a borderline view of this aspect of NOS.

(c) Existence of imagination/creativity in all stages of scientific inquiry and knowledge generation

This view was held by only one participant, T12. He stated that scientists use their imagination and creativity during all stages of scientific investigation, and use them to create explanations and theories. It seems he holds a sophisticated and comprehensive understanding of the role of imagination/creativity in scientific investigations as is indicated by the following extract:

> Scientists use their imagination and creativity from the first instance of observing a certain phenomenon, or when facing a problem, but this needs a high level of thinking strategies from the scientist... An example is Newton's story with his creation of the general law of gravity; there is nothing new concerning the falling down of an apple on the ground, apples fall down every day. But, it is Newton's active and creative brain and his mental readiness that enabled him to make a connection between that fall of the apple towards the ground and the force that keeps the moon in its track around the earth, and the earth in its track around the sun. From these direct observations using his senses, Newton, through his active and open mentality, could utilise this observation of the falling down of the apple to get to and create the general law of gravity.

Clearly he acknowledges the inferential and creative nature of scientific inquiry and knowledge generation in all stages of this process. It also indicates his awareness of the holistic process that relates scientific inquiries and knowledge generation, since he could link the empirical, inferential and creative nature of science and scientists' work, along with the direct and indirect evidences scientists employ to arrive at their claims and novel creations.

In summary, it might be concluded that two thirds of the participants hold a naïve view of the imagination/creativity of NOS, while three teachers hold a borderline view, and only one carries an informed view of this aspect of NOS.

4.3.4 Subjectivity and Theory-Ladeness of Science

Science as a human endeavour is subjective in nature, where subjectivity is integral to the creation and advancement of scientific knowledge (Kuhn, 1962; Abd El Khalick, 1998). Scientists prior knowledge, training, personal beliefs, values, biases, creativity, expectations, theoretical commitments, experience, gender, age, and the impact of their society and culture on them influence their scientific activities and the way they conduct their investigations (AAAS, 1990; Ryan and Aikenhead, 1992; McComas, 1998; Chalmers, 1999).

Scientific knowledge is also theory-laden. This is because our knowledge and understanding of existing theories influence what we choose to observe, the nature of the observation we make and how we interpret these observations. In addition, the background factors mentioned earlier also impact scientists' theory choice and method of investigation, including observation, interpretation and use of imagination (Abd El Khalick, 1998; Chen, 2006). We can appreciate this characteristic of subjectivity in science if we portray science as a discipline that involves human enterprise (Liu, 2003).

Most of the questions in the questionnaire and the follow-up interviews presented chances for the teachers to express their views of the subjective nature of science, either implicitly in Questions 1, 2, 3, 9 and 11 of the questionnaire, or explicitly in Question 4 of the third part of the follow-up interview where teachers were asked directly whether it is possible to eliminate subjectivity from scientists' work. Combined analysis of responses to the implicit and explicit questions revealed three emergent categories that characterise teachers' views of this tenet:

(a) science and scientists are objective
(b) science and scientists are temporarily (at times) subjective
(c) science and scientists are inherently subjective

(a) Science and scientists are objective

The vast majority of the participants, three quarters, hold this view of science and scientists as being objective. They believe that the main difference between science and other disciplines such as arts and philosophy (but excluding religion which is seen as objective) is the objectivity of science: "*Science differs from philosophy and arts in its objectivity*" (T1). They suggest that this objectivity of science is a result of the scientific method that scientists follow in their work and investigations as exemplified by the following quotations:

> Scientific knowledge is absolutely objective because it is a product of the scientific method that will not allow for any sort of subjectivity (T1).

> Sometimes scientists' intuition and creativity might play a role in directing their research that might affect the objectivity of their work, but if they follow the scientific method step by step, these factors will not have any effect, especially because the scientific method includes an empirical stepwise procedure that would guarantee the objectivity of the scientific knowledge produced, and scientists' work (T4).

> When following the scientific method carefully all observers should see the same observation in the same manner, and get the same results (T6).

> As long as science is experimental and standardised, then all scientists all over the world should arrive at the same results, that's why science is objective and universal (T3).

They believe that the objectivity of science is what gives it its value and trustworthiness as T5 below purports:

> Science must be objective, otherwise it will lose its value and reliability, and then every society would deal with science differently, but this is not the case in reality, due to the universality and objective nature of science.

It is worth mentioning here that most of the teachers in this group (eight of the nine, with the exception of T4) rejected the notions of creativity and imagination in science at the grounds that they might spoil the objectivity of science. Seven of the nine (with the exception of T1 and T2) also rejected the socio-cultural embeddedness of science for the same reason.

In Question 8 of the questionnaire, which presented the teachers with a scientific controversy that relates to the possible causes of the extinction of dinosaurs, teachers were asked to explain how is it possible for scientists to propose two different hypotheses for the dinosaur extinction although they had access to the same data. Teachers' explanations were divergent. Five of them ascribed this difference to scarce and insufficient data. Their view was to accept both interpretations temporarily until new concrete evidence was found that either supports one of them or replaces both of them. In contrast, two of the teachers refused to accept any of the explanations because the phenomenon had occurred long ago, so experimentation to prove which the correct one is was impossible. These two participants also stated that they support neither interpretation because the scientists have insufficient data and they didn't follow any scientific method:

> Actually I am not persuaded of any of these interpretations. It is most likely that these scientists have proposed their explanations from reading the history and the universal changes that occurred via hundreds of millions of years, through which they built their predictions, which is too subjective, and not acceptable as long as it does not stand on concrete evidence. Maybe the dinosaurs became extinct because their surrounding environment became unsuitable for them to survive or advance, and was not necessarily due to a volcano or a meteor. Or it might be Allah's decision to replace these creatures with others on the ground that cannot live in parallel with dinosaurs (T6).

In addition there were two participants who ascribed the difference in explanations to the possibility that the scientists didn't follow the scientific method, or used their imagination and creativity. However, in both cases they expressed the view that it is not acceptable to ignore the scientific method or use imagination and creativity.

As such, we can conclude that the participants of this group hold a naïve view of the subjective/theory-laden nature of science and scientific knowledge.

(b) Science and scientists are temporarily subjective

This group consisted of two participants who are distinguished by their claim of the existence of subjectivity in science and scientists' work. They agree to accept this notion only temporarily because they think of it as a shortfall that should be eliminated from science to maintain its reliability and value. They regard science and scientists as objective in general, especially when they conduct empirical investigations under standardised conditions. But sometimes they might be subjective due to the differences in their personal, social, academic background, or the way they conduct their investigations. This subjectivity can be eliminated and avoided if these scientists separate their own beliefs and personal biases from their professional work in science, and if they follow a standardised method in their investigations like the scientific method. Both these teachers believe that scientists making the same observation do not differ in the data they collect from their observation, but they might differ in how they interpret the data which might lead, sometimes, to different findings. In response to Question 8 concerning the extinction of dinosaurs, they attributed the difference in explanation to the method of investigation used by each group of scientists which might have been affected by their training, pre-knowledge or theoretical paradigms. According to the participants, these factors play a significant role in this case due to the lack of sufficient data, so that "*We have to accept both of them temporarily, until we can access more evidence in the future, because in reality there is only one truth*" (T9).

As such, we cannot say that these two participants hold an informed and acceptable view of the subjective/theory-laden nature of science, although their responses suggest some understanding of the subjective nature of science. Hence they are classed as borderline.

(c) Science and scientists are inherently subjective

This sub-theme was only held by one participant (T12) who probably holds an adequate understanding of this tenet. He believes that scientists' observations, investigations and interpretations are influenced by their personal and professional backgrounds and beliefs including their pre-knowledge, training, theoretical paradigms, disciplinary commitments, and other socio-cultural or political backgrounds as well. He thinks that this difference in scientists' work and the different findings obtained are natural in the scientific process. His argument is that scientific phenomena are objective in nature, but science and scientists are subjective due to differences in their professional and personal backgrounds. His informed view of this notion might be inferred from his response to Question 8 concerning the dinosaurs' distinction, where he could articulate a sophisticated understanding of the subjective nature of scientists' work and its underpinnings:

> Scientists have proposed two different explanations that might be equally acceptable. That is because very frequently scientists make observations that are not objective from the early beginnings, in other words, it might include some biases and personal values. Observations are frequently theory-laden which will later affect the scientific knowledge to be produced. The theory-ladeness of observation is related to scientists' pre-experiences and their own personal beliefs. Moreover, these explanations are the results of inferences from mental entities and might not be real, where the scientist's brain plays a major role in developing and completing the picture of the issue in his/her mind. Consequently it is normal to have these different explanations that each of them might be equally true or false.

In summary, most of the teachers, nine out of the twelve (T1-T6, T8, T10 and T11) hold a naïve view of the subjectivity/theory-ladeness nature of science, and view science and scientists as being totally objective. However, two of the participants (T7 and T9) hold a borderline view of this tenet, agreeing that science and scientists can be temporarily subjective. Finally, one participant (T12) holds an informed view of this tenet portraying science and scientists as inherently subjective.

4.3.5 The Tentative Nature of Science

The current view as outlined by McComas (1998) portrays the whole body of scientific knowledge, including facts, theories and laws are durable, but tentative and not absolute. It is reliable because it is based on empirical evidence, but never absolute. Evidence, either direct or indirect, supports the validity and trustworthiness of scientific claims, but cannot guarantee any scientific claim to be true or absolute. All scientific elements such as facts, theories, principles and laws are subject to change in light of new evidence that might arise as a result of technological and theoretical progress, or reconceptualisation and revision of prior evidence and old knowledge (Abd El Khalick, 1998; Liang et al., 2009). Additionally, change in the socio-cultural perspectives or the shift in research paradigms might lead to a change in the extant body of the scientific knowledge (Liu, 2003) that might take the form of evolutionary (Popper, 1968) or revolutionary (Kuhn, 1970) change.

There were several opportunities in the questionnaire and the interview for the participants to express their views of the tentative nature of scientific knowledge, especially Questions 1, 4, 5, 6 and 7. Analysis of teachers' views regarding this tenet indicates that they can be classified into three main emergent categories:

(a) Some categories of scientific knowledge are permanent and absolute, while others are subject to change.

(b) All categories of scientific knowledge are tentative, but some of them are more permanent than others.

(c) All categories of scientific knowledge are subject to change.

(a) Some categories of scientific knowledge are permanent and absolute, while others are subject to change

This category characterizes, at a broad level, the view of nine of the twelve participants (T1, T2, T4, T6-T11) who recognised the tentative nature of scientific theories, while claiming that other forms of scientific knowledge such as facts and laws are permanent and absolute. It is worth noting that none of these teachers regarded all scientific knowledge as permanent and absolute. They regarded theories as subject to change because they are not proven yet. However, when theories attain enough evidence and are proven, they turn into laws or facts, then becoming certain and permanent. These teachers think of theories as provisional knowledge, that is, in a state of transition towards being proven or falsified in light of new evidence and technological advancement which might verify or falsify them. The following response to Question 5 by T10 represents this parallel view of the permanent and absolute nature of scientific facts and laws on the one hand, and the tentative nature of theories on the other:

> Scientific facts such as "the sun rises in the east" or "water is composed of hydrogen and oxygen" and scientific laws like Mendel's laws of heredity are truths that would never change. But with theories like Darwin's theory of evolution, they might change in the future, because such theories are not based on or derived from empirical experiments, and therefore, might change in light of new empirical evidence or new technological advances and scientific discoveries (T10).

When the participants were asked how they think the change or development of scientific knowledge takes place, seven of them said that change occurs through the developing nature of scientific knowledge by which the new knowledge is added via new discoveries. Two of the participants stated that the change can take the form either of the addition to the existing body of knowledge, or the restructuring of it. An example of restructuring was offered by T4:

> The initial theory of the mechanism of seeing was that a ray transmits from the eye to the object, and then is reflected back to the eye. But scientists restructured this claim and proved that a ray is reflected from the object to the eye that enables the human being or animal to see it.

Additionally, in response to Question 6 concerning the structure of the atom and Question 7 concerning the classification of the species, they expressed their view that scientists are certain of the construction of the atom and the classification of the species. They pointed out that scientists must have conducted relevant empirical experiments or observations to become certain of these constructs and to verify the accuracy of their claims. None of them said that these constructs might be tentative. In response to Question 8 concerning the extinction of dinosaurs, they tried to justify the discrepancy between scientists' conclusions, but did not mention that their hypotheses might be tentative.

These findings suggest that this group of participants is likely to have a naïve view of the tentative nature of science, though I have to acknowledge that some scientists might support the spirit of these views could equally be classed as borderline.

(b) All categories of scientific knowledge are tentative, but some of them are more permanent than others

This category represents the view of two participants, T3 and T5. These two teachers conveyed a view that all categories of scientific knowledge might change in light of new evidence or new discoveries by advancement in technology:

> There is nothing that is absolute in science. There might come an era with new discoveries and technologies that change what

> knowledge exist nowadays by addition or restructuring. For example, it was thought for a long time that the earth is the centre of the universe till Copernicus came and disproved this claim and suggested that the sun is the centre of the universe. Who knows! Maybe one day scientists could find out another planet represents the centre of the universe other than the sun (T3).

Similarly, T5 pointed out that scientific knowledge might change in the future, though it is durable and reliable within the extant time and conditions when it was created. She submitted the flagstone experiment as an example to show the durability versus changeability of scientific claims.

However, in their response to the difference between theories and laws (Section 4.3.8), they stated that laws are certain and proven types of scientific knowledge that are reliable, verified and constant, while theories are immature laws that might change, and once proven they turn into laws that are certain and constant.

Additionally in their response to the questions relating to the structure of the atom, the classification of the species and the extinction of dinosaurs, they did not indicate any possibility of tentativeness in any of these issues.

When they were asked in the follow-up interview how they think scientific knowledge develops, they responded that it might develop either by an addition to the existing relevant knowledge (accumulation), or by restructuring the existing knowledge to accommodate the new, or sometimes a new theory totally replaces an old one.

These findings suggest that these two teachers were thinking in line with modern science education literature which calls for portraying science as tentative in nature in some aspects, but with inconsistent and naïve views in other related aspects. Consequently, these two participants are classified as holding a borderline view of this tenet.

Again, many would class these participants as informed, but as a result of the inconsistency revealed within the bigger picture of other related tenets, I believe they should be regarded as borderline.

(c) All categories of scientific knowledge are subject to change

Only one participant, T12, believes that all forms of scientific knowledge are accepted tentatively and are subject to change. He believes there is nothing absolute in science; even scientific facts might change. But this extant knowledge is reliable because it is empirically based and has supportive evidence for its acceptance in light of current available provisions:

> We are satisfied with the scientific knowledge we have today because it has enough supportive evidence to convince us of it, and enable it to work properly, but we do not know what the future might bring to us concerning its durability and reliability...the continuous advancement of technology coupled with new discoveries, scientific revolutions or change in the theoretical paradigms or the socio-cultural values might change any part of the body of this existing scientific knowledge.

This participant's view of the tentative nature of scientific knowledge was consistent over all questions that were related to this issue either explicitly or implicitly. For example, concerning the structure of the atom, he thinks that scientists are not totally certain of the structure of the atom because it was inferred from empirical data. In response to the question concerning the classification of the species, he believes that scientists are not certain because the concept of the species is very abstract. His responses are consistent with the contemporary informed understanding of the tentative nature of science.

In summary, in light of the above discussion it might be concluded that nine participants (T1, T2, T4, T6-T11) hold a naïve view of this tenet, while two (T3 and T5) hold borderline views, and only one participant (T12) holds an informed view of the tentative nature of science.

4.3.6 Social and Cultural Embeddedness of Science

Science is a human enterprise and a social institution that affects and is affected by the society and culture in which it works (McGinn, 1991).The society and culture in which science is produced affects how and what kind of science is to be done or not. Organisations such as NSTA (1982; 2000) and AAAS (1990) considers science as embedded with various social and cultural elements like religion, values, traditions, philosophy and world views, politics, economics, societal pressures, power structures, and geographical and historical factors. As such, science reflects the social and cultural values of the community in which it is practiced, and so is not universal. Consequently, scientists' backgrounds and their upbringing in a certain culture influences their view of science and the way they practice science and deal with it and its outcomes.

Teachers' views of this tenet were extracted from their responses to Questions 1, 8, 9, and 11 of the questionnaire, and to Questions 3 and 5 of the third part of the follow-up interview. These questions assessed their views on the social and cultural influences on the generation and development of scientific knowledge. The analysis of these views generated three emergent categories as follows:

(a) Science is universal, with no socio-cultural influences;
(b) Science is socially and culturally embedded, but should be universal.
(c) Science is a human endeavour that is socially and culturally embedded.

(a) Science is universal, with no socio-cultural influences

This category represents the views of seven of the twelve participants whose perspectives are captured in these quotations:

> In my view, science is universal because science does not belong to a certain nation or a property of any group of people, or specific countries, and is not distinguished by any country's habits, traditions, culture or values (T3).
>
> Science is universal, and should not be affected by any social or cultural values, otherwise it would lose its trustworthiness, and people in each society would deal with it according to their own experience and mentality (T5).
>
> One of the most important characteristics that science enjoys and distinguishes it from other disciplines like religion and the arts is its objectivity, and being free from any personal biases, or any political or socio-cultural impacts that society might impose, because science is not a property of a certain person or a certain

> society. It does not belong to its creator, but belongs to human beings all over the world who can access it and benefit from it (T10).

> One of the issues concerning the nature of science that I stress in my teaching is training the students to look at science from a global point of view that is free from any social or cultural values related to a certain society (T8).

Considering religion as part of the socio-cultural structure of any society, four participants rejected any influence of their religion on the way they view science. In contrast, two of them believe that a major role of science in a Muslim community is to prove religion as coming from God through related scientific indications and evidences, by proving scientifically the information narrated in the Quran.

However, one teacher claimed that due to his religious beliefs, he cannot think deeply or creatively about some scientific phenomena in order to avoid God's anger toward him, because:

> There are some issues that are the concern of God and we, as human beings, do not have the right to argue or interfere with them, such as the source or the mechanism of the start of life on the ground, or to try and think of evolutionism from a purely scientific point of view rather than believing that we have been created as human beings since the beginning by God, as narrated in the Quran (T11).

Some elements of these quotes resonate with spirit of science, especially the lack of personal ownership within the body of scientific knowledge. However, this group of teachers (T3-T6, T8, and T11) were classified as naïve holders of this tenet because they rejected any social, cultural, political, economical, or religious impacts or influences on science. They also did not recognise that different cultures could impact on the use of scientific knowledge and the way scientific investigations are conducted, nor recognise that socio-cultural contexts could impact on what and how scientific knowledge is generated. Furthermore, the view of religion held by this group of teachers, coupled with their tendency to either combine science and religion, or to segregate them might also explain their naïveté of this tenet.

(b) Science is socially and culturally embedded, but should be universal

This category represents the view of four of the twelve participants who, while recognising the social and cultural influences on science to some degree, emphasised the importance and vital need for a universal and objective science. While the views of all four teachers are regarded as borderline, their complexity and diversity was evident in their responses. For example, T9, as explained in the following quotation, is against any social or cultural influences on the scientific endeavour at a personal level:

> Politics, economics, society or culture should not be allowed to interfere in the scientific enterprise, but in reality they do interfere, and, sometimes, control the directions of science. For example, test-tube babies were opposed when they first appeared for quite a long time in our society due to religious and cultural considerations, so that it was a shame for any couple who did it, and people used to prefer not to have babies rather than obtaining them through this process. But, then when people understood it properly and realised that it does not contradict their religion they accepted it...I think scientists should clarify and explain science and its outputs in a manner that is acceptable to the society to whom this science is offered. (T9)

She (T9) calls for a universal science, which what she thinks is ideal and what we should strive for. But at the same time, she admits that she cannot neglect the power these factors have on science, and that she has to obey the socio-cultural norms of the surrounding community, even if she is not persuaded of them at the personal level. It seems she does not demonstrate a mature understanding of the organic relationship between science and society that we can never operate in a vacuum; we are always doing science in a particular society and culture that has its influence on our endeavours:

Similarly, according to T7, though she believes that science should be free of any socio-cultural influences, she thinks that scientists cannot isolate themselves from their socio-cultural and religious sphere when conducting science. She separates science and other socio-cultural factors at a personal level, but cannot do so in public. The following quotation explains her position:

> Science and scientists' work has to follow the religious and socio-cultural norms of society. For example, a scientist cannot adopt any

> scientific attitudes or outputs that are in contradiction with the society or culture, though s/he might be persuaded of it at the personal level .... I, personally, separate scientific innovations or explanations from my socio-cultural values that relate to these issues, but sometimes I cannot express that explicitly in public .... I do not think it is wrong to do experiments that clearly contradict my religion or cultural norms, but I cannot say that, or try to do that.

In contrast, T1 acknowledges to some degree the socio-cultural embeddedness on science, which reflects an informed element of this tenet. However, his actions are compromised by refusing to think of, or teach, certain scientific issues like evolutionary theory for religious considerations:

> Science is universal and is not universal at the same time. It is universal in that it is not the property of any person or nation or even its creator, and because people all over the world can utilise it and get advantage from it. However, it is not universal in that it cannot be separated from the society and culture where it works. For example, a society will not maintain any patent or new scientific development that contradicts its social or cultural values. When I teach science, I always avoid teaching any issues that oppose my cultural or religious values like cloning, or the evolution theory.... Even I do not allow myself to think of issues that might be taboo "Haram" in my religion like thinking seriously of Darwinism. (T1)

According to T2, though he acknowledges the universality of science as a human endeavour, he thinks that the products of science should be accepted or rejected in light of the religious/cultural norms of the surrounding society. This in turn will influence what and how scientific knowledge is generated and how knowledge is transferred and comes embedded. The following quotation by T2 illustrates his inconsistent views of this tenet:

> Science, as a discipline and human endeavour, is universal and is not a possession of a specific nation. The way it works and the research it carries out are universal as well. The role of society is to accept or reject the outputs of this science for socio-cultural or religious considerations. For example, cloning is absolutely discarded because of religious considerations. We also do not believe in the evolution theory, or teach it to our kids, because it contradicts with our religious beliefs, although this theory is accepted by a lot of people in western countries, because they believe in a separation between religion and science.

This group acknowledged that in reality society, culture and religion influence science, and are affected by it. However, it seems that they do not have an adequate understanding of this organic relationship between science and the culture in which it is embedded, though the focus of the teachers was more on the products of science, and how socio-cultural factors affect how they are used. Clearly this could have an indirect effect on how science is practiced. For example, none of them could elaborate on the economic issues, funding for research, or possible political concerns that might influence the kind of science to be practiced or not. Another feature of this group is their preference to have a universal science that is, according to them, objective and reliable. It is a goal of science, but not realistic. They think that the development of communications and the accelerated exchange of information through electronic forms would be very helpful to promote the universality of science, and restricting the socio-cultural impacts "*the tremendous current developments of electronic communications has broken a lot of the cultural barriers between communities that might facilitate the universality of science".* (T9)

Although this group of participants hold informed elements in their view, their actions reflect a naïve view because of the power of their cultural and religious beliefs. They all acknowledged the socio-cultural embeddedness of science reflecting an informed view. However, they hold parallel inconsistent applications and actions that compromise their views. Though their personal views of this tenet have many informed elements, they can be characterised as borderline because they do not portray these views in public or in their teaching.

(c) Science is a human endeavour that is socially and culturally embedded

This category represents the view of only one participant (T12), who responded that science reflects the social, cultural and religious values of the society. This view was made clear in the following quotation from him:

> Science is a natural reflection of socio-cultural values, because it is built mentally by individuals or groups who belong to societies or cultures that diverge in their characteristics, where science is a subjective reflection of the social values of these people or groups in their social and cultural disciplines .... Science is built up of a proper mental arrangement of the experiences and practical

> experiments of the individual, which cannot be separated from its historical, social, cultural or political disciplines. (T12)

He adds that "*Science gains its strength and power when it interacts and reacts with its social and cultural environment enabling it to be creative, and to be able to solve the society's dominant problems by any method that suits the culture*". As such, this participant portrays an informed view of the socio-cultural embeddedness of science that is in line with the contemporary views in science education.

In summary, as indicated from their responses, participants' views of the socio-cultural embeddedness of science can be briefly characterised as follows; seven of the participants (T3-T6, T8, T10, T11) hold a naïve view, while four of them (T1, T2, T7, T9) hold a borderline view, and only one (T12) possessed an informed view of this aspect.

Related to this issue is the social dimension of science (sociological NOS) (Abd El Khalick, 1998; 2008) which focuses on the role of the scientific community in the acceptance and legitimisation of the new scientific knowledge, and in increasing the objectivity of scientific claims. He suggests that although science is empirically based, it is socially negotiated by scientists. Communication, negotiation and criticism of new knowledge by scientists in conferences, symposiums, forums, journals and journal blind peer reviews legitimise scientific claims and act to validate the scientific knowledge in parallel with empirical evidence, as scientists strive to gain support and reach consensus. It reflects science as a human endeavour. Additionally, this mutual agreement coupled with blind peer reviews increase the objectivity of scientific claims and the work of scientists.

No questions in the questionnaire explicitly addressed this issue. However, Questions 6 and 9 provided an implicit opportunity for the participants to express their view of this aspect, while Question 5 in the third part of the follow-up interview was designed to address this issue explicitly. No participant in this study mentioned the scientific community or anything relating to the social dimension of science. When asked directly what role the scientific community play in science, they all said that they had no idea of the meaning of "scientific community". After the term was explained, participants could not explain what such a "scientific community" might do to validate the scientific knowledge or increase its objectivity. Their responses suggest that they have no knowledge of this aspect of NOS.

4.3.7 The Myth of "the Scientific Method"

The existence of one universal step-by-step scientific method with sequential activities that scientists follow in their scientific investigations to reach conclusions is a widely held misconception about the nature of science and its development (Kattoula, 2007). In reality, there exists no single "scientific method", but rather multiple ways of doing science, that might be experimental, descriptive or theoretical, and might be influenced by scientists' own paradigms, prior knowledge and training (Lederman et al., 2002). Scientists might utilise any method or any way that "works" to enable them reach their conclusions. They do not rigidly follow a cookbook method. "*They observe compare, measure, test, speculate, hypothesise, create ideas and conceptual tools, and construct theories and explanations*" (Abd El Khalick, 1998:341).

Two main categories emerged from the analysis of participants' responses to the questionnaire and the follow-up interview, especially responses to Questions 1, 2, 3 and 11 of the questionnaire and to Question 3 of the third part of the follow-up interview:

(a) Science is characterised by a universal stepwise "scientific method".

(b) There is no single stepwise "scientific method" in science, rather the orientation is towards 'what works' in practice.

(a) Science is characterised by the universal stepwise scientific method

This category represents the view of the overwhelming majority of the participants, eleven out of the twelve, who described science as being characterised by "the scientific method". They believe in the existence of a single and universal step-by-step method that is used by scientists all over the world when they do science or solve problems. According to these participants, this method is composed of a series of steps that follow a particular sequence. The specific number and labelling of the steps vary from person to person, but in summary the following represents this perspective. The scientific method starts with the awareness of the existence of a certain problem. This is followed by the characterisation of the problem, and proposing of a hypothesis to solve it. Experiments are then carried out to test the hypothesis (data collection) followed by collection of results. Finally, the problem is solved and a conclusion is reached. According to these teachers, this "scientific method" is what distinguishes science from other disciplines like arts or religion. They do not believe in any flexibility in the stepwise procedure of "the scientific method". They view it as a logical, standardised and systematic method that leads to accurate and valid results. The following quotes by some of these participants illustrate this view:

> Science follows the scientific method step by step to reach new knowledge. (T3)
>
> One of the most important things that I want my students to be aware of concerning the nature of science is that there is a universal stepwise scientific method that they should follow to avoid any loss or mistakes in their learning and doing of science. (T6)
>
> The scientific method means working under a scientific frame and a very specified method with specific sequential steps that would lead to accurate results, and distinguish science from non-science, and enable avoiding randomness and corruption in the scientific work and advancement. (T2)
>
> Development of scientific knowledge needs experiments, because the way to generate any new knowledge is through suggesting relevant hypotheses and predictions, testing them with some experiments to get the observations that prove and ensure the new knowledge being extracted. We cannot attain this new knowledge unless we follow a procedure guided by a very well-defined scientific method. (T1)
>
> If different people follow the scientific method precisely, they will reach the same results (T9).
>
> The scientific method is very crucial to guarantee the validity and reliability of any knowledge being produced or problem being solved. Although sometimes some new knowledge or unexpected findings appear accidentally, we have to go back and follow the scientific method from the early beginning to see if we will get the same findings systematically. If so, we would accept them, if not, then we have to throw them away (T6).

These quotations are typical of a traditional view of this tenet with science relying on one universal stepwise scientific method in scientific investigations.

(b) There is no single stepwise scientific method in science, rather the orientation is towards what works in practice

This category represents the belief of only one participant (T12). This teacher believes that scientists do not follow a single stepwise specific method. He does not even believe in the existence of such a "scientific method". When he was asked, through the follow-up interview whether scientists follow a single universal scientific method, he said:

> If you mention the term "scientific method" in front of someone who possesses the minimum level of sophisticated understanding of how science works in reality, he would laugh at you. Of course, there is no such "scientific method"; scientists do not have to follow it, even sometimes they do not start with a certain defined problem. It is one of my goals when I teach my students at school to persuade them that no real stepwise scientific method exists in science.

He believes that the development of science occurs in light of its reliance on a methodology that integrates the empirical, inferential, and logical rational aspects in a workable station, while sometimes development is achieved through logical inference from observations and without experimentation. For example, *"Newton created his laws of motion and the general law of gravity relying on his mental inference, without any experimentation"*. He also ascribed the existence of multiple methods in doing science to the kind of paradigm that the scientist is affiliated with, that imposes its subjectivity and biases on the way of looking at, and dealing with, science. This participant clearly holds an informed and highly sophisticated view of this tenet.

In summary, it might be concluded that eleven of the participants (T1-T11) hold naïve views of this tenet believing in a single, universal and constant stepwise scientific method, while one participant (T12) holds an informed view of this tenet regarding scientists as creative and subjective and resorting to any method they find suitable for the case and that fits with their theoretical paradigms and biases. It was not possible to identify any participants with a borderline view of this tenet.

4.3.8 Epistemology of Scientific Theories and Laws

Scientific theories are inferred explanations of observations of natural phenomena and associated laws (AAAS, 1993; NSTA, 2000). They are constructed of concepts that are in accordance with related observations and laws, and that aim to propose new explanatory models of the world for enormous sets of apparently unrelated observations that would provide guidance for future investigations (Abd El Khalick, 1998). In contrast, laws are quantitative descriptions of the relationships among observations of natural phenomena that are used to express what has been observed. Theories and laws are different kinds of knowledge, with no hierarchical relationship between them, where laws do not have a higher status than theories, and one does not become the other (Lederman, 1998). They are both created to interpret and describe phenomena (Chen, 2006). A scientific law says something happens, while a scientific theory explains why and how something happens[9] (Kim, 2007).

Participants' views of the epistemology of theories and laws were identified mainly from the analysis of their responses to Questions 4 and 5 of the questionnaire and related follow-up interview. Their views of this tenet were classified into three main categories as follows:

(a) Theories become laws when there is proof; a hierarchical relationship exists.

(b) Theories and laws are different types of knowledge, with theories being invented, and laws being discovered and more certain.

---

[9] In fact, this tenet is probably the most controversial and least agreed upon among science educators according to the above framework. For example, many might argue that laws are more secure than theories, and less likely to develop and change, because laws are quantitative descriptions based on observation, where theories are explanations based on inferences. In light of this definition, one might also challenge that laws are more durable because the gap between the law and the evidence is smaller, since interpretation, inference and creativity do not play a significant role.

(c) Theories and laws are different types of knowledge, with no hierarchical relationship between them.

(a) Theories become laws when there is proof; a hierarchical relationship exists

This category characterises the views of eight out of the twelve participants. These teachers all described scientific laws as "proven" theories, where scientists discover laws to use in producing theories. Laws exist in nature and scientists follow the scientific method to discover them, so they are absolutely and permanently correct. Laws are linked to facts that do not change. On the other hand, theories, being invented by scientists, are not absolute but are subject to change. Laws have a higher status than theories. However, once theories are adequately tested and supported by direct evidence they become laws. The following quotation by T9 illustrates this naïve view:

> Theory is subject to change and can be falsified. It does not need much evidence or empirical experimentation for approval, because it might change at any time in light of new conditions or new evidence. But a law is permanent and constant and is provable by experiments and quantitative representation. For example, the theory of evolution is subject to change and falsification, while Mendel's laws of heredity are absolutely and permanently correct.

Additionally, four teachers in this group (T2, T3, T8, T10) did not differentiate between formulae and laws when they offered density = mass/volume and number of moles = mass/molar mass as examples of laws. Three of them (T2, T3, T9) see laws as part of more related comprehensive theories. For T3 and T7, theories do not need experimentation or proof because they keep changing. T10 views of a theory as a preliminary hypothesis that has not yet been exposed to testing to prove its reliability. In contrast, T5 believes that scientists develop their laws from related theories subject to following "the scientific method" in creating these theories that would yield the related laws.

As such, this group of teachers hold a naïve view of this tenet, one that the literature suggests is extremely common.

(b) Theories and laws are different types of knowledge, with theories being invented, and laws being discovered and more certain

This category represents the view of three participants, T1, T6 and T11 concerning this tenet. These three teachers provided a definition for theories and laws that is close to the modern view. They demonstrated that theories and laws are two different types of knowledge, with a theory being wider and more comprehensive than a law, sometimes including some laws within its structure:

> Theories are more comprehensive and more general than laws. A scientific law is sometimes derived from a theory. For example the mass/ energy law E= mc2 was derived from the Einstein's theory of relativity (T6).

They believe that laws can be tested through empirical evidence, while theories cannot be tested directly, but through their predictions and their success in interpreting and explaining the phenomena that relate to the issue.

However, these three participants still believe that laws are more certain and have a better trustworthiness than theories because "*laws stand on empirical evidence and describe relations between observable and directly accessible phenomena, while theories are more mental images, explanations and predictions of phenomena that might be falsified or change more frequently than in the case of laws*" (T1). They also believe that laws are discovered, while theories are invented:

> Theories are invented to develop explanations and predictions concerning lots of variables and factors that are highly abstractive and comprehensive such as the Big Bang theory or the theory of evolution (T11).

Therefore, these three teachers were classified as holding a borderline view of this tenet.

(c) Different types of knowledge, not hierarchical

This view was held by only one participant, T12. This participant believes that theories and laws are two different types of knowledge that support each other, where theories are explanatory and laws are descriptive. Both are invented, are subject to change, and possess the same degree legitimacy as pieces of reliable scientific knowledge. He explains his view of laws as being tentative and subject to change:

> A scientific law is a generalisation that describes the regularity or a relationship between certain natural variables that are achieved, in most cases, from experimental data. These experimental data are not absolute and might be subject to change, and consequently the law that includes them might change accordingly.

Concerning the relationship between theories and laws, he stated:

> These are different forms of scientific knowledge. For example, Newton developed his general law of gravity before he created the theory of gravity which, after it was developed, supported the previous laws of gravity that have been created. Besides, the theory sometimes evolves as a result of a creative action that depends on imagination and intuition without any reliance on related laws, and is sometimes difficult to prove. For example, upon dependence on Newton's law of gravity and learning the tracks of the known planets, scientists proposed the presence of new planets within the solar system. Then after these planets were discovered, scientists' confidence of this theory was enormously increased.

In summary, it can be concluded from the above discussion that eight teachers (T2-T5, T7-T9, and T10) hold naïve views of this tenet, while three participants (T1, T6 and T11) hold borderline views, and only one participant, T12, holds an informed view of this aspect of NOS.

4.4 Summary of Qualitative Findings

This summary provides an overview of teachers' views of NOS. Table 4.3 below provides a summary of participant teachers' views of NOS across the eight tenets of NOS, and the overall performance of each teacher on the major categories (namely, naïve, borderline and informed views).

However, I have to acknowledge that this classification (naïve, borderline, informed) is more complex and subjective than it might appear. While I have adopted, perhaps, a more rigorous or strict classification in line with the literature, I am mindful of the fact that these views are on a continuum and the classification is artificial because it is imposed by me. Therefore it will be flawed and the reliability of it might come under question. However, it does not really impact on the significance of my findings because whether it is naïve or borderline between naïve and borderline, or in the middle of borderline, or borderline between borderline and informed, those little divisions are not important if we get the broad picture especially through the quotations and other related pits that give the value and the strength of the study and its findings. The danger of people working in this field is being dogmatic about these classifications that will result in losing sight of the bigger picture of participants' views of the topic which I have tried to avoid.

As Table 4.3 shows, it is evident that the overwhelming majority of teachers hold inadequate views of all tenets of NOS. Eleven out of the twelve participants did not hold sophisticated views for any of the eight tenets.

The most problematic aspects were the empirical bases, inferences and theoretical entities, and the myth of scientific method with eleven teachers holding naïve views of these three tenets. Same teachers did not believe in the reliance of science on indirect evidence to support it. Rather, they view science as a discipline that is solely based on hard data and tangible measurable facts as evidence to prove it. They also lack an understanding of the role inference plays in the creation and development of science. They regard theoretical entities as copies of reality that scientists have direct access to and are certain about. Additionally, this same group of participants hold a naïve view of "the scientific method", believing in the existence of one universal stepwise scientific method that all scientists follow.

Table 4.3: Summary of teachers' views of NOS across the NOS tenets

NOS Tenet / Participant	Empirical Basis	Inference and Theoretical Entities	Imagination and Creativity	Subjectivity and Theory-Ladeness	Tentativeness	Socio-cultural Embeddedness	Scientific Method	Theories and Laws
T1								
T2								
T3								
T4								
T5								
T6								
T7								
T8								
T9								
T10								
T11								
T12								

Naïve   Borderline   Informed

By comparison, three quarters of the participants conveyed inadequate views of the tenets regarding the subjectivity and theory-ladeness of science, the tentativeness, and the epistemology of theories and laws, while two out of the twelve of the participants hold borderline views of these tenets, and only one participant portrayed an informed view of them. The analysis of the participants' responses to the subjectivity and theory-ladeness of science revealed that nine of the twelve of them thought of the absolute objectivity of science and scientists, while two of them regard science and scientists as temporary subjective, with only one participant believing that science and scientists are inherently subjective.

In a similar manner, nine participants rejected the tentative nature of all scientific knowledge. They supposed that some categories of scientific knowledge such as facts and laws are permanent, true and absolute. However, two participants demonstrated a borderline view in their belief that all categories of scientific knowledge are subject to change, but some of them are more permanent than others. Only one participant demonstrated a view that all categories of scientific knowledge are subject to change.

Again, nine of the twelve reflected an inadequate view of the relationship between theories and laws indicating a hierarchical relationship between the two categories, with theories becoming laws when having sufficient evidence to prove them. However, two of the participants manifested a borderline view of this tenet. They accepted the view that theories and laws are different types of knowledge, but they still considered laws to be more certain and more constant than theories.

Nonetheless, more participants provided borderline views of the role of imagination/creativity and socio-cultural embeddedness of science (three and four respectively), although the majority hold naïve views of both. Eight out of the twelve participants denied any existence of imagination or creativity in science, while three of them hold a borderline view believing in the existence and need for imagination and creativity in certain stages of scientific investigations. Similarly, seven out of the twelve participants conveyed a view of science as universal and free of any social or cultural influences, while four of them believed in the socio-cultural embeddedness of science, although they believe that science should be universal.

An examination of individual views of NOS tenets as Table 4.5 indicates that individual's performances covered the full spectrum from cases at the one extreme who hold naïve views of all eight tenets to one case with informed views of all the tenets at the other extreme. These individual performances can be grouped into five main categories:

1. Two participants (T8 and T10) hold naïve views of all the eight tenets of NOS;
2. Another five participants (T2, T3, T4, T6 and T11) hold naïve views of seven tenets and a borderline view of only one tenet;
3. Three participants (T1, T5, and T7) hold naïve views of six tenets and borderline views of the remaining two;
4. Another participant (T9) holds naïve views concerning five tenets and borderline views of the remaining three;
5. Finally, only one participant (T12) portrays an informed view of all the NOS tenets, while none of the other participants seemed to hold any informed view of any of the eight tenets of NOS.

Table 4.4: Individual participants' overall performances regarding NOS tenets

Participant teacher	Number of tenets with naïve views	Number of tenets with borderline views	Number of tenets with informed views
T1	6	2	0
T2	7	1	0
T3	7	1	0
T4	7	1	0
T5	6	2	0
T6	7	1	0
T7	6	2	0
T8	8	0	0
T9	5	3	0
T10	8	0	0
T11	7	1	0
T12	0	0	8

Though it was a difficult and complex operation to put the participants in each category above side by side to make comparison and identify themes or background variables that are common between them, it is worth noting the following patterns and characteristics that emerged through the analysis concerning the above categories.

The two participants (T8 and T10) with the most traditional views, who hold naïve views of all the tenets of NOS, possess no formal educational teaching qualification. This lack of educational qualification might, partially, explain their extreme naïveté of all tenets of NOS.

Within the second group most traditional views (T2, T4, T3, T6, and T11), who hold naïve views of seven tenets of NOS and with only one tenet with a borderline view, three of the five teachers hold only a diploma in general sciences. As explained in Chapter 1, a two-year diploma programme is a track that used to exist in some Palestinian higher education colleges. Teachers who hold this diploma as their highest qualification are usually weaker in their scientific discipline than their counterpart colleagues who hold a Bachelor or Masters degree (Khaldi, 1998).

By comparison, T9 who appeared slightly less traditional, and T12 with the most informed views of all tenets of NOS, both hold a Masters degree in their science fields and another Masters degree in science education. This indicates that they are very well qualified in both the discipline they teach and in science education. T12 who represents a special case with informed views of all tenets of NOS, also attended a specialised course about NOS delivered by a PhD student for 36 hours spread over six weeks in August/September 2007 to 19 school science teachers serving in different Palestinian governmental school, and then, as part of the cohort, was followed up for eight weeks in his classes concerning the implementation of this topic in his teaching. This student had been conducting empirical research for his PhD thesis to assess the influence of an explicit-reflective instructional approach on in-service school science teachers' understandings of NOS. The study utilised a pre-test, post-test single-group design to assess the impact of the intervention on participants' understandings of NOS (Wahbeh, 2009).

In light of the values obtained for numbers of individual participant's overall performance on NOS tenets (Table 4.4), it can be concluded that, with the exception of T12 who articulated highly sophisticated views of NOS, all participants hold traditional, uninformed views of science.

4.5 Quantitative versus Qualitative Findings of Teachers' Views of NOS

Both the quantitative and qualitative phases gave broadly similar results, suggesting that the majority of Palestinian science teachers participating in this study hold predominantly naïve views. The qualitative survey to some extent indicates a more naïve belief set than does the quantitative survey. For example, the qualitative survey indicated seven of the sample of the twelve held naïve beliefs in respect of socio-cultural embeddedness, while only 4 % of the quantitative sample were in the naïve category for this tenet. This classification, however, in the quantitative survey depends entirely upon the boundaries used for naïve/borderline views, and this in turn depends upon the number of questions contributing to the tenet. As detailed in Chapter 3, the more questions included within the set contributing to a particular tenet, so the score is likely to regress towards the mean (Coolican, 2004). Because the questions contributing to each tenet are not entirely explicit to the reader, even in the original VOSE model of Chen (2006), and because the interpretation of some questions contributing to each tenet is open to question and subject to cultural values, it is not possible to establish the precise boundaries between naïve, borderline and sophisticated views. Even after a critique of the survey in a Palestinian context by seven academics, and piloting amongst 35 science teachers, in retrospect it is not clear that the quantitative survey was completely unambiguous in use or interpretation. For these reasons, quantitative surveys of the VOSE type should be used with caution. While I do not consider this survey to be as reliable as the qualitative interview format which followed, I do believe it fulfilled the purpose of being indicative.

In fact, the statistical analysis of questionnaires such as the VOSE questionnaire is not straightforward, and requires great caution in interpretation. In the first place, as detailed in Section 3.8.1 in Chapter 3, the variables fall between ordinal and interval level measurements, and are bounded between one and five, making the application of parametric statistical methods inappropriate, as Figure 4.1 shows.

More importantly, each tenet is composed of between three and thirty one separate items, which are simply averaged to obtain the mean tenet scores for each teacher. This in part contributes to the pseudo interval nature of the distributions seen in Figure 4.1; "The Scientific Method" included six items, divisible by three and giving category increments of 0.33. "Nature of Observation" on the other hand contained five items, giving category increments of 0.5. "Subjectivity/Objectivity" included the greatest number of items (31), leading to the smallest spread in the data.

Furthermore, perhaps most importantly, a Likert scale is interpreted at the point of the questionnaire respondent as ranging from one (total disagreement) to five (total agreement). However, mean scores cannot be interpreted in this way. A mean of 3.5 is a statistical construct indicating that the subject has agreed with slightly more items than they have disagreed with; it does not mean they slightly agree overall. This is not particularly a criticism of the VOSE questionnaire, but is more widely the case, in for example the interpretation and implementation of student satisfaction or attitudinal surveys. However, in this study the values of the standard deviations for all the NOS tenets shown in Table 4.1 are too small ranging only between 0.24 and 0.67 indicating that the variation within each tenet is low. These low values support the argument that the mean score values of each tenet are representative of teachers' views of it. This low variation within each tenet suggests that teachers' responses within each tenet tend to be consistent around the same place which means that data did not vary much.

Finally, there might be also some strong cultural issues in the interpretation of VOSE. For example, the response to Item 1.5 about the validation of scientific knowledge was "*No, the authoritative position of the scientists who develop the theory affects others in accepting it*". In Arabic "authoritative" means "political and physical power", and is not related to the reputation of the individual scientists. This difference between the languages may have confused respondents. It is a problem with VOSE that many items can contribute to more than one aspect of NOS, leading to a subtlety of answers that may not survive translation or transfer between cultures. This may be a more general issue with questionnaires of this type. For these reasons, quantitative surveys of the VOSE type should be used with caution.

It is worth noting that although at the level of individual tenet the quantitative and qualitative findings do not always closely correspond, at an item level findings are virtually identical in the two phases. This is because Chen (2006), who developed VOSE, utilised some of the previous items from the VNOS-C instrument of Abd El Khalick (1998). For example, the qualitative data gathered through VNOS-C and the follow up interview indicated that eight out of the sample of twelve teachers held naïve views of the imaginative/creative nature of science. When the 277 teachers were asked in the closed questionnaire whether scientists can use imagination while doing research, 60 % of them responded negatively, and selected the response "*imagination lacks reliability*" (Item 3.5), thus portraying a naïve view of this tenet. For the socio-cultural embeddedness of science, the qualitative data showed that seven out of the twelve participants believe that science is universal with no socio-cultural influences, and were classified as naïve holders of this tenet. Likewise, when the teachers were asked in the quantitative phase: "*do you think research is influenced by social and cultural values?*" (Question 2), 57.4 % of them responded positively "*science requires objectivity, and this cannot relate to social norms, which are sometimes subjective*" (Item 2.4), reflecting a naïve view of this tenet according to this item.

Other situations when the qualitative data gathered supported the quantitative findings at the item level were in the tenets relating to the myth of "scientific method" and the epistemology of theories and laws. For the myth of scientific method, the qualitative data categorised eleven out of the twelve teachers as naïve in that they believe that science is characterised by the universal stepwise scientific method. Similarly, 92 % of the 277 teachers who answered the closed questionnaire responded positively to Item 9.1; *"most scientists use "the scientific method" because it guarantees reliable and correct results"*, and thus were categorised as naïve according to this item. For the epistemology of theories and laws, eight out of the twelve respondents to VNOS-C were classified as naïve in their view that theories become laws when proved. Similarly, 72.9 % of the closed questionnaire respondents agreed that; *"if a theory is proved it becomes a law, scientific law usually has more evidence"* (Item 7.2), and thus were classed as naïve.

4.6 Discussion and Conclusions

It can be concluded from this research that Palestinian science teachers hold traditional views of NOS in respect of most of its main tenets. The results of this study are therefore consistent with those of several earlier studies which have generally revealed that teachers possess an inadequate understanding of NOS, with most holding fluid beliefs that lack coherence or consistency (Schmidt, 1967; Carey and Stauss, 1970; Pomeroy, 1993; Lakin and Wellington, 1994; Murcia and Schibeci, 1999; Smith and Anderson, 1999; Dekkers, 2002; Khishfe and Abd El Khalick, 2002; Liu and Lederman, 2002; Tsai, 2002; Yalvac and Crawford, 2002; Cakir and Crawford, 2004; Dogan and Abd El Khalick, 2008; Wahbeh, 2009).

On the other hand, these results are at odds with more recent studies (Abd El Khalick and BouJaoude, 1997; Abd El Khalick and Lederman, 1998; Haidar, 1999; Akerson, Abd El Khalick and Lederman, 2000; Morrison, Raab and Ingram, 2007), which have established a more positive view of teachers' understanding of NOS. For example, Haidar

(1999) found that Emirates pre- and in-service teachers hold mixed views of NOS that cannot be classified clearly as traditional or sophisticated. A similar result was found by Morrison, Raab and Ingram (2007) who found that teachers in Washington, America hold "intermediary" understanding of most aspects of NOS, but their ideas of the epistemology of theories and laws were naïve. Similar to this study's findings, Akerson, Abd El Khalick and Lederman (2000) found that most of the teachers hold very limited views concerning the epistemology of theories and laws, while their views of the other tenets of NOS ranged from naïve to borderline to adequate. In another study in USA, Abd El Khalick and Lederman (1998) found that teachers' beliefs were consistent with contemporary understanding of NOS with the exception of areas of social and cultural embeddedness of science, and the relationship between laws and theories. My study revealed some level of sophistication related to the socio-cultural impact.

An interesting aspect of the findings of this and other studies is that science teachers in different parts of the world appear to show different patterns of understanding of NOS. For example, in a comparative study of teachers' conceptions of NOS conducted on a cohort of British science teachers and another cohort of Pakistani teachers, Halai and McNicholl (2004) found that Pakistani teachers tend to merge science with religion and find it difficult to separate the two, while the difference between religion and science was obvious for the British teachers who were found to hold an adequate understanding of this aspect. The authors attributed this discrepancy to the difference in the cultural and religious contexts of the Pakistani and British teachers. I too found a strong tendency on the part of Palestinian teachers to merge science and religion in their belief and practice. In a recent study McCarthy, Sorensen and Newton (2010) noted that in the beginning science student teachers in England generally have a poor understanding of, or are unable to articulate their understanding, of certain aspects of NOS, but that they do not hold positivist views in relation to the corpus of scientific knowledge. This is clearly not the case for the group of Palestinian science teachers involved in my study. On the other hand, the Palestinian teachers generally held slightly more sophisticated views concerning the socio-cultural embeddedness of science than did the UK student teachers. This is perhaps as a result of the Palestinian teachers' views regarding the close relationship between science and religion.

This is not a straightforward issue to resolve; the Lebanese study of Abd El Khalick and BouJaoude (1997) and Emirates study of Haidar (1999), although placed within the same geographical context and a similar cultural background as the current study, came to different conclusions about the strengths and weaknesses in relation to NOS in their sample of teachers.

Clearly this research has raised methodological issues and specific problems related to the instrument in my quantitative phase. It is debatable how far a questionnaire developed for Taiwanese teachers (Chen, 2006) can be extrapolated to the Middle East without significant cultural issues arising in the interpretation of the instrument. I noted for example apparent difficulties in understanding of some items relating to the incremental nature of knowledge generation, which may have been culturally dependent.

Overall, the quality of the data generated by this instrument, and similar instruments, may be compromised by the grouping of questions which appear logical in one cultural setting, but may not seem natural in another environment. I have noted that the answers to individual items provide much more enlightening evidence of the respondents' views than do the mean values grouped according to tenets.

However, despite the problems identified in the quantitative data gathered for teachers' views of NOS using the closed questionnaire, such as the difficulty in establishing the precise boundaries between naïve, borderline and sophisticated views and the difficulty in interpreting mean values in terms of the Likert scale from which they were derived, the triangulation of the data, the size and representative nature of my samples, and the richness of the data generated in my qualitative phase allowed me to be confident in the results I have presented in this chapter.

In conclusion, I hope that an understanding of the current situation within the Palestinian context will help to identify strategies which can support teachers, and ultimately learners, to see science as more than a rigid body of facts to be transferred from textbook to learner, in line with the broad aims of science education in Palestine. However, these findings suggest that the challenge this presents is significant.

The reasons why Palestinian science teachers hold predominantly naïve views of NOS are explored and discussed Chapter 5.

Chapter Five—Research Findings: Perceived Reasons for Teachers' Views of NOS

5.1 Introduction

The initial approach of this study was to conduct a quantitative survey of Palestinian science teachers' views of the nature of science (NOS) in order to identify sub-samples holding naïve and sophisticated views, which could be utilised for research into their practice. However, based on the findings of the quantitative survey, it became apparent that it was impossible to identify teachers with sophisticated views across most tenets of NOS (see Chapter 4 for details of research findings). It was, therefore, judged appropriate and significant to refocus the study to explore in depth the nature, causes and context of teachers' views of NOS, and attempts to identify the factors responsible for this apparent naïveté in teachers' views of NOS across the sample of Palestinian science teachers.

In this chapter the reasons why this might have been so are discussed in detail in order to provide an answer to the second research question: According to Palestinian science education stakeholders, what factors influence science teachers' views of NOS?

5.2 The Participants' Background Information

The selection of the participants for this phase of the study was informed by the guideline that sampling for qualitative research is determined by the research questions under investigation and the aim of increasing the scope and range of data exposed to explore multiple realities (Patton, 1990). A careful selection of participants from whom rich and rigorous information could be obtained was seen as helpful in achieving this goal. As a result, my main criteria for sample selection for this phase were Palestinian professionals who were experts or researchers in the field of NOS and were involved in science teacher education in Palestine. They were judged to be best placed to offer explanations of the naïveté of teachers' views, and suggestions on how to improve teachers' understanding of this topic.

The backgrounds of the ten Palestinian academics and other six education officials who were selected for this phase are detailed in Chapter 3. In summary, the group of academics consisted of eight males and two females. Six have a PhD in science education, one a PhD in curriculum design, one a PhD in the philosophy of science, one a PhD in physics with publications on NOS, and one was in his final year of PhD study in science education when this study was conducted. Seven members of the group were science education lecturers at the Bachelors degree level in four universities in the West Bank, another was a physics lecturer, and the remaining two were researchers in two non-governmental teacher education research institutions that work with in-service science teachers to promote teacher empowerment and professional development. The group of six education officials composed of two MoEHE in-service teacher trainers, two MoEHE school teacher supervisors and two science textbook authors, with the aim that the inclusion of this group would provide an insight into how these factors (in-service teacher training, education supervision and school science textbooks) might play a role in improving or hindering teachers' views of NOS, and to triangulate academics' explanations and recommendations on the topic.

5.3 Perceived Reasons for Palestinian Science Teachers' Views of NOS

This section explores the stakeholders' views of why Palestinian science teachers hold such naïve/traditional views of NOS. The intention was to explore the likely reasons for the naïveté of teachers' views of NOS, and the possible strategies to improve their understanding of the topic through interviewing different sectors of people who were involved in the area and would potentially have insightful opinions about it. A second aim was to triangulate the findings from these different groups to validate the results and strengthen their trustworthiness. However, when I conducted the interviews and asked the education officials about their conceptualisation of NOS, I found that all but one of the textbook authors, teacher trainers, school supervisors hold naïve views of the topic, and could not contribute to provide insights about the inadequacy of teachers' views of NOS and possible solutions. Consequently, I decided to change the focus of my exploration with this group of six education officials to the nature of their misunderstandings and the possible role that these might play in developing school teachers' inadequate views of NOS. Therefore, the main findings presented and discussed in this chapter and in the next chapter draw on the ten academics' views in relation to the explanation of teachers' naïveté of NOS and the possible ways to improve their views of the topic, and only use the data from the textbook authors, MoEHE teacher trainers, and MoEHE school supervisors to provide evidence of the role textbooks, MoEHE teacher training and MoEHE school supervision play in the generation of the problem.

The purposive sample of ten Palestinian academics was interviewed (see Chapter 3 for detailed methodology and sample selection) and their responses to the semi-structured interview (Appendix 5) were transcribed and coded. The coding of the data involved combining detailed information contained in the participants' responses in light of four main themes used as a general framework for the analysis process:

1. explanation of teachers' naïveté of NOS;
2. improving teachers' views of NOS;
3. factors supporting the development of teachers' views of NOS;
4. factors hampering the development of teachers' views of NOS.

The coding and categorisation of the responses led the creation of a number of categories and sub-categories that allowed for a simpler description of the data, and facilitated a smoother analysis of the data and drawing of conclusions. In the next step the data from the interviews regarding the first theme explaining the inadequacy of teachers' views of NOS were pulled together into main categories, where the set of transcripts were treated as a whole for the purpose of developing the main categories. I searched for patterns in each category in order to make comparisons and make summaries of the patterns. I examined the quotations that appeared to represent examples of similar underlying categories or sub-categories.

As a result, eight main categories emerged from the data as explanations of the naïveté of teachers' views of NOS. These emergent categories were:

1. science textbooks;
2. structure and policies of the education system in Palestine;
3. the Palestinian socio-cultural background;
4. teachers' own personal values;
5. teaching approaches at school and university levels;
6. teacher training programmes;
7. educational supervision;
8. school resources.

Within each of these eight categories, a number of aspects and issues were identified and reported. These categories are fully described in the following sections, giving first an outline of the context and then an analysis and discussion of these findings.

5.3.1 Science Textbooks

Historically, textbooks have played a significant role in teachers' work and pupils' learning (Phillips, 2006). Teachers still use them as a primary teaching resource (Stinner, 1992; Radcliffe et al., 2004). Weiss (1993) pointed out that science teachers in the United States rely heavily on textbooks, and for many of them it is the only resource for structuring and developing their lesson plans. Similar studies conducted in the Arab world by Yusuf (2000), BouJaoude (1999), Ali (1998) and Thabyan (1994) in Palestine, Lebanon, Sudan, and Saudi Arabia respectively indicated that science teachers in these countries also rely heavily on the textbook as the main source they use in their teaching. Similarly, Sanger and Greenbowe (1999) stated that science teachers in secondary schools in the United States cover at least 85 % of the content contained in science textbooks. More recently Chiappetta et al., (2006) stated that more than 90 % of the teachers in secondary schools in the United States rely totally on the textbook as the sole resource in the organisation of their teaching and the assessment of their students although, according to Chiappetta and his colleagues, textbooks should be used by teachers as one type of instructional material to help them meet the national curricular goals through their lesson planning and teaching.

These studies demonstrate that the majority of teachers worldwide utilise the available textbooks as a major source in their teaching. Consequently, it is extremely important that these textbooks offer scientifically accurate and educationally balanced content, and reflect contemporary views of NOS.

Below is a description and discussion of the participants' views on the Palestinian science textbooks, including the potential role they play in influencing teachers' views and understanding of NOS, and the extent to which these textbooks present NOS in an appropriate way.

All ten academics interviewed in this study regarded science textbooks as a main reason for teachers' inadequate views of NOS. They all emphasised that the content of most textbooks reflects a very traditional view of science. According to the academics, these textbooks present only the final product of the scientific process, without any discussion or description of the historical development of the concepts, or the mechanisms or procedures by which knowledge has progressed and developed. Eight of the academics were aware of the process by which the new Palestinian science curriculum was designed and developed. They acknowledged that there was insufficient concern about including NOS as a main theme within the textbooks, and that most of the textbook authors did not possess adequate understanding of NOS, nor did they know how to include it in textbooks. They were not trained to deal with this topic while designing and developing textbooks and therefore an accurate perspective of NOS was almost absent from the textbooks. Their view was that many misconceptions about NOS were inadvertently promoted within the textbooks. Below are quotations that represent the academics' views of textbooks:

> A curriculum is composed of three main elements: a textbook, a teacher who teaches from this text and the educational and

> psychological environment where the educational process takes place. In the Palestinian context the curriculum is represented by the textbook as the sole source of knowledge that the teacher follows and depends on entirely... With the failure of these textbooks to reflect the nature of science properly, we can imagine the significant negative effects these textbooks have through transmitting naïve and erroneous views of NOS on the part of teachers and their students. (A2)

A2, who is an expert in curriculum design and development, stressed two major reasons for teachers' naïveté of this topic: 1) teachers' heavy reliance on textbooks as a source of the knowledge they pass onto their students, and 2) their confidence that the textbooks are "true" and "accurate" in everything. This view is shown in the following excerpt from her interview:

> Most, if not all, of the teachers deal with the textbook as a "holy book", that is indisputable and absolutely right. If any controversial issue or any disagreement arises among teachers on a certain issue, the textbook will be their term of reference. As there are lots of troubles in our textbooks concerning NOS, especially when many teachers totally rely on them, these textbooks may have an awful role in developing these misconceptions and naïve views of science.

A1, A3 and A4 were in agreement with A2 above in her claims that textbooks reflected inadequate views of NOS and that textbooks presented science as an absolutely "true" body of knowledge. A1 commented that "*the scientific concepts are presented in the textbooks as "true" and "accurate" pieces of knowledge that leave no space for criticism or scrutiny*". They also supported A2's claim of teachers' heavy reliance on the textbooks as their sole source of knowledge. For example A1 commented on this issue:

> In cases when an error or mistake occurs while conducting an experiment that might lead to an odd result, the teacher and his/her students should look for the causes of the error or mistake, but they would not suspect the knowledge being taught.

A3 believes that the current curriculum hinders the use of sources of knowledge other than the content of the textbooks, so that use of the textbook is not usually supplemented with knowledge from other sources or new methodologies or activities. The reason is that school teachers rely solely on this text as a curriculum model, as stated by A2. They also try to cover all of it following the sequence and procedure exactly as presented in the text without making any attempt to go beyond the written text. He pointed out that science textbooks contain a lot of misconceptions concerning science and the way it works as presented in the books' written text, pictures, activities and experiments, "... *sadly teachers pass these erroneous ideas to their students without any attempt to think of their accuracy, because they are fully confident of "the holiness" of the text"*.

A4 raised another issue that might explain the limited views of NOS held by teachers:

> Science textbooks offer scientific concepts, laws, theories ... as the ultimate outcomes of knowledge, without following up their progress and developmental stages in a historical context. Consequently, a lot of chances that might explain NOS are lost, ending up with these naïve views teachers and students hold about this topic.

Academics' views of textbooks as a significant factor in explaining teachers' naïve views of NOS can be summarised in three main points. The first is their belief that these textbooks do not reflect a contemporary view of NOS, and contain misconceptions concerning the topic because textbook authors were not adequately trained in this area when the new Palestinian science curriculum was established. The second point is the heavy reliance of teachers on these textbooks in their teaching and the use of them as the sole resource for teaching and learning. Finally, is the belief and confidence of teachers in the validity and reliability of these textbooks as the absolute source of "true" knowledge.

Following the interviews with the academics, two textbook authors were interviewed to shed light on what was done towards addressing NOS in the new Palestinian science textbooks, and to support and triangulate the findings obtained from the academics. One of them (TA1) was the coordinator of the national team of science curriculum authors, and shared in writing the broad aims of the science curriculum (curriculum document). Although I interviewed each of them separately, there was a high level of agreement about NOS and the way it was addressed when the new Palestinian science curriculum was designed.

When asked about their conceptualisation of NOS, both interviewees responded that they did not have a precise understanding of the term, and that they were more concerned with science and scientific knowledge than the nature of science. They regarded the term as more to do with education and philosophy, which is thus beyond their interest as they are "*people working in science, not in education or philosophy*" (TA2). As a consequence of this, I had to brief them on NOS and its main tenets. As a response to my explanation of NOS, they appeared embarrassed and said that they did in fact know and understand most of the issues related to NOS but had not understood my initial question.

In response to a question about whether they and other textbook authors had received any preparation on how to include NOS in the curriculum and textbooks, they emphasised that there was no training at all concerning NOS or any of its main aspects. When questioned about any initiatives to include NOS within the new Palestinian science curricula and textbooks, they both stated that including NOS was explicitly raised in the main document (broad aims) before the textbooks were designed. However these aims and issues were not fully translated in the textbooks because there was no proper follow-up on these issues when the textbooks were designed. TA1 explained this as follows:

> Including NOS within the textbooks was not stressed or followed up by the textbook authors' coordinator or the director of each textbook author. In fact, it was a matter of concern for the authors themselves and their desire and ability to include NOS or not. For example, we have had a textbook author who was interested in the nature of science and could design a fantastic chapter about NOS that was included in a Year 9 Science textbook. Unfortunately, school teachers did not like this chapter, and some of them could not understand it. Some of them thought it was an education topic that was not suitable to be included in a pure science textbook. Therefore, many of them ignored it, while others moved it to become the last chapter ... so that if they do not have enough time they can leave it out ...They think it is not as important as other "pure" and concrete science parts of the textbook.

Clearly, these responses by the textbook authors supported the academics' claims of the lack of concern about the inclusion of NOS within the new science textbooks, despite it being mentioned in the broad aims of the curriculum document. These two interviews also suggest a lack of understanding of NOS of some of the textbook authors. This might explain the number of misconceptions and naïve views of NOS these textbooks reflect.

Data from the interviews with the academics and textbook authors revealed that these stakeholders identified science textbooks as a major factor in explaining the inadequacy of teachers' views of NOS. Science textbook authors' naïve views of NOS and their lack of training or in-depth understanding about the topic, coupled with their description of the textbook design process, might explain the failure of these textbooks to reflect contemporary views of NOS. In this context, Khaldi and Wahbeh (2003) contended that for Palestinian teachers, the textbook determines exactly what teachers should teach students about science. It is obligatory for them to cover the whole textbook over the academic year. At the beginning of each year they have to provide the head teacher with a detailed plan showing how they intend covering each section of the textbook over the course of the year. They have to stick to this scheduled framework to cover the text, and may be monitored by the head teacher who might periodically observe their teaching.

As a result of these stakeholders' identification of the textbooks as a significant factor that might explain the inadequacy of teachers' views of NOS I then had a cursory look at the science textbooks to see how do these textbooks present and deal with NOS (although this was not initially planned). I noted virtually a total absence of contemporary views of NOS in the content, activities, figures and assessment. It seems that the textbooks reflect very traditional views of NOS, and include many of misconceptions concerning the topic. For example, I found that in Chapter 1 of a Year 9[10] Science Textbook (Shawabkeh et al., 2006:13) the authors stress absolute objectivity as a core characteristic of science, and present scientific knowledge as ultimate outcomes of facts that are constant and

---

[10] This is the only chapter in any Palestinian school science textbook that addresses the topic of NOS explicitly.

"true". The chapter also addresses science as *"a global human activity"* (p.9) stressing its universality but neglecting its socio-cultural embeddedness. I also noticed a trend to adopt an inductive approach to knowledge generation that stands on the notion that since scientific knowledge is achieved empirically and is based on observation, is valid and "proven". As stated in Year 9 science textbook (Shawabkeh et al., 2006:13), *"science starts with observation and relies on it"*. According to this perspective, the development of science knowledge relies totally on empirical observation, neglecting any other processes. It also fails to consider the historical development of the concepts or the context in which they were generated.

As a result, students and teachers get the impression that scientists are reliable and do not make any mistakes in their work, and that their work is not affected by the surrounding social and cultural sphere. Furthermore, the trouble of adopting the inductive approach is coupled with presenting "the scientific method" as a sequential step by step process in Year 9 textbook (Shawabkeh et al., 2006:14) following the empirical inductive approach of knowledge generation and development.

Therefore, given the nature of the textbooks design concerning NOS as described by academics and textbook authors and my cursory analysis, coupled with the heavy reliance on textbooks in teaching within the Palestinian context, the potential of these textbooks to facilitate the development of traditional views of NOS by teachers is obvious.

These results concerning the failure of Palestinian science textbooks to reflect adequate conceptions of NOS are consistent with those of earlier studies that have generally revealed the failure of textbooks in many countries to reflect a correct and balanced conception of NOS. However, a review of the literature in this area reveals that most studies examined science textbooks from a broad perspective of NOS that deems NOS as a general framework for scientific literacy. In this regard, Khaldi (2004) examined the new Palestinian textbooks for Years 6, 7 and 8 looking at the balance of four scientific literacy aspects as identified by Chiappetta and Collete (1984): science as body of knowledge; science as way of thinking; the investigative nature of science; and the interactions between science, technology and society. The results of the study showed that the textbooks in all three classes present the above four themes in an unbalanced way concentrating only on science as a body of knowledge, and failing to address the other three themes of scientific literacy that are basic aspects of NOS. Similar results were obtained by Yusuf (2000) using the same framework to analyse a Palestinian Chemistry Year 11 Textbook and by Ali (1998) in a study of Sudanese textbooks. Likewise, BouJaoude (1997) found that Lebanese textbooks concentrate on science as a body of knowledge and on the interactions between science, technology and society, while neglecting the other two themes. Research on science textbooks in the United States (e.g., Garcia, 1985; Chiappetta, Fillman and Sethna, 1993; Phillips, 2006) also revealed inadequate explanations of the four themes of scientific literacy.

However, the only study I found that targeted the representations of the eight main themes of NOS (Abd El Khalick, 1998) as a framework for analysing science textbooks was done by Abd El Khalick, Water, and Le (2008). They found the representations of NOS in high school textbooks in the United States to be poor.

As such, results from this study and similar studies at the national, regional and international levels indicated the failure of most science textbooks to address the topic of NOS in an adequate and balanced manner.

5.3.2 Structure and Policies of the Education System in Palestine

As a result of the Oslo Agreement between the Palestinians and Israelis in 1994, the Palestinian National Authority took responsibility for education in Palestine for the first time, and established the first Ministry of Education and Higher Education (MoEHE). MoEHE took control of the funding and administration of public schools, which form 76 % of the total number of schools in Palestine. See Chapter 1 for a detailed description of the historical development and structure of the Palestinian education system.

Seven academics indicated that Palestinian education can be viewed as a deeply centralised system that promotes naïve/traditional views of NOS. The following quotation represents this view:

> In such a centralised system, teachers and head teachers (and even teacher trainers and supervisors) are deprived of the freedom to be creative in their discipline. They have to adhere to and follow the text and cover the whole content that is very "sacred" for the decision makers in the Ministry. (A9)

This system, as seen by these seven academics, is only concerned and preoccupied with the coverage of the content of the textbooks within the allocated time framework. As such, the focus in teaching is on knowledge as a product, with almost total ignorance of other important issues and activities such as discussions, experiments, or critical aspects that can lead to adequate understanding of NOS. Five of these seven academics went further in criticising this centralised system as having a deep-rooted, hierarchical and bureaucratic structure, an academic administration that imposes itself on all aspects of the educational system, with an absence of any accountability or critical stance. A8 commented:

> The academic administration is the sensitive nerve that reflects itself on all aspects of work. It either facilitates or impedes the work. It seems in Palestine, the educational administration hampers work and effective production and maintains a backward system.

Three academics questioned the qualifications of decision makers and the rationale for their appointments, as espoused in this quote by A3:

> Our educational leadership lacks any logical scientific or professional view of work. The decision makers at the top of the Ministry's hierarchy lack the minimum qualifications. They were assigned to their positions for political reasons. This explains the heavy corruption in their work and in dealing with matters.

Four academics alluded to the concept of a "hidden curriculum" within the Palestinian context at the policy decision making level in the Ministry as is indicated from the following quote by A8:

> I am afraid there exist some hidden policies at the level of decision making in the political and educational leadership to avoid the

> promotion of individuals' criticality and awareness, because the existence of a society with high scientific literacy and awareness among its individuals will threaten the political system that rules the community. (A8)

Similarly, A3 was critical in criticising the current education leadership, and also alluded to the existence of such a "hidden curriculum":

> Our outstanding problem lies in this oppressive educational system that tries its best to maintain this traditional banking education[11] that will not have the ability to enhance reform movements or make any change in society. It aims to cause people to live as slaves for the regime whose only role is to memorize knowledge and give it back without any attempt to criticize it or think about it. These non-thinkers and illiterate people are much easier to be led and controlled, and will not make much trouble for the authority's leadership.

As explained by A10, the political regime tries through its educational leadership to avoid improving the criticality and social awareness of the public because, from his perspective:

> Once people become scientifically literate and critical, there would be a huge struggle between these literate people and the authority regarding the non-scientific way this oppressive and backward regime leads the country and deals with peoples' affairs.

From the viewpoint of these four academics, it seems that it is easier for the political and educational leadership to maintain the status quo by promoting a traditional education system that does not encourage independent and critical thinking in individuals, but rather blind obedience to the authority.

As such, the responses of the academics interviewed in this research to this issue highlighted the structure of the Palestinian educational system, the way it works and the "hidden policies" imposed on the Palestinian education as significant factors in explaining the current poor state of the education system in Palestine at a general level. It could also account for

---

[11] Banking education is a key concept in Paulo Freire's philosophy of education (Freire, 1970). He refers to the traditional form of teaching where the students' mind is being compared to a bank in which we deposit the money (information) and then take it out without any thought process from them. He contrasts this with a liberating form of education which he refers to as dialogical education; that is constructing knowledge in a dialogue involving the students and teachers.

the immatureness of teachers' views of NOS and the absence of efforts or concerns about improving teachers' views on the topic in particular.

Academics argued that the current educational leadership, which is viewed as oppressive and uninformed, does not encourage a critical mentality that would lead to the development of informed thinking about science. If this is the case, it seems understandable that teachers who function within such a system will embrace a traditional view of NOS and teach students in the same way as they themselves were taught. In such a system I can imagine that the responsibility of schools is to maintain, rather than change, the status quo.

5.3.3 The Palestinian Socio-Cultural Background

According to Norman (1980), human beings understand and interpret the world around them using the cognitive models and images they build about the world through their direct interaction with it. These cognitive images humans hold are very much related to their social contexts. Within this framework, Cobb (1994) argues that in interpreting a certain phenomenon or action, a person recalls a cognitive image that s/he finds suitable, but that the social context under which the phenomenon has happened increases the possibility of recalling one particular cognitive image rather than another.

Learning, from a social constructivist point of view, involves two dimensions (Driver and Bell, 1986). The first is the personal dimension, where learning is an active probing of cognitive models (images) in which humans hold onto their ability to interpret the information that arrives cognitively through their interaction with the surrounding environment. The second is the socio-cultural dimension based on the distinction between personal, intuitive daily knowledge and the formal knowledge of the specialized cultural society. Learning takes place through enculturation where the individual reorganizes his/her knowledge through fitting his/her personal learning with the vocabulary of the symbolic culture of the specialized society (Driver, 1986). The socio-cultural environment determines to a huge extent how an individual functions, interprets and reacts to various stimuli (Jegede and Okebukola, 1991) Thus, although knowledge is personally constructed, it is socially mediated as a result of the experiences and interaction with others in that social context (So, 2002). Tobin stresses this socio-cultural dimension of learning when he defines human learning as "*a process in which human beings actively construct their own conceptions facilitated by social interaction and develop consensus in a community to improve on existing knowledge*" (Tobin, 1993 cited in Kang, 2005:3). Similarly, Pajares (1992) considers that beliefs are shaped through a process of enculturation and social construction. Constructivists identify that there is a strong relationship between learning and the context, as the latter plays a central role in the development and organization of ideas. The extent to which one sticks to the cognitive models s/he holds depends on the efficiency of these models to interpret the knowledge gained from the surroundings (Driver and Bell, 1986).

This review suggests that teachers' beliefs and views cannot be isolated from their social context, their upbringing or their socialisation. The socio-cultural structure that surrounds learners and teachers plays a major role in the way they learn and develop their views of different matters.

In the Palestinian context, according to most of the academics interviewed in this study, the socio-cultural structure, coupled with the social understanding of religion and the way the individuals are brought up play a crucial role in developing people's (including teachers) naïve views of NOS. According to seven of the academics, the way individuals are grown up in Palestine fits more with a traditional naïve view of science, which reinforces the existence of one objective source of knowledge that is accurate, reliable and constant. Six of these academics explained that there are some social and cultural values and beliefs that corroborate this traditional view of science. The following quotation by A8 illustrates these values:

> Keeping in mind the heavy commitments of the Palestinian people to rooted habits and traditions, with resistance towards any change or development, the absolute obedience of the young to the old people in the tribe and the inherent respect given to them and their

> guidance without having any right to discuss or criticise anything that is going on around them [the young people], and following and maintaining what has been inherited and the absence of any critical spirit, you can understand the naïve thinking of people including teachers that might be extended to their thinking and understanding of knowledge and science.

According to these academics, factors exist within the structure of the Palestinian social system that have facilitated the development of these social and cultural values. A4 describes: "*the Palestinian community is an authoritative patriarchal society*". The father is the absolute term of reference and the source of knowledge and "*children should obey him and pay full loyalty to him*" (A5). A2 commented on the impact of these socio-cultural values on the thinking of young people:

> This non-scientific socialisation process and the readymade answers will lead the individuals to think of knowledge as absolute and permanent that they would never criticise or doubt, because they are not brought up to challenge their father's knowledge and wisdom.

These academics affirmed that this patriarchical system at the family level, coupled with the authoritative social structure at the community level, facilitates the development of naïve views of NOS. A7 explained this factor when he stated:

> We live in an authoritative community that starts from the father then the school teacher then the head teacher then the university teacher ... till we reach the head of the national presidency, where no one can dare to think critically or question what those who are above him/her are doing or saying. This will ultimately lead to banking education, as teachers who live in such a social system will find it easier for them to behave traditionally, and to say that concepts and other elements of knowledge are absolutely true, and there exists a single reality and objectivity, and not to try to think critically, because their main preoccupation is to give back the knowledge they teach following the same way they learned it.

Consequently, as supposed by these academics and explained by A7 above, these social and cultural values are reflected in teachers' and students' preferences and inclinations towards an uncritical approach and the rote learning of knowledge, leading to the more traditional views of science that they hold.

Another related aspect of the Palestinian socio-cultural background, raised by three of the academics, is that there is a view within this traditional eastern conservative culture that there are certain Western ideas that we can adopt and import to into our society, while there are others that do not suit our culture and should be rejected. These three academics indicated that the ideas related to the philosophy of science is the sort of knowledge that is "taboo" and should be rejected, and that "*it seems it is only allowed for us to receive the product of science from western society, not its philosophy*" (A9).

Within the broad socio-cultural perspective, religion was identified by four academics as playing a role in explaining the traditional views teachers hold about NOS. Specifically, they believe there to be a widespread attempt to combine science and religion in their teaching, and a tendency and desire to explain natural and scientific phenomena using religious scripts, and to "prove" the religious scripts scientifically. Four academics mentioned a religious belief held by the public, including teachers, that people must make use of scientific logic and methodology to demonstrate the match between what is mentioned in religious books concerning natural phenomena and what science has revealed about them, in order to make people more certain of their religious beliefs and spiritual faith as a true and absolute doctrine coming from the heavens. The problem here, from the perspective of these academics, is that the axioms and rules that science and religion stand on are different, in that "*science is empirically based, while religion depends on spiritual faith, and thus cannot be always scientifically proved or explained*" (A5).

These academics shared the view that the projection of religion onto science will lead teachers and students to view scientific knowledge as absolute, objective and constant, like they view religious knowledge. They pointed out that there is a misunderstanding between the religious heritage people hold concerning science and their spiritual beliefs. According to these spiritual beliefs, all sciences and knowledge exist in religion and the holy books especially the Quran and the Bible, and the role of human beings and scientists is to discover this knowledge, including facts, laws, theories, etc. The danger of the effect of this belief on teachers' views of NOS, according to these academics, is that it leads people to deal with all scientific knowledge as facts that are absolutely true, constant and objective. They also stressed that this view disregards the human element and role in science, and leaves no room for inferences or creativity in science and scientists work, as elucidated by A10:

> If we take this belief [that all knowledge exists in the holy books] for granted then it will be almost impossible to boost the soul of creativity or the advancement towards new initiatives or new inventions by our teachers and students.

However, two of the academics who characterised themselves as non-religious, went further to suggest that religion itself might be a source for developing such naïve views of NOS. They claim that religion relies on unseen secrets that the followers are supposed to accept and believe as absolute fact without being provided with a logical explanation or scientific evidence.

> We do not have the right to criticise or question any information narrated in the Quran or Bible. For example the script in the Bible and Quran that Jesus was born to a virgin does not fit with a scientific view or a logical approach to explain such a phenomenon. (A6).

These two academics assume that the way religion and religious issues are explained might lead to a naïve view of NOS. A3 elaborated on this issue:

> The lack of the existence of a wide margin in explaining religion, and the belief that there is only one right explanation that only a specialised religious person who can do this job and provide it to the public will lead to such naïve views of NOS. We do not have in our religious heritage the possibility to take a certain religious script and discuss it and look from different angles to explain it that we might disagree on. Rather there is only one correct explanation that we have to accept and believe in, and consequently science will work on the same format.

Therefore, according to these two academics, it is better to view science and religion as different enterprises. They consider that a secular reform movement in education separating science and religion is the effective solution to the religious and related socio-cultural troubles that might hamper the efforts for advancement.

As indicated from the academics' responses, the study highlights some effects of the Palestinian socio-cultural background, the way individuals are brought up and their social understanding of religion on teachers' understanding of NOS, and the potential impacts these factors might have in developing traditional and inadequate views of NOS in the Palestinian community, including teachers. Academics in this study assume that the Palestinian socio-cultural context, being overwhelmingly conservative, authoritative and patriarchal could negatively influence teachers' understanding of NOS.

This assumption is consistent with several research findings worldwide that have shown that the socio-cultural environment determines to a great extent how an individual functions, interprets, and reacts to various stimuli, which may influence their views and understanding of NOS (Jegede and Okebukola, 1991; Shumba, 1999; Cobern and Loving, 2000; Abd El Khalick and Akerson, 2004; Halai and McNicholl, 2004; Liu and Lederman, 2007; Mansour, 2007). The uniqueness of the Palestinian socio-cultural context might lie in that the Palestinian community is relatively small and has not progressed as far socially and economically as other communities (Rihan, 1999). Consequently, there is a tendency towards traditionalism in the social and cultural spheres which might be extended and reflected in the individuals' social and cultural values. This tendency is clear for example in students' tendencies towards memorisation and rote learning in schools and universities rather than towards critical thinking or any criticism of what exists. In contrast, these communities bring up individuals to accept entirely the traditional social and cultural heritage and keep them as they are.

However, to what extent can we generalise these socio-cultural features and values to the whole Palestinian context? I think there exist individual and group differences that make it difficult and dangerous to draw such generalisations about Palestinian society, i.e. labelling it as a traditional, conservative, patriarchal and authoritarian society. These claims might be partially true, but they should not be exaggerated. The danger here is to think of them as constant features of the Palestinian or other Arabic and Eastern societies. For example, some academics I interviewed mentioned that there is a tendency in Palestinian society, as a traditional eastern conservative culture, to adopt the product of science without its philosophy. I suppose this way of thinking might represent the view of a sector of society who look with suspicion on any ideas coming from western societies, making it important to study the accompanying historical and political conditions that led to this way of viewing western culture by this group of people.

Another major socio-cultural feature that arises from the findings is the interplay between teachers' religious views and their influence on their views of NOS. Here it should be clarified that the argument is about the influence of teachers' understanding of religion on their views of NOS specifically, and not the influence of religion on teachers generally. The results of my study concerning this issue suggest that the misconceptions teachers hold about the interplay between science and religion, and their naïveté of NOS, are mainly because of their individual and social understanding of the nature of religion and science. It seems, for many of the teachers, there is no separation between religion and other aspects of life, including science. They believe in Islam as a way of life, and do not believe or accept the fact that science and religion are two different ways of knowing; rather they mix them together and make value judgments on them projecting each of them onto the other. In cases when they find conflict between the religious script and scientific claims, such as the evolutionary/creationist debate, they go with the religious script denying the scientific perspective without looking at them as two different ways of knowing that rely on different axioms or sets of rules, where one depends on spiritual faith and cannot be proved experimentally while the other is empirically based.

These findings are consistent with Abd El Khalick and Akerson (2004) who found in their study in the USA that participants who held a belief that science and religion are in conflict with each other did not show progress in their views of NOS, while those who believed that science and religion are two different ways of knowing showed improvement in their views of NOS.

However, though several studies have shown that teachers' socio-cultural beliefs and religious views (sometimes called worldviews[12]) might interact with their views of NOS (e.g., Jegede and Okebukola, 1991; Allen and Crawley, 1998; Dzama and Osborne, 1999; Shumba, 1999; Cobern and Loving, 2000; Abd El Khalick and Akerson, 2004; Halai and McNicholl, 2004; Liu and Lederman, 2007; Mansour, 2007), these studies came out with contradictory findings. For example, Liu and Lederman (2007) found that the participants who held traditional worldviews held sophisticated views of NOS, such as accepting the idea that science is subjective, culturally embedded and has limits. However, Ogunniye et al., (1995) and Shumba (1999) found that non-western teachers who held traditional worldviews were more inclined to have naïve views of NOS. Similarly, Halai and McNichol (2004) found in their comparative study of Pakistani and British teachers' conceptions of NOS that Pakistani Muslim (non-western) teachers could not see science and religion as different types of knowledge and tend to mix them, while their British non-Muslim counterparts could identify the difference between science and religion as different types of knowledge.

At odds with these findings, Haidar (1999) inferred that teachers' sophistication about the tenets of NOS were a result of their religious beliefs about the world that agree with a constructivist view of science. Nevertheless he argued that the traditional views of science are in conflict with teachers' religious beliefs.

Considering the complexity of people's religious beliefs and how they look at religion might create a complex relationship between teachers' views of NOS and their religious beliefs (Abd El Khalick and Akerson, 2004). This relationship depends on the compatibility of teachers' religious views with science, whether they think of them as two different ways of knowing, and

---

[12] Lederman and Liu (2007) define a worldview as a set of values and beliefs held consciously or unconsciously by a group of people about the nature of reality that forms their terms of reference to make sense of the world.

avoiding value judgments about both ways of knowing, or mixing them together comparing and projecting each of them on the other without being aware that the axioms and set of rules that each of them stands on are different from the other which is the case regarding the thinking of some Palestinian teachers (ibid). Considering that Palestinian society is predominantly Islamic, with teachers already holding immovable religious beliefs and assumptions of the world, there is a crucial need to help these teachers organize their religious beliefs with the contemporary NOS to reach a state of "cognitive equilibrium" (Daghir and BouJaoude, 1997).

I support Abd El Khalick and Akerson's (2004) argument that the "discord" between science and religion should be discussed to enable teachers to see them as compatible, without any existence of contradiction between Islam and science as two different ways of knowing with each having its own set of rules. An examination of the history of Islam (Al Hayani, 2005) reveals that Muslims contributed significantly to the discovery and innovations in different spheres of knowledge such as medicine, botany, geology and politics, which indicates the historical compatibility of Islam and science.

5.3.4 Teachers' Personal Values

Science is acknowledged as a human activity reflecting the socio-cultural norms and environmental conditions where it is utilised and practiced. Consequently, as Hodson (1993b) argues, different societies might define and think of science and its endeavours differently due to the discrepancies in their own values and aspirations.

Despite the importance of teachers holding sophisticated conceptions of their disciplines, the academics interviewed in this study indicated that Palestinian science teachers hold some traditional personal values that might explain their current views of NOS. The academics suggested three main personal values that might account in part for teachers' inadequate views of NOS. The first, raised by six academics, was that teachers believe that the knowledge they possess is what gives them their authority and power over their students. Therefore, this knowledge should be accurate, reliable and objective in order to increase their authority and power. According to these academics, teachers believe that they are the carriers and possessors of the "absolute knowledge" whose role is to transfer it to their students. A10 explained teachers' unsophisticated views concerning this issue, and why it is justified from their point of view:

> Teachers feel very afraid and frustrated if they face any question or enquiry from their students that they cannot answer, because this will undermine their power and authority and put them under scrutiny. Consequently they think that they have to possess immediate and true answers to maintain their power. Accordingly, this traditional view of the objective and correct science is justified and helpful for them.

The second personal value teachers hold, raised by seven academics, is their belief that they should behave and teach in a way that is in harmony with the socially and culturally dominant view of science. From the perspective of these academics, Palestinian society is still holding the absolutist myth that science is always accurate, objective and reliable. For that reason:

> Teachers try to give science a huge halo and "sell it" to their students as true, universal and objective facts so as to be accepted by the community with its dominant culture that supports these naïve views of NOS. (A7)

The third personal value, emphasised by nine academics, that plays a major role in shaping teachers' naïve views of NOS relates to how teachers' believe science should mix with religion. Academics indicated that teachers hold a value that science should serve religion and support its arguments. Most teachers hold a view that science teaching should be directed toward "proving" facts, concepts, and any other scientific knowledge mentioned in the Quran. Academics suggested that most teachers hold a belief that all sciences exist within the Quran and that the role of scientists is to discover them. Scientific knowledge is accepted when it fits with the relevant religious script, and is rejected if it contradicts the religious script. These academics argue that this meshing of science and religion creates many misconceptions about science and leads to immature understanding of NOS, as explained by A3 below:

> Combining science with religion in teaching leads to the creation of a naïve view of NOS, especially when teachers try to prove science and support it with relevant scripts from the Quran. This projection of science on religion leads to a lot of troubles concerning NOS as absolute values that are objective, permanent and absolutely true, with no room for imagination, creativity or inference which are the characteristics of religious knowledge .... For example, talking about the subjectivity and biases of science concerning a certain topic with the existence of related knowledge concerning the topic in the Quran will lead teachers to reject the subjectivity of science, or to raise a doubt about it. In such a case, they would believe that science might start being subjective, but at the end it would approach objectivity, and would develop to facts when it fits with the related religious scripts supporting it. The situation gets more dangerous when teachers start explaining a natural science topic as having religious origins.

This quotation implies that the integration of science with religion in teaching can lead to naïve views of NOS on the part of teachers and students.

One can understand these naïve values and personal models of reality (Wandersee et al., 1994) of teachers that lead to naïve understanding of NOS, given that Palestinian society in general is a dominantly authoritarian and patriarchal society (Sharabi, 1985), and which is coupled with the naïve social and religious understanding of science as raised by academics in a previous section.

5.3.5 Teaching Approaches at School and University Levels

The academics shared a view that the current teaching approaches adopted in school and university education support the development of a traditional view of science among the students and teachers for several reasons. For example, eight of the academics mentioned that school and university education is content-focused with almost a total exclusion of the nature of science or its historical development. A5 explained this orientation and the role it performs in creating these naïve views of NOS as follows:

> We Palestinians have a lot of very good professionals in education and other disciplines. Most of them are content oriented who are very knowledgeable and experts in their limited content .... These people do not possess the general cognitive framework or background for matters out of this limited discipline. They even do not have the theoretical or cognitive framework of the contexts they work in. For example, the TV expert is excellent in fixing TVs,

> but it is not necessary that s/he has a scientific view of matters. I cannot distinguish Palestinian medical doctors from other technicians, because these doctors know how to do their work in medicine, but they do not think scientifically and efficiently in other matters out of their specific content.

A6 ascribed this content-based approach to the absence of clear theoretical or philosophical underpinnings of Palestinian education, and to the absence of related courses at the university level of education:

> School and university science teachers hold a naïve view that students who join a pure scientific field such as chemistry or physics do not have to study any topics related to philosophy or history including the philosophy and history of science. What makes the situation worse is that the education system in Palestine is content-based and does not stand on a scientific view that is based on a concrete philosophical framework or a relevant cognitive paradigm.

Academics attributed this content-based approach to the lack of courses concerning the philosophy or history of science in the science faculties in Palestinian universities. A student can easily graduate with a Bachelors degree in any scientific field without studying any course about the philosophy or history of science. On the other hand, in some universities there is a course about the philosophy of science. However this is not mandatory, and so most of the students and teachers avoid registering for it. Consequently, from the point of view of these academics, teachers' shortage of the relevant knowledge about the philosophy and history of science, coupled with their content-based approach to teaching make them deal with the scientific knowledge they put forward to their students as true and absolute facts. They do not provide the students with opportunities to think, reflect, criticize this knowledge, or scrutinise it. A3 comments on this concern:

> Students are rarely taught the contexts of scientific knowledge development, or the paradigms and struggles that accompanied its progress and the changes that have occurred to it over its historical development. Rather, teachers present knowledge as ultimate and true outcomes, leading to rote learning and teaching of science.

However, A7 and A10 explained teachers' resort to indoctrination and giving scientific knowledge a big "halo" because they think the knowledge they have is a main source of their authority and power on the students, so they do not like to explain to their students that the knowledge they have is tentative.

A related problem identified by four academics was the detachment between the teaching approaches utilised in schools and universities and the reality and needs of the community. A7 states,

> There exists no connections between the science being taught and people's lives and their real practices. It is not clear that there are authentic attempts to utilize and dedicate science education to improve the conditions of people's lives.

This detachment between science teaching and people's daily lives is believed to lead to superficial thinking that, in turn, leads to naïve views and understanding of most of the subjects being taught in the formal education, including science. In this context, A10 commented,

> The absence of a suitable paradigm or strategy for modelling science to be transformative and relevant to serve the community and help in its liberation is what reflects this naïve/traditional image of science and science teaching.

The above analysis of academics' responses indicates the transmission, content-based approach to knowledge in school and university science teaching as a possible reason for the naïveté of teachers' views of NOS. It seems there are several factors that exist in school and university teaching approaches that might lead to inadequate views of NOS in the part of the students in both. The stakeholders of this study have shown that most of school and university teachers are content oriented. In other words, they are only concerned to cover the material mentioned in the textbooks as it is. The textbooks they teach do not address the topic of NOS adequately. They are not trained or interested to address NOS while teaching science topics. Some of them do not possess sophisticated views of the topic. For some of them, reflecting a naïve view of NOS is functional to gain the authority and power of science as people who possess this power. Given the existence of these variables and circumstances, one can understand the shortage of tackling the topic in school and university teaching.

It does not seem that universities will be in better position to take this topic into serious consideration in the near future. A recent assessment study of higher education needs in the West Bank and Gaza Strip funded by the United States Agency for International Development (USAID) revealed that the quality of higher education is declining in most Palestinian universities, and that the rates of return to university graduates are either negative or close to zero (Hashweh et al., 2004).

It is worth noting here that I have addressed the effects of school and university teaching approaches as one factor because I think teaching approaches in both are almost similar, and also because students who finish their school education go to university education, then after graduation they return back to teach in schools, so education in schools and universities affect each other and cannot be separated especially in modelling students' beliefs and views. I personally, as a Palestinian school and university graduate, have not noticed any difference or change in addressing this topic in my school and university level education.

5.3.6 Teacher Training Programmes

Many countries rely on their pre- and in-service teacher training to ensure a quality of teaching workforce who can be influential and effective in the development and improvement of school education and students' achievement. In Palestine, teacher preparation and training was given priority by MoEHE in its first and second five year development plans for 2001-2005 and 2008-2012 respectively. The aim was to prepare and qualify teachers who are committed to their students, and ensure they possess general knowledge and subject matter knowledge, think critically and systematically about their practices and bear the responsibility for guiding their students' learning (Hashweh et al., 2008). Refer to Chapter 1 for the history and nature of teacher training in Palestine.

In this section I present and discuss the views of the stakeholders on the teacher training programmes, the potential role they play in influencing teachers' views and understanding of NOS, and the extent to which these programmes present NOS in an appropriate way at the pre- and in-service levels.

Academics expressed their dissatisfaction with teacher training programmes at both the pre- and in-service levels, as can exemplified by A9 who is an associate professor in science education, and a lecturer in a teacher preparation program at a Palestinian university. He was also the coordinator of the Teacher Education Strategy in Palestine that was conducted and supported by UNESCO in 2008 to improve teacher education in Palestine (Hashweh et al., 2008):

> Current teacher training preparation programmes are very traditional, and let me say, ineffective in general. Their focus is mainly on the theoretical aspects of the teaching/learning process with significant ignorance of the reality of teaching in actual classroom settings ... To date I do not know of any solid programme that has been designed with a clear educational vision and goals for teacher preparation ... Concerning NOS in teacher training programmes, to the best of my knowledge, I can say this topic is almost nonexistent.

Academics shared the view that pre-service teacher training programmes are very weak, and do not give NOS enough attention. Seven of the academics stated that pre-service teacher training in the universities focuses on science teaching methods and the implementation of the school science curricula, almost totally ignoring the nature of the subject itself. A4 commented on this issue that pre-service students do not have a chance to conduct activities or laboratory experiments that provoke questions or real problems that would improve their understanding of NOS. A4 went further in his criticism to say:

> Pre-service teacher training programmes are built of heavy pre-cooked "prescriptions" with a stepwise procedure that is taught to prospective teachers to use in every aspect of their teaching process. Therefore even if these "prescriptions" contain some elements concerning NOS, teachers will not teach them in a proper way that reflect NOS, rather they will teach them the same as they teach other pieces of the science content. Accordingly, their students will study such material the same as any other parts where they try to memorise it for the exam without thinking deeply about it or its purpose in relation to NOS.

According to these seven academics, pre-service teacher training programmes lack specialised courses about the philosophy and history of science or the nature of science. A1, A4 and A5 mentioned that there is only one optional course in some universities, but the uptake is very low so it is rarely taught.

These findings regarding teacher education related to NOS in Palestine do not appear to be in conflict with the international perspective. According to Loving (1991) and Gallagher (1991), most of the teacher preparation programmes do not impose or require a compulsory course in history and philosophy of science. While there are some research initiatives to explore the success of initiatives to develop prospective teachers' understanding of NOS (Abd El Khalick, 2005; McCarthy, Sorenson and Newton, 2010), there has not been a widespread implementation of the teaching of NOS embedded in teacher preparation programmes. In addition, separate courses on NOS in teacher education are also not common place internationally (Loving, 1991).

Concerning the in-service teacher training programmes offered by MoEHE, academics shared a view that these programmes are not influential in addressing this topic. To the best of their knowledge they do not know of any training programme that has been conducted with the aim to explore or improve teachers' views of NOS. Four of the academics said that they do not know of any teacher trainers who are qualified to train teachers on this issue. Five academics believed that most of the teacher trainers in MoEHE do not hold informed views of NOS. These academics contended that in-service teacher programmes are content-based, as exemplified by the statement that "*their main aim is to train teachers on implementing the curriculum, without dealing with issues related to NOS*" (A5).

Three of the academics attributed the absence of NOS in in-service teacher training programmes partially to the fact that teacher training is attached to the funding offered by foreign donors to the Ministry who impose their agenda on the training and what should be taught. This claim is clear in the following statement by A7:

> It's who pays the musical band who decides what they sing, I mean it seems that the donors who pay for teacher training in Palestine

> do not want Palestinian people to be well literate in these issues or have a deep understanding of NOS that would enable them to be critical thinkers of everything around them that would be harmful to the stabilisation of the educational and political regimes.

Following the interviews with the academics, two in-service teacher trainers were interviewed to shed light on what is being done towards addressing NOS within the training courses offered to school teachers by the Ministry, and to support and triangulate the findings obtained from the academics. One of them (TT1) was the director of in-service science teacher training in MoEHE, and the other was the director of teacher training in the Education Directorate Office of Qalqielya (TT2). The perspective of the Ministry is clear in this quote from TT1:

> Our policy in the Ministry is to train school teachers in areas where there is a heavy need for training. We do not think that there is a need to conduct a training course on NOS as an independent subject. Our priority in training is on areas related to the basic teaching strategies, the content of the textbooks and classroom management as crucial aspects that are of most concern to us.

As explained by TT1, to date the Ministry has not conducted any training concerning NOS, and has no plans to. TT1 made it clear that *"we do not have any specialised training materials for this topic in the Ministry"*. TT1 stated that teachers believe they do not need training in NOS, as revealed by a needs assessment questionnaire distributed by the Ministry. He acknowledged that he himself does not know much about NOS. He asked me to explain to him the meaning of NOS and its importance for teachers. While he said he was convinced by my explanation, he recognised the difficulties:

> I am not sure if we can find some qualified trainers who can do the job properly for us if we decide to include this topic in our training agenda for the future.

Another concern he raised was that some of the training courses and workshops are funded by external donors whose donations are conditional to the teaching of specific topics. He was unsure whether donors could be persuaded to support this topic.

In the second interview TT2 ascribed the current naïve views of NOS held by teachers to the Ministry's policy of training that does not give this topic enough attention. TT2 stated he is aware of the importance of this topic for successful science education. He holds a Bachelors degree in biology education from a well known teacher preparation college in Algeria. His responses indicated that he holds an informed view of NOS. When asked why he did not conduct any training on NOS, although he was aware of its importance, he answered:

> In-service teacher training is very deeply centralized, I mean the training subjects and topics come from the Ministry. The responsible people in the Ministry assume that they are aware of teachers' needs in training. Sadly, they do not consider the teaching of NOS as a primary goal for training. They are more concerned about training teachers how to implement the curriculum and manage the classrooms.

According to TT2, as long as the focus of the educational leadership, the supervisory system and teacher training remains on the coverage the content of textbooks, there will not be much hope that topics such as NOS will be taken into consideration in the near future, because the textbooks either ignore the topic or present it erroneously.

As indicated from the above analysis of academics' and teacher trainers' responses, it appears that teacher training programmes at the pre- and in-service levels are not successful in addressing the topic of NOS properly, or efficient in promoting teachers' views of this topic. It seems that this topic is not given enough attention or focus in the pre-service teacher education programmes run by Palestinian universities. I have had a cursory look at the course outlines of the different undergraduate teacher training programmes offered by the twelve universities we have in the West Bank of Palestine (although this was beyond the brief of my formal research). I did not find any compulsory course that is designed exclusively around this topic. However, the majority of the course outlines do include a section on NOS in the science methodology modules. However, the responses of two academics suggest that this section is not addressed. My experience in teacher education support this view.

Similarly, my findings suggest that in-service teacher training programmes do not pay any attention to this topic. The lack of knowledge and understanding of the topic by the director of the in-service science teacher training unit in MoEHE, the lack of qualified trainers or training materials on the topic, and the absence of this topic from the Ministry's agendas for current or future plans for training are evidence of the failure of in-service teacher training programmes to address the topic properly.

Again, these findings regarding in-service teacher education related to NOS in Palestine do not appear to be in conflict with the international perspective. My time spent in England has led me to understand that it is not necessarily the case that Western countries are in a better position or in a perfect position in this regard. For example, certain teacher educators have no further training than the training they receive to come a teacher.

It seems unlikely that teacher training programmes will be developed in this area in the near future as those managing teacher training are not aware of the topic or its importance for school education. As a result, they will not give it enough attention; rather they think that it's the responsibility of the universities who should qualify prospective teachers in the topic before they enrol in teaching with the Ministry. This mentality held by the decision makers, coupled with the rigid centralised system in which the Ministry operates, makes the chances to work on this topic very difficult for other responsible people such as teacher supervisors or teacher trainers who might be knowledgeable and keen to work on the topic.

Nevertheless, I have to acknowledge that I do not support the claim that all foreign donors to the MoEHE have a hidden agenda and refuse to fund projects that address topics that might promote the reflective thinking of Palestinian citizens about issues such as NOS. I do believe that this perspective has originated from a long history of mistrust by a group of Palestinians who look with suspicious to any financial funding coming from the West due to the political conditions, and the generalisation of certain cases where the fund was directed exclusively towards projects that support the enculturation between the Palestinians and Israelis that some

Palestinians including academics are against. That's may be why they generalise across all projects.

My final reflection on findings related to teacher education programmes concerns the position of these academics within the problem. They have highlighted several problems and yet none has mentioned why they have not had any success in this area. Are they in fact, part of the problem?

5.3.7 Educational Supervision

This involves a continuous progressive process carried out by specialised educationalists who work with teachers with the aim to improve teachers' abilities and talents and to assist them to solve any troubles they might face in their teaching (Beach and Reinhartz, 1989). These specialised educationalists are usually appointed by the ministry of education to visit school teachers regularly to monitor their work and progress, and to provide them with any support they need (Sergiovani and Starratt, 1988). After the Palestinians took responsibility for education from the Israelis in 1993 and established the first Palestinian Ministry of Education, they prioritised the improvement of educational supervision by providing the educational supervisors with relevant training courses (MoEHE, 1998). Each educational supervisor was granted 90 training hours on academic supervision by experts in the field, and provided with suitable supporting materials and documents concerning the content and pedagogy of their subject (ibid).

An analysis and discussion of academics' views on a possible relationship between educational supervision and teachers' understanding of NOS follows. Despite the increased attention given by MoEHE to educational supervision, nine of the academics referred to it as a possible reason for teachers' traditional views of NOS. They think that most supervisors fail in their role because most do not hold any formal qualification in educational supervision: "*To date, there is no qualification to be an educational supervisor*" (A8). Six of the academics consider that supervisors regard their main task when they go for supervisory visits as checking that teachers cover the content of the text exactly as it is formulated in the textbook. These academics said they can understand the traditional behaviour of teachers and their ignorance of NOS. This is because textbooks do not include NOS, except in a short chapter in Year 9. Supervisors feel that it is not their responsibility to focus on such a topic when the curriculum is based on the content of the textbook. Another issue that these academics raised was that they think that supervisors might not have informed views of NOS, as A9 explains:

> There is nothing to make us assume they [supervisors] are different from other teachers who hold naïve views of NOS, because the only criterion for supervisors' selection for the job is having five years of teaching experience in schools. You do not even have to hold a teaching qualification to be a supervisor.

In a similar manner, A8 worked as an educational supervisor for ten years after he got his Bachelors degree in Physics, prior to travelling to the United States for a PhD in science education. He then came back to work as an assistant professor in an education college in one of the universities in the West Bank. The following quotation by A8, as a person who lived the reality of the supervisory system, sheds further light on this situation:

> Educational supervision is still without any precise identity, which determines its responsibility. It has yet to achieve what it was intended to, because of the very traditional and unorganised approach in its plans and practices. So we cannot expect from such a poor supervisory system to give priority, or take care of NOS when the supervisors themselves, I am afraid, do not have the minimum adequate understanding of it .... I am afraid that a lot of our current supervisors will not be happy to see one of their teachers adopting and reflecting contemporary views of NOS in his/her teaching because these views are against what they believe and know about NOS, or [laughing] because they will not understand what is going on in the class.

In essence, academics did not believe supervisors were in a position to address the naïve views teachers hold of NOS.

Following the interviews of academics, two education supervisors were interviewed to explore their role related to NOS. I found that both supervisors hold traditional views of NOS. When I asked S1 about his conceptions of NOS, he replied, "*NOS are facts, laws, concepts, theories and natural phenomena we learn and explain to our students, and try to use in our daily life*". He regards theories and laws to be absolute because "*they are proven explicitly in the textbooks*". In response to my question concerning her understanding NOS, S2 said:

> As long as all the scientific knowledge exist in the textbooks and we have access to it at any time we want, we do not have to know much about its nature. As supervisors our main focus is on the content of knowledge not its nature, which to be honest, I do not have a clear idea about, though I do not feel of a huge necessity to know about either.

They both emphasized that they do not consider NOS as a core part of their supervisory process because it is not important and they were not trained how to address it. They both expressed their satisfaction with supervision having a content-based focus. S2 stated,

> Our main task is to follow up teachers' work and make sure that they cover each part of the textbook on time as scheduled in the annual plan, and to check that they provide the students with correct scientific knowledge and information.

Concerning the chapter about NOS in Year 9 textbook, S1 said he cannot see any difference between it and any other piece of scientific content in the way it should be taught. According to him, NOS should be taught as any other piece of scientific knowledge. In contrast, S2's view was that this topic is more related to education or philosophy which, in her view, is not necessary. She said she does not like that chapter, so that when she visits schools, she tries to avoid observing lessons when teachers are dealing with this chapter: "*I prefer to attend classes when I can see real and concrete science and scientific knowledge*".

This attitude of supervisors was corroborated by T12 when interviewed to explore his views of NOS. He was found to hold sophisticated views of NOS taught about NOS by adopting an explicit reflective approach. T12 told me that an education supervisor got angry when he observed him teaching Year 10 about NOS in a Biology lesson about the cell. From the supervisor's perspective, NOS should only be taught in the chapter that is devoted to this topic in the Year 9 textbook. He asked him to repeat the lesson he taught again without any exposure to NOS in any part of the lesson.

In light of the above analysis of the academics' and education supervisors' responses, it might be suggested that the current supervisory system hampers the development of informed and contemporary views of NOS among teachers and learners. The expertise, understandings, beliefs and practices of the supervisors appear to reinforce teachers' traditional views of science.

These findings are consistent with previous related studies conducted on the Palestinian supervisory system and supervisors' work which identified several gaps and troubles in the supervisory system and supervisors' work in Palestine (Odwan, 2000; Khaldi, 2004). This lack of formal qualifications of education supervisors might be explained by the absence of related policies in MoEHE that require such qualifications as a condition for hiring people for this job. The absence of a specialised programme in education supervision in Palestinian universities might also explain the lack of supervisors' qualifications in supervision. However, I have to acknowledge that I am not aware of the situation (the qualifying of supervisors) being that different in other countries. My time spent in England and conversations I have had with colleagues from different countries led me believe that there is no formal qualification specifically for supervisors in many countries, including UK, Australia, United States and South Africa.

5.3.8 School Resources

A teacher, the students, a curriculum and an educational environment can be considered as the core components of a formal teaching process. School provisions and logistics such as laboratories, computer workshops connected to the internet, resource rooms, etc. shape an important aspect of the educational environment that helps teachers and students to play their roles efficiently. In general, Palestinian public schools are very poor in terms of provisions and logistics (Hashweh, Khaldi and Mas'ad, 2004). Many schools all over the country lack resource rooms, laboratories and the basic equipment and materials required to teach science effectively (ibid). This shortage in provisions is due to the poor funding of schools, particularly because these schools were run by the Israeli Civil

Administration until 1994 and were deprived of enough support or concern from the Israeli Government (Khaldi and Wahbeh, 2000). See Chapter 1 for the historical development of the educational system in Palestine.

Five of the academics highlighted the poor school provisions and logistics as a reason that might partially explain teachers' naïve views of NOS. Their view is that a rich environment and abundance of relevant equipment would enable teachers to manipulate and conduct any activity or experiment that might help explain NOS, as was explained by A5:

> In a rich teaching environment, teachers might have a chance to explore some of the NOS tenets such as the nature of observation from related laboratory activities they can do with their students.

A4, who has taught a course about technology and media in education for several years and is currently in charge of the Media of Education Centre in a teacher training programme in one of the Palestinian universities, justified the necessity for such rich facilities and provisions:

> In cases where schools are well equipped and have the necessary raw materials and instruments teachers might adopt problem solving approaches from the problems of everyday life they and their students experience and suffer from, such as water pollution in their local area. They might plan to measure it, define its reasons, and try to propose some approaches to decrease it, and try then to see how feasible these approaches are. Through such an activity they would find that there is no such stepwise "scientific method". They might live the reality of being creative, imaginative, and inferential. They would also have a real chance to differentiate between observation and inference.

A5 supported A4's view of the importance of resources and added:

> A rich teaching environment might encourage keen teachers to imitate scientists in their work utilizing suitable activities that would give them a chance to live scientists' work and scientific knowledge development mechanisms in reality, which would reflect sophisticated views of NOS on their part and their students.

However, A3 stressed more the necessity for qualified human resources (teachers) who can utilise these facilities effectively. He deems that any facilities or rich provisions will not be useful or influential without having a teacher with already informed views of NOS, who utilizes the laboratories and other provisions for suitable activities that were carefully planned for the purpose of improving students' understanding of NOS.

Although half of the stakeholders regarded the poor teaching environment and lack equipment as a contributing factor for teachers' inadequate views of NOS, I share the opinion of A3 above. Even with the existence of a well-resourced teaching environment, the problems will not be addressed unless teachers hold informed views of NOS and the teaching of it. Conversely, I would argue that having a qualified teacher with adequate views of NOS and a curriculum that addresses NOS can be effective even without access to well equipped science laboratories. However, I can concur with the views of the interviewees in this study that it appears that the Palestinian school system is problematic in relation to NOS in three of the areas mentioned above: curriculum, teachers and teaching resources.

5.4 Summary

This chapter has presented an analysis and discussion of the possible reasons and underpinnings that might explain the nature and context of Palestinian science teachers' views of NOS from the point of view of Palestinian academics. It has discussed the possible factors responsible for the apparent inadequacy in teachers' views of NOS that the research has revealed, as seen by Palestinian academics.

The analysis revealed eight main areas academics identified as contributing to the naïveté in teachers' views of this topic. The first area was the teaching of the science curriculum with the textbook as the only instructional resource that teachers use. These textbooks, according to the academics, are content-based and present the final products of scientific knowledge. In addition, NOS as a theme was ignored within the new Palestinian curriculum when the textbooks were developed, and authors were not trained on how to deal with this topic in the design of these textbooks. The negative role these textbooks play is regarded as huge because of the heavy reliance of teachers on these textbooks in their teaching, and the use of them as the sole resource for developing curriculum, coupled with their belief and confidence in the validity and reliability of these textbooks as the absolute source of "true" knowledge, which they have to follow.

The second area was the structure and policies of the education system in Palestine. Three main issues were stressed in this regard. These were the deeply centralised hierarchical and bureaucratic structure of MoEHE with its main concern being knowledge as a product, the non-qualified and non-professional education leadership who occupy the high positions in the Ministry at the decision-making level which hampers the work, and the belief in the existence of a "hidden curriculum" that attempts to prevent the improvement of individuals' scientific literacy or criticality that might threaten the educational and political regimes who rule the country.

The Palestinian socio-cultural background was the third and most prominent area of the discussion. Three main aspects were confirmed in this regard: The first aspect was that the Palestinian cultural background and the way individuals are brought up in an authoritarian and patriarchical culture, which hampers any sort of critical thinking, coupled with a general belief in the existence of one source of knowledge that is accurate and permanent. The second was the general cultural tendency to import the final outcome of science from western civilisation without importing the philosophy of science or NOS, too. The third aspect was related to the social religious understanding of science, especially people's tendency to compare scientific knowledge and religious knowledge with an aim to "proving" religion through science, or vice versa.

The fourth area noted by academics that explains the research findings was teachers' own personal values that their knowledge is what grants them power and authority, so this knowledge should be accurate, constant and objective. They hold another value that they have a religious commitment to do their best while teaching to "prove" religion via related scientific evidence that corroborates related knowledge narrated in the holy books. They also believe that they should behave and teach in congruence with the social and cultural values and norms of the society which are naïve in regard to NOS.

Teaching approaches of science at school and university levels was the fifth area to explain teachers' inadequate understanding of NOS. Teaching in schools and universities is content-based, focussing on science as a body of knowledge, detached from students' and teachers' needs and everyday life, and lacks information about the philosophical underpinnings of the knowledge taught or its historical development. Teachers generally deal with the scientific knowledge as "true" and constant. They do not provide opportunities for students' reflection or questioning of the knowledge.

Teacher training programmes was the sixth area of discussion. These programmes at the pre- and in-service levels are content-based and lack any focus on NOS, the philosophy or the history of science. In-service teacher trainers and other responsible people in the Ministry are not qualified or concerned about training teachers on this topic.

The seventh area was the educational supervision. Supervisors are not in a position to address the superficial views that teachers hold of NOS. Their main interest is to inspect the coverage by teachers of the content of the textbooks within the allotted time frame. Supervisors generally are not professionally qualified for their role, or to help teachers improve their understanding of NOS. Rather, most of the supervisors seem to hold naïve views of NOS.

The eighth and final area discussed was school resources. Most of the schools are not well-funded nor do they have the necessary resources and facilities to enable teachers to address the curriculum in a practical and problem-based way, allowing for an understanding of the processes and nature of science to be developed.

The findings of each of the above eight areas were followed by a discussion and evaluation from the point of view of the researcher, who has extensive experience within the education system and a deep understanding of the socio-cultural context of Palestine. The findings of each area were linked to the related literature and put in their related regional and international contexts (where possible).

In the next chapter, academics' opinions on possible ways to address the problems related to teachers' outdated views of the nature of science are explained and discussed.

Chapter Six—Research Findings: Possible Strategies to Improve Teachers' Views of NOS

6.1 Introduction

Having considered and discussed in Chapter 5 the possible reasons behind teachers' uninformed views of NOS, and identified possible factors responsible for this apparent naïveté across the sample of Palestinian science teachers, this chapter presents, analyses and discusses academics' suggestions of possible ways to improve Palestinian science teachers' views of NOS. The perspectives on the factors within the Palestinian context that might either facilitate or hamper efforts to promote teachers' understanding of the nature of science are also reported and discussed. This chapter seeks to provide an answer for the third research question: What views do Palestinian science education stakeholders hold regarding the advancement of science teachers' views of NOS?

6.2 Promoting Teachers' Views of NOS

This section presents academics' views of the possible ways to advance teachers' understanding of NOS. Academics' responses to the semi-structured interview (Appendix 5) were transcribed, coded, and collapsed into categories and sub-categories. As was explained in Section 5.3 of Chapter 5, the coding of the data involved processing detailed information contained in the participants' responses in light of four main themes used as a general framework for the analysis process. Three of these themes are relevant to the third research question:

1) improving teachers' views of NOS;
2) factors supporting the development of teachers' views of NOS;
3) factors hampering the development of teachers' views of NOS.

The coding and categorisation of the responses led to the creation of a number of categories and sub-categories that allowed for a clear and structured description of the data, and facilitated the data analysis and drawing of conclusions. Six main categories of possible approaches recommended by the stakeholders to improve teachers' views of NOS emerged from the data and are presented here in random order:

1) Tertiary science teaching and teacher preparation programmes;
2) Teaching as a well-resourced profession;
3) Palestinian science textbooks;
4) Education supervision and in-service teacher training;
5) Educational leadership and the administration system;
6) Public scientific literacy and critical social awareness.

6.2.1 Tertiary Science Teaching and Teacher Preparation Programmes

All academics stressed that Palestinian universities could play a crucial role towards the development of teachers' views of NOS. Universities, they believe, should improve their undergraduate teaching of science in general, and their teacher preparation programmes in particular, to enable them to participate effectively in enhancing prospective teachers' views of NOS.

Improving Tertiary Science Education

The academics stressed the necessity of training the scientists who teach different science courses (physics, chemistry, biology, etc.) in Palestinian universities in order to improve their understanding of NOS, and to qualify them on reflecting contemporary views of NOS as part of their teaching in all the subjects they teach. This issue was explained by A5 who is an assistant professor of physics education in a Palestinian university:

> I am afraid our scientists who teach in science colleges do not possess adequate views of NOS. So, we need a series of workshops and seminars that include relevant practical activities to improve their understanding of NOS. We also need to make a lot of effort to convince them, and teach them to include NOS as part of their teaching, i.e. to teach the subject content as well as the historical development of the subject.

A1 said that universities should impose clear policies that encourage their teachers to research and publish on this topic, such as providing funds for such research, or counting publications on NOS towards a teacher's academic promotion, as happens with publications in the discipline.

Eight of the academics stressed for the need to impose a compulsory course on the philosophy and nature of science for undergraduate science students at colleges. A8, who is a professor in the philosophy of science and the head of the philosophy and cultural studies faculty in a Palestinian university, commented:

> We need such a core course for all students to enhance our students' scientific literacy and critical reflexivity .... I would argue that we need such a course for all undergraduate students, and not only for science students. This course should be prepared and taught properly by very well qualified academic staff.

Seven of the academics mentioned the need to reform the assessment process in the universities. Three of them called for adopting take-home exams that are of open-ended nature and research-based. A2 justified this by saying:

> This approach to assessment will promote the criticality and reflective thinking of the students, and would compel them to read more and search for the possible solutions that will improve their understanding of NOS.

Another group of two academics considered that there is a need for a policy to be imposed on the scientists who teach in science colleges to include some questions about NOS in the exams they carry out to measure their students' achievement. A8 mentioned that *"the current assessment of students' achievement is only focused on content with almost total ignorance of NOS in most of the courses being taught in the University"*.

Improving the Teacher Preparation Programmes

All academics appealed for improving the quality of teacher preparation programmes in Palestinian universities. Six of the academics shared the view that policies need to be generated in the universities and MoEHE to improve the academic quality of students entering these programmes to become school teachers. From the perspective of these six academics, mainly academically weak students seem to enter the field of teaching when they fail to find other options, since the standards for acceptance by the teacher preparation programmes and education colleges tend to be the lowest of the university programmes. Thus, from their perspective, there is a need to raise the standards for accepting students into these programmes and to "*provide incentives and scholarships to motivate outstanding students to join this field*" (A9).

Two of the academics suggested a need to create a partnership between the universities, MoEHE and other non-governmental educational institutions in order to facilitate collaboration in the development and implementation of a clear and shared philosophy and strategy related to teacher preparation. This, they believed, would positively contribute to the improvement of teachers' views of NOS, because in each of the three areas (universities, MoEHE and non-governmental educational institutions) there exist professionals who are interested in this topic. A9 explained the significance of such joint work for advancing effective teacher preparation:

> A collaborative effort of selected professionals from the universities, MoEHE and the civil society will be very influential due to the diverse knowledge and expertise each of them holds concerning teacher preparation. Consequently, such cooperation and exchange of experience between these workers in the field of teacher preparation will be very fruitful.

A9 further justified such cooperation by explaining that the university staff are strong on theoretical issues, while people from MoEHE know the reality and flaws in teacher preparation because of their everyday contact with teachers and schools. In addition, professionals from civil society and non-governmental organizations are very helpful in the flexibility they might provide for the cooperative work, as they are free from bureaucratic procedures that might exist in universities or the Ministry. He suggested that they are more sensitive to teachers' needs because teachers trust them and talk freely to them about their problems.

Interestingly, four of the academics recommended that there is a need to revise the structure and content of science teacher preparation programmes starting from an assumption that these prospective teachers have outdated views of NOS. Consequently, one of the prominent tasks for the programme would be to induce a conceptual change in participants' views of NOS. These academics suggested several approaches that might be adopted in these programmes to achieve this. Three of them emphasized the positive role of action research in this regard. For example, one academic suggested that a "change by practice" approach using selected activities from relevant action research projects would be beneficial. The following quotation by A9 provides an explanation of this call:

> We [academics in teacher preparation programmes] need to work with our students and other interested in-service teachers side by side in collaborative action research, where we can plan together and conduct significant activities that explain NOS. We can also develop a joint culture of looking critically at what we teach and learn, and to question things and develop the spirit of positive criticism of issues. This way we can improve the capability to teach about the nature of science while teaching the science itself.

In this respect, A10 stressed the need to put the student teachers in authentic instructional contexts, and to provide them with a foundation to teach NOS effectively. A10 mentioned the requirement that the participants in these programmes need to possess a rigorous knowledge of content in their disciplines. He argues that "*teachers will not be able to teach about NOS effectively unless they possess a strong background in the field they teach coupled with a sophisticated understanding of NOS*". This view has a strong support in the literature (e.g., El Muhtaseb, 1994; McCarthy and Youens, 2005; Hashweh et al., 2008).

These findings concerning academics' suggestions for improving teacher preparation programmes is consistent, at a general level, with the results of a teacher education strategy project for Palestine funded by UNESCO and conducted by a group of Palestinian academics (Hashweh et al., 2008). They offered a holistic national teacher education strategy to update and improve the current teacher preparation programmes in Palestinian universities in order to fit with the contemporary international trends in teacher education. The strategy included a vision for teachers, teacher education programmes, continuing professional development programmes, teaching profession and managing the teacher education system.

This analysis suggests that the academics were very insightful in their ideas and suggestions for improving teacher preparation programmes in Palestinian universities. This is probably because most are involved in these programmes and so have the confidence and depth of understanding that comes with experience. Interestingly, although all the academics raised the need to reform teacher preparation programmes and to give special attention to NOS, they looked at the possible improvements from different perspectives highlighting different areas for development. I believe that no single suggestion could solve this complex issue. Rather, I propose that all of these recommendations have merit and could contribute to the development of a holistic vision for teacher preparation programmes that addresses NOS in an effective and meaningful way.

This standpoint is underpinned by the following question: If the stakeholders in this study have identified several problems related to NOS within teacher preparation programmes, and made many recommendations to address these issues, why they and others have not taken practical steps to implement some or all of these suggestions? They are the exact people who are involved in teacher training and are therefore surely in a position to take action? Simply put, I am afraid if it was easy it would have been done. It would have been done in Palestine and it would have been done in other countries. Similar recommendations can be identified in the literature: make NOS explicit in teacher education programmes; prepare teacher trainers and supervisors; run specialised courses about NOS at the undergraduate/postgraduate levels. What is not in the literature are ideas about how to do these things. What should a teacher education module on NOS look like? How, specifically, should NOS and science content be effectively integrated? I would argue that one of the most challenging roles of any science educator is to develop an effective curriculum package at any school or university teaching level to be developing in students an informed and sophisticated understanding of NOS. I contend that few people in Palestine and even internationally have got the knowledge, insights and range of skills required to achieve this aim. The implications of this claim will be explored in Chapter 7.

As seen from academics' opinions and recommendations on tertiary science education and teacher preparation programmes, they assert that teaching about NOS in parallel with teaching the content knowledge would be helpful in promoting prospective teachers' understanding of science. My view is that this seems a worthwhile but ambitious recommendation. However it requires teacher educators who hold sophisticated views of NOS and are qualified to teach about it. Another requirement for this vision is teacher education curricula that include NOS, which is not the case at present. These drawbacks lead me to believe that the more practical starting point would be a compulsory undergraduate course on the philosophy and nature of science, and then to follow with teacher preparation programmes when curriculum changes and human resources are in place.

I think developing a specialized and robust course about the philosophy and nature of science, as some of the stakeholders in this study have recommended, will be very effective and practical, especially if imposed on all undergraduate students as a compulsory course. Research conducted in this area shows that a specialized course on the philosophy of science was effective in promoting students' views of science (Billeh and Hasan, 1975; Matthews, 1994; Shapiro, 1996; Abd El Khalick, 1998; Abd El Khalick and Lederman, 2000a; Khishfe and Abd El Khalick, 2002; Abd El Khalick and Akerson, 2004; Abd El Khalick, 2005; Abd El Khalick and Akerson, 2009; Wahbeh, 2009).

For example, Wahbeh's (2009) study results, which was conducted in the same geographical, cultural and educational settings of this study, strongly support this approach. Wahbeh conducted an experimental study to assess the influence of an explicit-reflective instructional approach on school science teachers' understandings of NOS. The study utilised a pre-test, post-test single-group design to assess the impact of the intervention on participants' understandings of NOS. In part of his study, Wahbeh, offered a cohort of 19 science teachers with a series of workshops and training on promoting their understanding of NOS for 36 hours spread over six weeks. His findings indicated a significant improvement in the conceptions and understanding of NOS of almost all participants. However, it is worth noting that his findings showed that the most frequent challenges faced by participants while addressing NOS in their teaching were related to the depth of their NOS conceptions. The researcher ascribed these challenges to participants' lack of the necessary PCK related to NOS.

6.2.2 Teaching as a Well-Resourced Profession

Eight of the academics shared the view for the need to improve the status of the teaching profession, and to increase teachers' salaries and improve their working conditions. A9 commented that, "*there is a need to increase the attractiveness of the teaching profession in comparison with other professions*". Five of the academics pointed out the unfortunate fact that, due to their low salaries, most male teachers are compelled to find part time jobs for supplementary income. It was suggested that teachers often become menial labourers in construction, which further drains the physical and creative energy needed for the classroom. The need to find additional income leaves no time for teachers to reflect seriously on their teaching process, and negatively affects their commitment to their teaching and their desire for professional development:

> When teachers get reasonable salaries that cover their expenses, they will be more committed to their profession, and they will have enough time to read more about the topics they teach. They will also look for continuous professional development of their teaching that would certainly positively affect their views of NOS, at least in the long run. (A10)

Academics also appealed to the decision makers in MoEHE and other policy makers to raise the status of the teaching profession so that students who are outstanding and academically strong will be encouraged to join the profession and take responsibility for improving teaching, including the teaching of NOS. A9 commented on this issue:

> There is a great need to improve the status and conditions of the teaching profession because most of the teachers, especially the male ones, are not satisfied with their social status as school teachers due to their low salaries. This dissuades parents from encouraging their children, especially the males, to choose teaching as a future profession.

On a related issue, four of the academics indicated the need to improve teachers' working conditions, including the provisions and facilities in schools, such as well equipped laboratories, chemicals and other necessary raw materials and equipment, as well as computers connected to the internet. A3 explained the importance of a well-resourced environment for teaching NOS:

> Having access to a rich environment, teachers can teach more effectively about NOS utilizing related laboratory experiments and other related hands-on activities. For example, they can conduct the flagstone experiment of Lafawazieh that is very helpful in explaining a lot about NOS if planned and conducted properly.

According to these academics, the availability of adequate resources and working conditions will help teachers to plan and conduct any practical activities or simulations that might be helpful in explaining NOS, and would improve teachers' and students' understanding of the topic.

I argued in Section 6.2.1 that teaching mainly attracts lower qualified students because it does not compete well with other professions open to science graduates. Enhancing the teaching profession by improving teachers' living and working conditions, as recommended by academics, is likely to encourage the higher qualified and outstanding students to enrol in teacher training. This is likely to have a positive impact on the quality of teaching and learning, including of NOS. While this initiative would require extensive funding, it does seem a crucial step for the improvement of the quality of education in Palestine in general, and within the area of NOS specifically. Teachers who feel valued and support are likely to feel committed to their profession and to improving their own professional development.

6.2.3 Palestinian Science Textbooks

All academics emphasized the need to reconsider the Palestinian science textbooks as exemplified by A2 who made it clear that, "*restructuring the textbooks to address the topic of NOS properly is the right baseline we have to start from to guarantee successful progress towards improving our poor textbooks*". According to the academics, many improvements are needed so that textbooks reflect a contemporary view of NOS. They expressed their opinion for the need to reorganize the textbooks in a way that addresses NOS explicitly in each chapter. Texts should be enriched with suitable activities and hands-on applications that explain and interpret all aspects of NOS. A10 stated:

> These activities should be linked to students' and teachers' everyday lives and needs, and should stem from the country's history and its social and cultural heritage.

In this regard, A3 pointed out the need to teach science topics in an integrated manner merging chemistry, physics, biology and earth science together in a workable situation and linking them with students' everyday life through a Science, Technology and Society (STS) approach. He believed that this would promote the scientific literacy of teachers and students, which in turn would improve their understanding of NOS.

A3 recommended collaboration between all science teachers within a school in teaching various science topics:

> This team teaching approach will provide valuable chances for teachers to exchange ideas about the topics being taught, and for students to share different views of the same topic that would provide space for rich discussion on the topics in order to improve the critical thinking of teachers and students.

Furthermore, six of the participants raised the issue that teachers need to be provided with respectable teacher guides that provide them with suitable procedures and mechanisms that enable them to present and teach science and explain its nature side by side. Interestingly, A2 and A5[13] suggested a similar holistic and detailed mechanism that they believe will be efficient to reform the current science curriculum to reflect a modern view of NOS and help teachers teach it properly. A2 is an expert in curriculum development, and was the leader of the new Palestinian Curricula Development Centre that was established immediately after Palestinians took the responsibility on education from the Israelis in 1993. The strategy I am quoting from her is based on a big project she led on the whole Palestinian curricula design, where she translated the model she

[13] A5 was a student of A2 during his Masters and PhD, and has subsequently worked with her.

used on the textbooks design to NOS. Her background could explain why she was able to make such detailed suggestions within an interview context. Below is a description of this strategy, as explained by A2:

> We have to start contacting the experts on this topic from the universities, MoEHE and other related national educational institutions to form a steering committee of eight experts and a coordinator who develop a clear vision and build the broad groundwork. Then, each of these will lead a specialized group of five people who will form a committee to address one of the main tenets of NOS. Each committee will consist of an expert in the discipline content, an expert in pedagogy, an education supervisor from MoEHE, an outstanding and distinguished school teacher, in addition to the expert from the steering committee above. This will provide a variety of thinking and knowledge base in the group, whose work needs to be research oriented. As such, we will have eight committees each working very professionally and rigorously on one aspect of NOS over all the science textbooks .... These committees need to meet regularly and work together on each of the current school textbooks and teacher's guidebooks revising them and making suitable enrichments to improve their potential to reflect and offer an informed view of NOS.

However, A2[14] and A5 affirmed that the implementation of such an ambitious strategy is subject to the accessibility of necessary financial support and the participants being given full authority for decision making.

As such, the academics' opinions for improving science textbooks so that they reflect contemporary views of NOS were generally drawn around three main issues. The first was their view of the need to include NOS as a clearly defined main theme in teaching science, so that it will be addressed explicitly in the textbooks. This view is congruent with several studies that have shown the effectiveness of the explicit approach of addressing NOS in teaching (Akerson, Abd El Khalick and Lederman,

---

[14] It is worth noting that although she worked hard to develop improved Palestinian curricula, due to the volatile political situation and the politicization of education, A2 was fired from her position because, as she claimed, her political perspectives were not in line with that of the Palestinian National Authority's vision at that time (mid 1990s). While I was interviewing her, she got agitated and started weeping. She felt very sad that she was deprived of getting the chance to share in developing the Palestinian curricula which is "her bread" as she described it.

2000; Abd El Khalick, 2001; Khishfe and Abd El Khalick, 2002; Abd El Khalick and Akerson, 2004, 2009). The second issue was the need for teachers to collaborate and adopt an integrated approach to teaching science, incorporating chemistry, physics, biology and earth sciences as one subject. This teaching, according to the academics, should also be strongly linked to students' everyday lives and practices. The interactions between science, technology and society should be emphasized as well. This view is in line with several studies that have recommended addressing these issues as core themes in science textbooks and in classroom practice (Yager, 1990; McGinn, 1991; Cheek, 1992; Ramsey, 1993; Solomon, 1993; Bybee and De Boer 1994; NRC, 1996; Chiappetta and Koballa, 2002; Khaldi, 2004).

I think this is an ambitious vision because it means redesigning the textbooks using an integrative approach to address NOS in a "Science Technology and Society" orientation within these textbooks. This approach, which has a focus on societal issues, is difficult to implement in contexts where freedom of speech is not encouraged. Given the troubled political history in Palestine, some limitations would undoubtedly be imposed on the examples to be used in this area. Teachers also need to be persuaded to work as a team to be able to implement this approach which might be difficult in Palestinian culture where teachers are more productive at the individual work level. While I support the integration of NOS within the entire curriculum, I am not convinced that the integration of the specialisms is necessary for the effective incorporation of NOS.

In the third issue the academics raised the need for decent high quality teacher guides to assist teachers to address NOS throughout their teaching. These guides should address the subject knowledge, the nature of the knowledge and the pedagogy. However, no teacher guides have been designed to date.

I support the holistic strategy offered by A2 and A5 to revise the textbooks, which involves professionals from the different sectors of science education. I believe it would have greater success if the issues raised by the academics and discussed above are taken into consideration. However, due to political considerations, it seems unlikely that the current MoEHE would give the kind of power and authority mentioned in the proposal to such a group of people and allow them to work freely on the curricula.

In addition to these recommendations from the academics, I support Duschl's suggestion that science textbooks should be restructured in a way that provides students with opportunities to develop an understanding of how scientific knowledge is generated, and with activities that emphasize the verification of that knowledge (Duschl, 1990). These textbooks should be structured in a suitable way to create opportunities for students to question data, design and conduct real experiments and extend their thinking beyond the information provided.

6.2.4 Education Supervision and In-Service Teacher Training

All of the academics argued that teacher supervisors and trainers in general need to improve their level of qualifications for the job. With regard to the topic of NOS, six of the academics stressed the need for supervisors and trainers to be provided with a concrete and specialized training on the topic of NOS and how to train others to teach about NOS. A9 commented that:

> Without a rigorous and very strong training of teacher supervisors and in-service teacher trainers, they won't be helpful to assist teachers in promoting their understanding of NOS, or teaching it effectively ... We also need to induce a conceptual change in their belief in the textbook, their roles, and the teachers' roles in parallel to our work on training them on the proper way to address this topic with teachers.

A6 suggested that the MoEHE should collaborate with Palestinian universities to establish a Masters programme for professionals, with different tracks such as supervision, teacher training, curriculum development, educational leadership, counselling, etc. His view is that these programmes need to be well planned and carefully conducted in order to produce the needed professionals and experts who can work hard to improve the current educational situation, including teachers' beliefs. A6 recommended drawing on the experience of developed countries like the UK and the USA. He recommended that MoEHE and the universities should invite professionals and experts in these fields from these countries to come to Palestine and help in the establishment of such relevant programmes.

Another related issue that five of the academics raised was the need for the training and supervision of teachers to be school-based in authentic classroom settings with relevant activities that link the theory to practice, with NOS as a main theme and aim of teaching. These academics emphasized the necessity that trainers and supervisors should work with teachers side by side to provide teachers with the suitable foundation and scaffolding in pedagogy and content. A10 recommended the adoption of action research as a framework for progress. He has extensive experience in action research for professional development, and has worked with some in-service teachers in collaborative action research in classroom settings. A10 explained:

> Establishing collaborative action research properly will give teachers, trainers and supervisors valuable chances for their professional development, and for changing their beliefs and reshaping them properly via appropriate practices of teaching and learning.

In this context, A2, as clarified in the following quotation from her, mentioned that supervisors and trainers need to change their mentality regarding their belief in the "holiness" of the textbook, provide opportunities for the liberation of teachers from a literal commitment to the textbook, and give them a chance to be creative within the disciplines and contexts they see suitable and effective for them to be successful in their mission:

> Teacher supervisors and trainers have to understand that the textbook is not another version of the Quran that teachers have to follow word by word. They [supervisors and trainers] should deal with the textbook as a teaching resource alongside other resources that might stem from teachers' initiatives or experiences.

A third issue raised by three of the academics was that supervisors and trainers can be effective in improving teachers' and students' views of NOS through the assessment of students' achievements and attainments. From the perspective of these three academics, trainers and supervisors should work together on developing suitable evaluative measurements such as tests and related assignments that include NOS as a key component so that the learners' understanding of NOS and science processes is examined. As a result, teachers would be compelled to read and develop their understanding of this topic and teach it properly to their students. I support this approach as it is quite widely accepted that in order for curriculum development to become embedded it needs the teachers to asses it in the course. Consequently NOS should be incorporated into assessment in a range of different ways so that teachers will be forced to start teaching about it.

As their responses above show, the stakeholders of this study think that education trainers and supervisors need a qualification for training or supervision. In addition, they need a special rigorous qualification in the topic of NOS and how to work effectively with teachers in order to enhance their views of this topic. These findings concerning the need for professional development for trainers and supervisors are consistent with the findings of a national study on a needs assessment and plan for a teacher training strategy in Palestine that was supported by UNESCO (Hashweh et al., 2008). In one part, the strategic plan recommended a continuing professional development programme to train the educational supervisors and teacher trainers. The plan also recommended developing research and collaboration between all the parties that are involved in teacher continuing professional development.

Concerning the academics' views of the possible ways to enhance trainers' and supervisors' abilities to promote teachers' understanding of NOS, I support these initiatives to improve the expertise and understanding of supervisors and trainers. However, I do not believe they will be effective in isolation. I think they need to be part of a broader strategy that has governmental and financial packing. Chapter 7 of this thesis discusses this issue in detail as part of the implications of this research.

6.2.5 The Educational Leadership and Administration System

The academics were very clear in expressing their dissatisfaction with the current structure of the education administration system and its leadership. Reforms are needed in different aspects, as explained by A9: *"Current human resources at MoEHE including the administrative personnel need a lot of development ... Providing a continuing professional development for them might be helpful"*. Four of the academics acknowledged that any reforms or advancement of the current state of Palestinian education will not be effective until a concrete accountability system for educational leaders and education policy makers is established.

They suggest that this accountability should be monitored and controlled by the existing education committee at the Palestinian Legislation Council. A8 proposed that the mission of this committee should be to:

> Work hard monitoring the MoEHE leadership to guarantee the integrity and professionalism in their work. They should do their best to get rid of the vast corruption in the Ministry work that is sadly spoiling Palestinian education.

Three of the above four academics intimated the need for the education system and leadership to be liberated from any foreign agendas that are imposed on Palestinian education and its endeavours. They suggest that these foreign agendas and their accompanying interventions and control leave a very limited margin for sincere Palestinian educational leaders to be free to impose their own agenda and policies for improving Palestinian education. In response, they emphasized the need for Palestinians to work hard to achieve economic independence by all possible means, as explained by A7:

> Once we arrive at this desired economic independence, we can impose our own policies and vision and direct the development process of our education system in any way we find suitable for our community and culture, rather than being imposed on us from outsiders.

Another aspect that eight of the academics raised was the clear need for MoEHE to move towards a decentralized system. A1 demonstrated the importance of this change:

> Establishing a decentralized system at MOEHE will help to solve many of the troubles, and will allow them to better meet the various needs of schools and teachers ... Such a decentralized system will grant schools and teachers the chance to freely and independently plan and undertake any relevant activities they find suitable for their improvement and professional development within their own settings and conditions in their schools.

The general perspective of these academics is that such a decentralized system allows valuable chances for school teachers, head teachers, supervisors, teacher trainers and other groups of people involved in school and teacher education to select their own activities in any way that suits their particular teaching and environmental settings. This may provide them with a flexible and rich teaching environment to be creative and effective in their work.

Three of the academics also stressed the importance of collaboration between MoEHE, the universities and other non-governmental educational institutions in order to encourage the exchange of ideas and an integrated approach to teacher education. This quote from A4 clarifies the desire for such collaborative efforts:

> MoEHE, the Palestinian universities and the interested bodies of the civil society who work on teacher empowerment have to coordinate and agree together on the qualifications and traits of teachers we need for schools so that the three of these parties can work coherently on teacher development ... They should collaborate and work together in establishing suitable mechanisms that would raise the status of the teaching profession and improve teachers' living conditions to enable them to be creative in their work.

These academics affirmed the need for these parties to have a shared philosophy and understanding concerning teacher preparation and continuous professional development, to avoid any conflict in their work on teacher empowerment.

The overwhelming majority of the academics (eight of them) suggested that the education leaders and decision makers should implement appropriate and explicit policies to raise the status and financial conditions of school teachers. A9 stated:

> Educational leaders and decision makers have to impose the appropriate policies to enhance teachers' working conditions, and should study seriously the possibility of increasing their salaries.

They also added that other related policies are needed to enforce school teachers to pursue lifelong educational opportunities, to attend related specialized courses in the universities to sustain their professional development, and to keep on top of any new initiatives in their field.

This discussion of academics' responses suggests that they hold the strong view that major reforms in the structure and mechanisms of work of the educational leadership are needed. Although their recommendations to increase the effectiveness of the current educational structures are very broad and most do not address the nature of science directly, I believe they are valuable and would ultimately have an impact on teachers' and therefore learners' understanding of NOS. The academics' appeal for the development of decentralized system, an improvement in the capabilities of the leadership and monitoring their work, seeking the realization of economic independence, and cooperation between workers in the field of teacher education all have the potential to make a positive impact.

However, as mentioned earlier, these suggestions are complex and challenging to implement. So while I think achieving economic independence is very valuable for the country, I do not believe that were it achieved it would guarantee a solution to the problems, simply because foreign agendas would no longer exist.

Likewise, the academics' suggestion that the work of the educational leadership should be monitored and controlled by the education commission at the Palestinian Legislation Council to ensure the quality of their work is also complex. I am not sure if such a commission would have the expertise to do this job effectively. In the past, members of such commissions were selected from the Palestinian Legislation Council members on the basis of political or tribal considerations, rather than their suitability for the role.

6.2.6 Public Scientific Literacy and Critical Social Awareness

All academics stressed the serious need to promote scientific literacy and critical social awareness in the whole of Palestinian society, as is indicated by the following excerpt from A5:

> Though we might have several exceptions of highly literate and critical thinkers among our university students, at a general level most of them are of low scientific literacy and critical thinking abilities, this might also be extended to the rest of the people in our community. This low literacy and awareness might be a result of several historical, economic, social, or cultural reasons .... Consequently a lot of work is needed in and out the formal education system to enhance people's scientific literacy and awareness.

Seven of the academics emphasized the need that in order to promote their scientific literacy and critical awareness, individuals should be educated to consider and appreciate others' views and perspectives, and understand that there might be different reasonable views on a certain topic. They should be more open to adapt to new ideas that are crucial for scientific progress. According to three of these academics, this can be achieved through multimedia such as the internet, TV, radio, drama and theatre, scientific museums, scientific field trips, journals and newspapers. According to A7, "*publicity is crucial to gradual social and cultural changes that will definitely lead to a comprehensive educational reform*".

Three of the academics confirmed that a holistic reform would require improving teachers' beliefs and views, because teachers constitute a large sector of society and could be a valuable group with power to influence the desired change. To achieve this goal on the part of teachers, five academics stressed the need to create cultural awareness and critical consciousness in teachers through carefully pre-planned teaching and training sessions. A7 clarified this view:

> This process should be undertaken and taught in realistic cases that are relevant to teachers' and students' real life and needs, and includes a lot of discussion and dialogue between the learners and teachers and possibly the surrounding general public, that would lead to the desired scientific literacy and critical awareness promoting teachers' and others' beliefs.

In another related and crucial aspect, seven of the academics stressed the need to promote teachers' religious literacy and awareness, and address any misunderstandings in their personal religious beliefs that may negatively affect their views and understanding of NOS. These academics shared a view of the necessity to induce a conceptual change in teachers' misunderstandings of the relationship between religion and science, and their religious responsibility to "prove" religion and to improve their students' spiritual faith and certainty of God through scientific evidence. From the perspective of these academics, teachers should be persuaded to avoid any projection of science onto religion or vice versa, because religion, according to these academics, is absolute and constant, while science is tentative.

In this context, these academics suggested possible mechanisms that might be helpful to clarify the relationship between religion and science. The following quotes are representative of these suggestions:

> Teachers have to understand clearly that religion looks at knowledge as a relative and open-ended system, and that the search to find the truth is an unlimited continuous process where multiple realities might exist and we cannot judge exactly which one represents the "true" reality, where science does not have a limited end (A8).

> We have to make it clear for teachers that religion does not contradict with science and gives a high value to empirical work and reflection on the world. It urges people not to take life for granted. Religion stresses on the need for continuous hard effort to learn and search continuously for knowledge about the world (A5).

> Religion encourages people and scholars to work in science and grants a high religious and social status to scientists as narrated in The Holy Quran (A2).

However, the views of two of the academics, who were non-believers, were at odds with those of other academics. They called for a secular philosophy that segregates religion and science completely in order to improve teachers' understanding of NOS, and to avoid any troubles caused by the mixing of science and religion in the teaching process. They gave Kamal Ataturk's reform approach in Turkey as a good model to follow. A10 stated, "*To solve our troubles, a national secular philosophy such as that adopted by Ataturk in Turkey would be very effective*".

Another academic, A7, refused to comment on the link or relationship between science and religion. He said, "*When it comes to religion and science, I feel I cannot distinguish right from wrong, so I prefer not to comment on it*".

These findings reveal a belief among most of the academics in the need to develop first, the general public and teachers' scientific literacy and critical awareness, and second, their social understanding of religion and the relationship between religion and science. Concerning the first issue, when one considers the meanings of scientific literacy,[15] it is clear that NOS is an important component. Therefore, promoting the scientific literacy of people will certainly improve their understanding of NOS. The purpose of scientific literacy education is to make people aware of the rewards and shortcomings of the constructs that figure their realities and make them conscious and critical of these matters (Yalvac, 2005). This education can also help to bridge the gap between the two cultures of practicing scientists and school science (Sorby, 2000). While I support these suggestions I am conscious of the challenges involved in identifying professionals who have the expertise to implement these ambitious strategies to promote teachers' scientific literacy.

On the second issue concerning recommendations to promote teachers' social understanding of religion in relation to science, I think this issue should be handled carefully and sensitively due to the complexity and significance of people's religious beliefs and worldviews. Many teachers hold religious beliefs that they see as distinct from the science they understand and teach. But the religious views they hold influence their science teaching and the way they interact with it and the nature of this

---

[15]Scientific literacy is defined by the Atlas of Scientific Literacy (AAAS, 2001:vi) as "knowledge *and skills in science, technology, and mathematics, along with scientific habits of mind and an understanding of the nature of science and its impact on individuals and its role in society*"

influence depends on the compatibility of teachers' religious beliefs with their views of science (Abd El Khalick and Akerson, 2004).

One approach to address this problem related to the interplay between science and religion is to attempt to develop the view among teachers that science and religion are different types of knowing, and that a different set of rules applies to each. As such, the assumptions of each cannot be utilized to make judgments on the validity of the other, and therefore value judgments about both should be avoided.

This approach is similar to that offered by Abd El Khalick and Akerson (2004) who argue that an effective instruction of NOS should include deep concerted efforts of discussing the "discord" between science and religion to persuade the learners that science and religion are different ways of knowing. They also stressed the need to discourage value judgments about both ways of knowing.

However, I believe that given the place of religion in Palestine, the promotion of conceptual change in teachers' beliefs towards a recognition of the distinction between these two ways of knowing might prove to be virtually impossible for many. To illustrate my belief, I share the following. While I was interviewing T12, the only teacher I identified with sophisticated views of NOS, I asked him how he deals with science topics that might seem to be in conflict with the related religious scripts, such as the evolution/creationism theory. He said he avoids teaching these topics and look for alternatives, though according to him, he personally thinks that the religious scripts are the true ones to follow. However, when I asked T12 how he differentiates between science and religion, he gave a very sophisticated view demonstrating clearly that they are two different ways of knowing and that while science relies on empirical evidence, religion depends on spiritual faith. But, when it came to internalizing this understanding and applying it in reality, it was not possible for him to translate this belief into practice.

I do not believe that the segregation between science and religion or a secular national philosophy, as some academics have suggested, will be a practical solution for the Palestinian socio-cultural context, this being overwhelmingly Muslim, where religion has a major influence on people's lives and would certainly influence their views of NOS.

6.3 Aspects in the Palestinian Context Supporting Positive Change

Academics contended that there exists an idiosyncrasy in several aspects of the Palestinian society and its distinctive context which are likely to facilitate attempts made to improve teachers' views of NOS. For example, four of the academics stated that the existence of just one united national curriculum in Palestine eases any attempts to plan for change and improvement at a national level. One academic pointed to the current centralized system in education as a facilitating agent for such a national level development, though he acknowledged that there are other negative aspects of such a centralized system.

From the perspective of three of the academics, another encouraging aspect within the Palestinian context is the presence of a democratic environment with multiple political, ideological, and religious parties, because it provides opportunities for discussion and dialogue that will enable people, including teachers and students, to look at things from different perspectives. A4 stressed the importance of these intellectual discussions between people in developing their critical thinking that will in turn help to improve their views of NOS:

> These discussions and occasional intellectual struggles will certainly develop the critical thinking and reflectivity in teachers and students which are basic prerequisites for any attempts to improve teachers' views of NOS.

Furthermore, four of the academics pointed out that there is an acute awareness among Palestinian specialists and experts in science education of the poor conditions within teacher education and school science teaching. These specialists might be productive if given the chance and power to work on the topic, as explained by A1:

> Though these scholars are few, they can share enormously in developing teachers' beliefs if provided with relevant resources and authority, because they are aware of the problems and the substantial need to solve them.

Interestingly, three of these four academics believe that these specialists could be successful if given the support from the Ministry and the universities, because current school teachers, especially the young ones, are discouraged with the traditional way of training and supervision. They are looking for change and for professional development. Moreover, "*a high percentage, around 80 %, of the current in-service school teachers are from the younger generation who have been teaching for five years or less*", as explained by A2. As seen by these three academics, it is much easier to work on teacher development with younger teachers in whom you can more easily induce a conceptual change in their beliefs, and improve their understanding of NOS when compared with the older. On the other hand, it is likely to be a very difficult task to work with older and more experienced teachers who are "*already burned out from teaching*" (A2) to try and change their beliefs and improve their understanding of NOS.

Three of the academics, who were Muslims, considered that a "correct" understanding of the Islamic religion, the dominant religion in Palestine[16], and a proper and careful engaging of it in teaching will facilitate the improvement of teachers' understanding of NOS. According to them, Islam encourages people to reflect on the universe and God's creation, and calls for inquiry and inference in several instances in the Quran. A5, who is a devout Muslim, explained this issue:

> There are plenty of scripts in the Quran that encourage believers to reflect on God's creation and to employ inferences and inquiry to become fully convinced of the existence of God and the correct truth of Islam. These continuous efforts for reflection and enquiries by people can be directed towards improving their understanding of NOS.

---

[16] The Palestinian community comprises 96% Muslims and 4% Christians.

From these three academics' perspectives, allocating the scripts in the Quran that encourage reflection and creative thinking on creation and engaging them properly in teaching might help improve the critical thinking of people and thus have a direct positive influence on improving their understanding of NOS.

Finally, it is worth reporting here that three of the academics could not think of the existence of any facilitating factors or promising conditions in the Palestinian context that might support the attempts to improve teachers' education in general or their views of NOS in particular. When I asked A10 about this issue, he answered me with a laugh, *"I don't know, what have the others whom you interviewed have answered? I will be very happy to learn if we have anything that might be helpful"*.

This analysis suggests that some academics believe that there are a number of factors that exist in the Palestinian context which might be helpful to facilitate the attempts to enhance teachers' views of NOS. These include the availability of professionally qualified specialists in science education who are keen to work on this area, and the existence of only one united science curriculum in Palestine. I agree that these two factors, coupled with the potential to secure financial support for the Ministry from donors, and the relatively small education sector in Palestine (Rihan, 1999), will support the required progress.

On the other hand, I question the view that the existence of a democratic environment and multi-political and religious parties support effective change in this area. Although this environment might provide fertile soil for improving people's critical thinking and awareness, it can also be a dangerous source of struggle between teachers, head teachers, counsellors, supervisors, trainers, etc. due to the political motives that ruin and fragment their potential power and yield hostility and conflict between them. This may make it too difficult to persuade them to work collaboratively, and will also be very difficult to undertake any reform at a higher or national level.

The other issue raised by some of the academics that might be controversial is their view that a proper engagement with selected religious scripts may be helpful for improving teachers' and students' reflective and creative thinking that may in turn, positively affect their understanding of NOS. This view is in conflict with that mentioned earlier encouraging the separation of science and religion as two different ways of knowing.

6.4 Potential Barriers to Improving Teachers' Views of NOS

Although some of the academics have contended that there exists a number of positive factors and conditions in the Palestinian context which might facilitate any attempts to improve teachers' views and understanding of NOS, they have also acknowledged the existence of a number of potential barriers and difficulties that are likely to hinder these desired attempts. These barriers and difficulties raised by academics can be classified into five main areas.

The first, as raised by four of the academics, is the lack of human capacity, and the large shortage of experts in this field in Palestine who are needed to meet the goal of improving teachers' views of NOS. As A9 explains, "*Unfortunately, we do not have a sufficient number of academics and professionals who hold relevant beliefs and experience to fulfil this duty*". According to these academics, Palestinian society has a shortage of the cadre of professionals who are needed to rebuild the curriculum and develop it to accommodate the topic of NOS in a proper way, to train teachers and supervisors on this topic and on how to address it in their teaching, and to develop suitable tests that would force teachers to learn and teach about NOS.

Related to this barrier, as raised by five of the academics, is the crisis of the shortage of financial support to cover the cost of the implementation of any ambitious plan that might be proposed. These academics stated that Palestinians lack the financial support that can be invested in sending some outstanding students or professionals to study for Masters or PhD degrees in this topic in leading universities in Europe or America, and come back with rich experience and fresh knowledge to improve the situation in Palestine.

However, concerning the financial issue, two of the academics see it as a more complicated matter. According to them, even in the cases when Palestinians get some external financial support to improve the Palestinian educational system, this support is directed towards definite projects that are imposed by the donors. It seems, as they maintain, that most donors are not interested in spending their money on this topic. A7 remarked on the inefficiency of using external funds to improve the Palestinian education system:

> As long as we depend on external donations to develop our education system, where the donors impose their policy on how and where to spend the money, we will not be able to be independent enough to invest the money on projects and programmes that stems from our real needs, rather than those agendas imposed on us. In such a case, in my opinion, I think we should not accept any conditional donations, even if we are badly in need of money, unless we are granted full authority to direct the donations to projects and programmes we think are relevant to our society and educational system's needs.

A third barrier raised by five of the academics is related to the ultimate difficulty of the potential to induce a conceptual change in older, experienced teachers' traditional views of NOS. Half of the academics declared that it is going to be an extremely difficult job to work with older and more experienced teachers who have developed their traditional views over a long period of time as these beliefs become deeply rooted in their cognitive systems and part of their personal characters. According to these academics, even with heavy relevant training and guidance for this sector of teachers, the chances of them being willing to change their views will be small. This caution is supported on a broad level within conceptual change literature which highlights the difficulties of effecting change (Hashweh, 1986; Wandersee et al., 1994).

The fourth barrier, recognized by seven of the academics, was seen as the quality of current educational leadership who are not qualified to deal with this topic properly, and who are not concerned about improving the knowledge and teaching of this topic. A6 was explicit in his criticism of the educational leadership and the way they manage education affairs:

> I am sorry to say that most of the people at the top of MOEHE are not well qualified. They are only anxious to let stuff move nominally, without paying enough attention to the reality and essence of matters. They give us an impression that they have built the ceiling, though they have not built the walls yet. I think as long as these leaders stay in their positions having the authority and decision-making power, we cannot take crucial steps towards developing our educational system.

In this context, these academics emphasised that the existence of such unqualified people and unprofessionalism among the educational leadership and policy makers in MoEHE is due to the politicization of education and the accompanying struggles between Palestinian political parties that, according to seven academics, are spoiling Palestinian society. They suggest that most staff at the top level of management in the Ministry have been appointed to their positions for political reasons, without much consideration to their professionalism or qualifications in the positions they occupy. Interestingly, all academics appealed for a complete depoliticisation of education, and for the MoEHE to be completely depoliticized in its work and duties. A4 stated, *"Depoliticizing the schools and the Ministry is a critical necessity to establish before heading towards reforming education in Palestine"*.

Finally, six of the academics pointed out the low scientific literacy and poor critical social awareness on the part of the general Palestinian community, including students, teachers and parents. A6 stated, *"In general, Palestinian people suffer from a relatively low scientific literacy that might negatively affect their understanding of NOS"*. This low level of scientific literacy, coupled with some sort of general ignorance, as raised by four of the academics, might act as barriers to any potential efforts directed to improve teachers' views of NOS.

In conclusion, this group of academics in the field of science education emphasized a number of factors that they regard as barriers to potential enhancement of teachers' views of NOS. These include the shortage of appropriate professionals, inadequate financial support, or the restrictions imposed on the use of the financial aid available from external foreign resources, the politicization and lack of professionalism of the current educational leadership, the low scientific literacy of the public, and the extreme difficulties in inducing a conceptual change in older and more experienced teachers.

Although each of the above factors might be a significant hindrance, I consider the lack of qualifications and professionalism of the educational leadership because of the politicisation of the education system to be of great consequence. It seems that in the deeply centralized education system we have in Palestine, it is difficult to effect meaningful change without having qualified and professional leaders at the top of the hierarchical structure of the Ministry, the only body who currently have the power and responsibility for the implementation of any change.

It looks as if the current leadership does not possess enough expertise or qualifications for strategic planning to improve teacher education or meet teachers' needs, as can be indicated from the deficiencies in the textbooks, teacher training and supervision, and policies identified in this study. I have personally experienced this deficiency in the knowledge and understanding of educational leaders in the Ministry. For example, when interviewing the in-service science teacher training coordinator in MoEHE in this study, I found that he holds superficial views of NOS. On another occasion, when I went to MoEHE to get their permission to conduct the interviews for my second phase of field work, I was asked to meet the director of the supervision and training department in the Ministry, who is one of the leaders and policy makers in MoEHE, to get his approval. He asked me to clarify my project and its main aims. I explained the topic, its importance, aims and possible implications. He approved my application to conduct my interviews, but his comment on my work on this topic was "*you are like someone who found some people starving and without bread* *to eat, and yet suggested on them to eat biscuits."* This means he considers my work on this topic to be very trivial, and that addressing such a topic is of no importance or of secondary priority.

The other variable that is likely to significantly hinder the efforts for improvement is the relatively low scientific literacy of the public indicated by the academics that will likely limit the extent and quality of reflection and critical thinking. This might be explained by the prevalent socio-cultural background and the way individuals are brought up in the Palestinian community, coupled with their social understanding of religion as previously reported and discussed in Chapter 5.

Finally, I think the volatile political, economic and social situation in Palestine might impede any potential initiatives for reforming teacher education in general, or enhancing teachers' views of NOS in particular.

6.5 Summary

This chapter has provided an overview and discussion of academics' views of the possible ways to improve teachers' views of NOS, and the potential catalysts and barriers that might facilitate or hamper the attempts to achieve this goal. The academics perspectives of improving teachers' views were categorized in six main aspects that they believe need improvement.

The first aspect to be improved was the tertiary science teaching and teacher preparation programmes. Universities need to implement well-designed courses about the philosophy and nature of science as compulsory courses for all students majoring in science or any education related field. University teachers should have the expertise to include NOS as a main theme in all science courses they teach. Similarly, teacher training programmes in universities should be revised at the structural and content levels to be efficient in bringing about a proper conceptual change of teachers' views of NOS in authentic instructional contexts, with an action research approach as a framework.

The second aspect was teaching as a well-resourced profession. A well resourced teaching environment is needed to allow teachers to conduct any relevant practical, or hands-on, activities that could develop an understanding of NOS. Alongside, teachers' living and financial conditions should be improved in order to positively affect their commitment to their teaching and their desire for professional development.

The third aspect to be improved was the science textbooks. Tremendous efforts are needed to restructure the textbooks and enrich them with suitable activities that demonstrate an informed view of NOS. To achieve this target, teachers need to be provided with high quality teacher guides and with relevant scaffolding from their academic supervisors and trainers.

The fourth aspect was the education supervision and in-service teacher training run by MoEHE. Education supervisors and teacher trainers need specialized qualifications to be able to do their job properly. To support teachers to address NOS effectively in their teaching, supervisors and trainers should work collaboratively with them in classroom settings, and provide them with any relevant scaffolding they might need.

The fifth aspect was the educational leadership and administration system. A high degree of professionalism and integrity in their work is needed. Educational leaders need to be free from foreign pressure on their endeavours and programmes. This freedom might be achieved by seeking economic independence for Palestine. Additionally, there is a need for the Ministry to move towards a decentralized system, and to cooperate and collaborate with the universities and other non-governmental educational organizations on teacher education. Furthermore, the educational leadership should implement appropriate policies to raise the social and financial status of school teachers. Other policies are needed to encourage teachers to pursue lifelong education in the fields they teach.

The final issue raised as an aspect that needs much improvement was public scientific literacy and critical awareness. There is a need to create a scientifically literate population, which would facilitate attempts to target comprehensive educational reform in general, and NOS in particular. There is also a need to promote teachers' religious literacy in order to address the misconceptions teachers hold concerning the relationship between science and religion. Teachers need to be persuaded to avoid any projection of science onto religion or vice versa, and to look at science and religion as two different types of knowing, where the set of rules that apply to each are recognised as different.

Those aspects within the Palestinian context that academics believe would facilitate the attempts to improve teachers' views of NOS were identified. These include the serious feeling about this problem among Palestinian science educators, the existence of only one national curriculum all over the country that will facilitate any attempt to bring about change at a national level, the availability of a democratic environment that helps to provide a fertile soil for reflective thinking and criticality, and the Islamic religion that encourages people to reflect on life and the universe, and calls for enquiry and inference of life and God's creation that might be used to improve people's understanding of NOS if handled properly.

However, the academics also highlighted barriers that might hamper the efforts to improve teachers' views of NOS. These include the shortage of human capital and professionals needed to work on the topic, inadequate financial support, the extreme difficulty in inducing a conceptual change in the traditional beliefs of older, experienced school teachers, the non-qualified educational leadership and administration system as a result of the politicisation of education, and the low scientific literacy and poor critical social awareness of a wide sector of Palestinian society, including teachers, students and parents.

The conclusions and implications drawn from these findings are presented and discussed in Chapter 7.

Chapter Seven—Conclusions and Implications

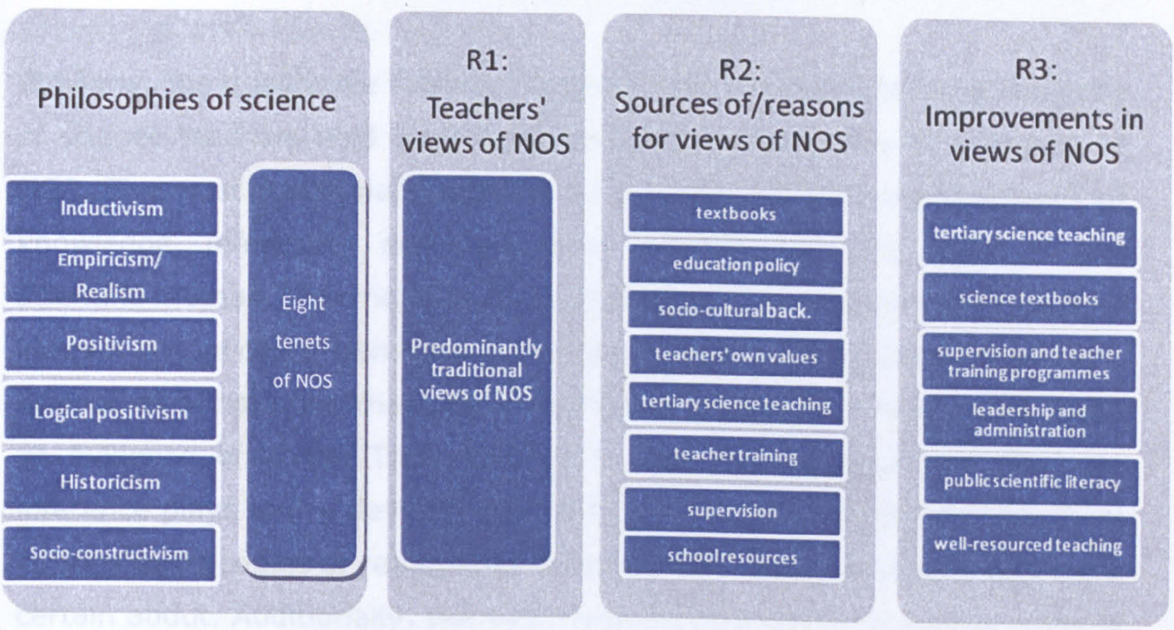
7.1 Introduction

The initial approach of this study was to conduct a quantitative survey of Palestinian science teachers' views of the nature of science (NOS) in order to identify sub-samples holding naïve and sophisticated views, which could then be used to explore the impact of views on classroom practice. However, the quantitative survey revealed that no teachers with what could be described as sophisticated views of NOS could be identified. It was therefore judged appropriate and significant to refocus the study to explore in depth the nature, causes and context of teachers' views of NOS, and attempt to identify the factors responsible for this apparent naïveté in teachers' views of NOS across the sample of Palestinian science teachers.

The findings have been presented in three chapters: Chapter 4 draws on both the quantitative and qualitative phases to explore Palestinian science teachers' views of NOS; Chapter 5 considers possible factors responsible for the apparent naïveté of these views, as seen by Palestinian academics; Chapter 6 presents and explores academics' suggestions of possible ways to improve Palestinian science teachers' views of NOS, and considers their perspectives on the factors that exist in the Palestinian context that might facilitate or hamper efforts to promote teachers' understanding of NOS. Figure 7.1 summarises the research main findings in relation to research questions and the theoretical framework.

In this final chapter I will begin with the conclusions in relation to my three research questions, before considering the implications of, and recommendations emanating from, these findings. After discussing the contribution of my research, I will address the limitations of the study and propose some areas for future research.

Figure 7.1: Research findings in relation to research questions and the theoretical framework



7.2 Conclusions

As noted above, my conclusions begin with a review of each research question in turn including a discussion of what can be drawn from the findings and emerging themes of each question. This will provide a framework for the discussion and presentation of the remainder of this concluding chapter.

7.2.1 What Views of NOS are held by Palestinian Science Teachers?

It can be concluded from both the quantitative and qualitative phases of this study that Palestinian science teachers hold predominantly naïve views of NOS.

The quantitative survey revealed that the views of a large and representative sample consisting of more than half of all Palestinian science teachers were outdated and superficial for most aspects of NOS. The only areas of NOS where the majority of the teachers showed slightly more informed and current views were the socio-cultural embeddedness and the tentative nature of scientific knowledge. Even in these areas the views could not be characterised as sophisticated.

Similarly, the qualitative findings revealed that the overwhelming majority of science teachers held traditional, unsophisticated views of all tenets of NOS. The most problematic aspects were related to the empirical basis of knowledge, inferences and theoretical entities, and the myth of the scientific method. The majority of participants did not believe in the use of indirect evidence to generate knowledge. Rather, they seemed to view science as a discipline that was solely based on tangible measurable facts as evidence of proof. They seemed to lack understanding of the role inference plays in the development of theory. They understood theoretical entities to be copies of reality that scientists had direct access to and were certain about. Additionally, the vast majority of them held a naïve view of scientific methods, believing that all scientists followed a universal stepwise scientific method.

The qualitative phase also revealed that a great majority of the participants conveyed inadequate views of the subjectivity, theory-ladeness and tentativeness of the scientific knowledge, and the epistemology of theories and laws, while a small minority of the participants held borderline views of these tenets, and only one participant portrayed an informed view of them. Analysis of responses concerning the subjectivity and theory-ladeness of science revealed that most of the teachers who were interviewed believed in the absolute objectivity of science and scientists, while a small proportion acknowledged that science and scientists could be temporarily subjective, and only one considered that science and scientists were potentially subjective. In a similar manner, most interviewees rejected the tentative nature of scientific knowledge supposing instead that some categories of scientific knowledge, such as facts and laws, were permanent, true and absolute. However, a minority of them demonstrated a borderline view in their belief that all categories of scientific knowledge were subject to change, with some being more permanent than others. Again, the majority reflected an inadequate view of the relationship between theories and laws, indicating a hierarchical relationship between the two categories, with theories becoming laws when having sufficient evidence to prove them. Nonetheless, more participants displayed borderline views of the imagination/creativity and socio-cultural embeddedness of NOS, although the majority of the participants held naïve views of both.

Overall, it might be concluded that both the quantitative and qualitative methods used revealed broadly similar results - that the majority of Palestinian science teachers participating in this study hold predominantly traditional, naïve views.

These findings are consistent with those of several earlier studies which have generally revealed that teachers possess an inadequate understanding of NOS, with most holding fluid beliefs that lack coherence or consistency (e.g. Carey and Stauss, 1970; Lakin and Wellington, 1994; Khishfe and Abd El Khalick, 2002; Liu and Lederman, 2002; Tsai, 2002; Cakir and Crawford, 2004; Dogan and Abd El Khalick, 2008; Wahbeh, 2009). However, some recent studies (e.g. Akerson, Abd El Khalick and Lederman, 2000; Morrison, Raab and Ingram, 2007), have revealed a more positive view of teachers' understanding of certain aspects of NOS.

An interesting aspect of my findings and those of other studies is that science teachers in different parts of the world appear to show different patterns of understanding of NOS. For example, Halai and McNicholl (2004) found in their comparative study of Pakistani and British teachers' conceptions of NOS that Pakistani Muslim teachers could not see science and religion as different types of knowledge, while their British non-Muslim counterparts could identify the difference between science and religion as different types of knowledge. I, too, found a strong tendency on the part of Palestinian teachers to merge science and religion in their belief and practice.

7.2.2 According to Palestinian Science Education Stakeholders, What Factors Influence Science Teachers' Views of NOS?

The reasons behind the apparent naïveté in teachers' views of NOS from the perspective of Palestinian academics can be ascribed to the following eight main factors:

Socio-cultural Background

The Palestinian socio-cultural background was regarded as having the most impact on the views of teachers, and it is in this area where a significant contribution is made to the knowledge in the field. Three main issues were identified in this area: The first issue was that the authoritarian and patriarchical nature of the Palestinian socio-cultural context, as identified by Sharabi (1985), hampers the development of an individual's critical thinking and perpetuates a general belief in the existence of one source of knowledge that is accurate and permanent. The impact that this has on NOS has not previously been identified. The second issue identified by academics was the general cultural tendency to import the products of science from western civilization without importing the western philosophy or nature of science. Again, the influence that this has on an understanding of the nature of science has not previously been established.

The third aspect was related to the social and religious understanding of science held by the general public, including teachers. In other words, there is a tendency to compare scientific and religious knowledge, with an aim to "proving" religion through science or vice versa without having a concrete theoretical framework from the perspective of science education. It is the social and religious influence on the understanding of science which is of particular interest. This finding is consistent with several research findings worldwide that have shown that the social and religious environment influence teachers' views and understandings of NOS (Jegede and Okebukola, 1991; Shumba, 1999; Cobern and Loving, 2000; Abd El Khalick and Akerson, 2004; Halai and McNicholl, 2004; Liu and Lederman, 2007; Mansour, 2007). However, interpreting comparative data without due consideration to the socio-cultural context can generate misleading interpretations. For example, Haidar (1999) inferred that teachers' relatively sophisticated understanding of NOS was a result of their religious beliefs, which favoured a constructivist view of science. This is contrary to the findings presented here for the Palestinian teachers. Although Haidar's (1999) study also involved Muslim teachers, they were from the Arabian Gulf and therefore culturally very different from the Palestinian sample described here.

This problem related to cultural and religious context becomes more significant when both the religious *and* culture differ in the two contexts. For example, Liu and Lederman (2007) found that Taiwanese teachers who held traditional worldviews held sophisticated views of NOS. This raises questions about the interpretation of terms such as "traditional" in different cultures. The current study supports the view that a deep understanding of the cultural and religious context can make a significant contribution to an understanding in this field.

Education Policy

The structure of the education system in Palestine and its "hidden curriculum" were identified by academics as playing a crucial role in the formation of science teachers' naïve understanding of NOS. Three main issues were stressed in this regard: the centralized, hierarchical and bureaucratic structure of MoEHE; the unqualified education leadership within the Ministry; and a belief in the existence of a "hidden curriculum" that attempts to prevent the improvement of individuals' scientific literacy or criticality as it might threaten the educational and political regimes who rule the country.

Teachers' Own Personal Values

According to the academics, teachers believe that it is their knowledge that grants them power and authority, and therefore it is in their interests that this knowledge is accurate, constant and objective. It is perceived that if teachers portray a more tentative, dynamic and subjective view of science it might call their own authority into question. Teachers are perceived to believe that they have a religious commitment to use their teaching to do their best to "prove" religion by drawing on scientific evidence that corroborates information in the holy books. The academics regard it as dangerous to mix the scientific knowledge with the religious knowledge as it will put the religious knowledge, which is objective and unchallengeable from a religious view, and the scientific knowledge which is potentially subjective and tentative, at the same level of legitimacy and validity. This blending leads them to view science and scientific knowledge as objective and "true". Teachers also believe that they should behave and teach in congruence with the social and cultural values and norms of Palestinian society which are naïve in regard to most aspects of NOS. For example, the majority of the people in the Palestinian society hold a value of respect towards old people in the extended family and fully trust their "wisdom". They think that the young should obey and accept uncritically everything that these "wise" older people say or do, even if they are not convinced of its merit.

Teaching Approaches at School and University Levels

Teaching in universities is content-based, with little attention to the skills and processes of science. The science is "delivered" in a way that is detached from students' and teachers' needs and everyday lives. No consideration is given to the philosophical underpinnings of the knowledge or to its historical development. University teachers deal with scientific knowledge as "true" and constant. They do not provide opportunities for students to reflect on or question the knowledge being taught which results in naïve banking education. Consequently, considering that school teachers have come through a system where their only experience of science is this one, they cannot be expected to teach in any other way, particularly given the nature of the textbooks and teacher education, as explained in the following points.

Science Textbooks

According to the academics, textbooks and the curriculum in Palestine are regarded as one and the same thing. This is because teachers do not have access to any curriculum documents, and textbooks are the only instructional resource that teachers use in their classrooms. Therefore, what is taught is what is presented in the textbooks. However, the texts do not address the nature of science. Rather, they present a body of facts - the final products of scientific processes - without ever alluding to how science happens. The main reason for this situation put forward by the academics is that when the current textbooks were developed in 2000, NOS was not addressed in the Palestinian curriculum to any degree and the textbook authors did not have the understanding of issues related to the nature of science, nor were they trained to address this topic in the textbooks.

These findings concerning the absence of NOS in Palestinian science textbooks support those of earlier studies at the national, regional and international levels that indicated the failure of textbooks to reflect a correct and balanced conception of NOS (e.g. Garcia, 1985; Fillman and Sethna, 1993; BouJaoude, 1997; Khaldi, 2004; Phillips, 2006; Abd El Khalick, Water and Le, 2008).

Teacher Training Programmes

Teacher training programmes at the pre- and in-service levels are content-based and do not focus on NOS. Neither includes any specialized courses or workshops that address the philosophy or history of science. In-service teacher trainers and others responsible in the Ministry do not appear concerned about training teachers on this topic.

These findings regarding teacher education related to NOS in Palestine do not appear to be in conflict with the international perspective. According to Loving (1991) and Gallagher (1991), few teacher preparation programmes address the history and philosophy of science. While there are evaluations of isolated initiatives to develop prospective teachers' understanding of NOS (Abd El Khalick, 2005; McCarthy, Sorensen and Newton, 2010), there has not been a widespread implementation of the teaching of NOS embedded in teacher preparation programmes. In addition, separate courses on NOS in teacher education are not common place internationally (Loving, 1991).

Educational Supervision

The main focus of teacher supervisors' work is to ensure the coverage of the content of the textbooks by school teachers within the allotted time frame. Supervisors generally are not professionally qualified for their role nor is their role to help teachers improve their understanding of NOS. Unsurprisingly, most supervisors hold naïve views of NOS. Consequently, they are not in a position to identify and address any issues arising when working with teachers in schools. My discussions with educators in several western countries leads me to believe that this situation regarding teacher supervision is the norm in many countries.

School Resources

Most schools in Palestine are not well-funded and therefore they do not have the necessary resources to enable learners to undertake practical science, which would lead to a more authentic view of how science works. However, at the moment this is not a key priority as the teachers need support to develop their understanding of NOS.

7.2.3 What Views do Palestinian Science Education Stakeholders hold Regarding the Advancement of Science Teachers' Views of NOS?

Possible ways to improve teachers' views of NOS, from the perspectives of the ten Palestinian professionals who were interviewed, address the following six areas: tertiary science teaching and teacher preparation programmes; teaching as a well-resourced profession; science textbooks; education supervision and in-service teacher training; educational leadership and administration; and teachers' and the general public's scientific literacy and critical social awareness. While there is clearly some correspondence between these areas and the causes of the problems identified by the academics, the correlation is not as strong as one might have expected.

Tertiary Science Teaching and Teacher Preparation Programmes

In line with suggestions made by several researchers in the area of NOS (e.g., Pomeroy, 1993, Mathews, 1994; Hashweh, 2009), the academics believe that universities need to play a more proactive role in educating all science and science education graduates about NOS. It was suggested that universities need to implement well-designed courses about the philosophy and nature of science, as compulsory courses for all students majoring in science or any education-related fields. Research conducted in this area shows that specialized courses on the philosophy of science have been effective in promoting students' views of science (e.g. Matthews, 1994; Abd El Khalick and Lederman, 2000a; Abd El Khalick, 2005; Abd El Khalick and Akerson, 2009; Wahbeh, 2009).

Similarly, teacher training programmes in universities should be revised at the structural and content levels to bring about the necessary conceptual change in teachers' views of NOS in authentic instructional contexts, with an action research approach as a framework for development. These findings concur with the results of a UNESCO teacher education strategy project for Palestine (Hashweh et al., 2008). They offered a holistic national teacher education strategy to update and improve the current teacher preparation programmes in Palestinian universities in order to fit with the contemporary international trends in teacher education.

Teaching as a Well-Resourced Profession

A well-resourced teaching environment is needed to allow teachers to adopt a practical, hands-on approach that helps to promote an understanding of NOS. In addition, teachers' living and financial conditions should be greatly improved to positively affect their commitment to teaching and their desire for professional development.

Palestinian Science Textbooks

The academics believe that every effort should be made to restructure the textbooks to include a focus on current perspectives of NOS, as well as examples of the Palestinian contribution to the history of science.

Teachers need to be provided with effective teacher guides and relevant scaffolding and support from their academic supervisors and trainers in the appropriate use of these textbooks. These suggestions are in agreement with Duschl's proposal that science textbooks should be restructured in a way that provides students with opportunities to develop an understanding of how scientific knowledge is generated, and with activities that emphasize the verification of that knowledge (Duschl, 1990)

Education Supervision and In-service Teacher Training

Interviewees felt that both teacher trainers and education supervisors need appropriate qualifications in order to be effective in their respective roles. It was suggested that a Masters programme for professionals would make a significant contribution, and that it is vital that teacher trainers and education supervisors work closely with teachers in classroom settings and provide them with support in the areas of NOS.

Educational Leadership and Administration System

Academics suggested that educational leaders in the Ministry need to demonstrate a high degree of professionalism and integrity in their work, and to resist the pressure from foreign sources to structure and manage their programmes in particular ways. It was felt that this freedom might be realized if economic independence in Palestine was achieved. Additionally, a need was identified for the Ministry to move towards a decentralized system, and to collaborate with the universities and other non-governmental education organizations on teacher education. Furthermore, the educational leadership should implement appropriate policies to raise the social and financial status of school teachers. Other policies are needed to encourage teachers to pursue lifelong professional education in the fields they teach.

Public Scientific Literacy and Critical Awareness

The academics questioned in this study suggest that by improving the scientific literacy of the public it would facilitate attempts to target comprehensive educational reform in general, and improve understanding of NOS in particular. This supports Yalvac's (2005) argument that improving the scientific literacy will improve their understanding of NOS, and Sorby (2000) who suggests that scientific literacy and critical awareness education can help to bridge the gap between the two cultures of practicing scientists and school science.

Most academics also stressed the need to promote teachers' religious literacy in order to confront the misconceptions teachers hold concerning the relationship between science and religion. Teachers need to be persuaded to avoid any projection of science onto religion and vice versa, and to look at science and religion as two different types of knowing, where the set of rules that applies to one does not necessarily apply to the other. This approach is similar to that offered by Abd El Khalick and Akerson (2004) who argue that effective instruction of NOS should include a discussion of the dissonance between science and religion in order to persuade the learners that science and religion are different ways of knowing. They also stressed the need to discourage value judgments about both ways of knowing.

7.3 Implications

As I have argued in this thesis, one of the most important aims of science teaching in Palestine, as in many countries, is the preparation of scientifically literate students. A sophisticated understanding of NOS is an important part of scientific literacy (Abd El Khalick and Lederman, 2000; AAAS, 2003). The broad aims of the school science curriculum in Palestine, as in many other countries, reflects the importance in modern society of science in general, and NOS in particular (AAAS, 1993; Driver, Leach, Millar and Scott, 1996; NRC, 1996; MoEHE, 2008). For these aims to materialize, it is vital that teachers have a sound understanding of the science content they teach, as well as contemporary views of NOS (Yager, 1990; Lederman, 1992, 2007). In addition, I think they also need to have an understanding of how to teach NOS, namely Shulman's pedagogical content knowledge (Shulman, 1986, 1987). The findings of this research, however, suggest that the challenge this presents is significant.

Consequently, and in line with the broad aims of science education in Palestine, an understanding of the current situation within the Palestinian context will help to identify strategies that can support teachers, and ultimately learners, to see science as far more than a rigid body of facts to be transferred from textbooks to learners. Here, the conclusions from my exploration are drawn together to form a clear picture of what a solution to the problem of teachers' naïve views of NOS might look like.

7.3.1 Implications for Teacher Education

In this section I discuss some implications that might help to provide a richer quality education for pre- and in-service teachers. I have argued that a key target of science education is to aid the development of sophisticated views of NOS in learners and that this requires teachers who hold informed views of NOS and are capable of addressing this area in their classrooms. However, the research findings revealed that most teachers neither hold contemporary views of NOS, nor are formally qualified to teach NOS properly. The following practical recommendations for tertiary science education and pre- and in-service science teacher training are made in light of the findings of this research, with due consideration to the complexity of the situation in which these implications would be carried out.

Tertiary Science Education

As in many western countries, this study suggests that many teachers in Palestine are entering the profession having never considered the nature of science during their own education. In addition, their experience of science at both school and university often reinforces the view that science is a body of facts to be transferred from teacher to learner. The fact that around 60 % of the school science teachers who are employed by MoEHE do not hold a formal teaching qualification indicates that more than half of school science teachers have not enrolled in any of the teacher preparation courses offered by universities (MoEHE, 2008). This means that currently the majority of teachers rely totally on their undergraduate science degree as preparation for teaching. Clearly while it is imperative that the number of teachers with a teaching qualification must increase, it is also vital that teachers with only an academic qualification have explored NOS in their studies. In addition, the undergraduate study of teachers who do have a professional qualification will also have an impact on their views about how science happens. Therefore, undergraduate programmes should provide students majoring in science with a current view of science, by integrating science processes with the concepts and using appropriate pedagogical approaches. In this context, Hashweh (2009) recommends that educators see tertiary science education as a conceptual change process with a primary aim to improve the learners' epistemological development.

The incorporation of the philosophy and history of science within tertiary science instruction would be helpful to address this problem. However, there has been debate in the literature about the merits of making a nature and philosophy of science course compulsory in all undergraduate science degree programmes (Matthews, 1994; Ackay, 2007). While certain prominent science educators in Britain question the value of this initiative (Millar, 2010, pers.comm), I strongly support this policy. I believe that if we are expecting school learners to have an understanding of how science works, then it is logical to expect our science graduates to continue to develop their breadth and depth of understanding in this area. I think such a course would enhance students' scientific literacy and social awareness, something I believe is necessary for Palestinian graduates who live in a society that is currently witnessing significant scientific and economic progress as a result of the peace process that is taking place in the region. The attempts to rebuild a stronger society in Palestine require highly trained science professionals who can aid in the reconstruction and development of the country. These professionals should have insight into the nature of science and be able to make informed decisions with regard to scientific endeavours and their impact on the Palestinian community.

However, the findings of this study revealed that teachers of undergraduate science courses are not qualified to teach about NOS because most do not have informed views of NOS. To address this problem the ideal would be for a specialized course on NOS to be offered to science teaching staff in all Palestinian universities with the aims of promoting their understanding and qualifying them to address this topic in their teaching. While this recommendation might be something to strive towards, given the current lack of both funding and suitably prepared academics to develop such courses, we need to start with more realistic and short terms targets. These should focus on raising the profile of NOS within the academic science community, through the existing lines of communication, including conferences, journals and more populist media.

Scientists and academics need to be made aware that research shows that they, together with teachers and teacher educators, have completely different understandings of the meaning and role of different scientific conceptual tools, such as hypothesis, theory, law and model (Yalvac, 2005). All educators, supported by informed academics in the field of the nature and philosophy of science, should work towards developing a shared language and understanding of these concepts of NOS and for related philosophical positions to be adopted and embraced by all these parties.

Pre-service Teacher Education

From the perspective of Palestinian academics, the fact that pre-service teacher education programmes are failing to facilitate the development of prospective teachers with current and informed views of NOS needs to be addressed. They believe that providers of these programmes and their academic staff should be responsible for reforming and redesigning the structure of the programmes and teacher education courses they offer to promote prospective teachers' understanding of NOS. I agree that radical changes to the content and structure of teacher preparation programmes are needed. I propose that changes are implemented at two levels: First, rather than limiting the coverage of NOS within the current programmes to one small chapter of one module (which is often ignored), I believe it should be integrated into all theoretical and practical aspects in all teacher education programmes. Regardless of the context and discipline, I support the explicit teaching of NOS (Abd El Khalick et al., 1998; Gess-Newsome, 1999; Lederman at al., 1999; Akerson, et al., 2000; Schwartz, 2004; Wahbeh, 2009). This, if implemented properly, could have a positive impact on teachers' views of NOS, and would be likely to lead to the conceptual understanding of the topic.

However, it is important to acknowledge that even the explicit teaching of NOS within teacher education programmes has had mixed success (Wahbeh, 2009). As with all misconceptions, it is difficult to shift fundamental views that have become so integrated into cognitive structure over many years. Because of these challenges, I suggest a second strategy needs to be adopted. My findings suggest that a specialized course on NOS and the history and philosophy of science should be made compulsory for all prospective science teachers. This approach is widely supported in the literature (Bybee et al., 1991; Johnson and Stewart, 1991; Matthews, 1994; Monk and Osborne, 1997; Abd El Khalick and Lederman, 2000; Irwin, 2000; Lin and Chen, 2002; Kim, 2007). This course should include both the content and pedagogy related to NOS. In addition, the course should provide teachers with opportunities to practise the teaching of science processes and how science works by preparing relevant lessons plans, and putting these into practice in real classroom settings.

As teachers' views of NOS are most likely to be closely tied to their values and affective dedications, such a course should include an exploration of the origins of teachers' views of NOS and the potential factors that might influence the development of these beliefs, such as religion, socio-cultural factors, school education and the media (Shubma, 1999; Mansour, 2007; Schwartz and Lederman, 2008). It is necessary that this course also attempts to induce a conceptual change linked to the most persistent and traditional views of NOS, which have been instilled into pre-service teachers throughout their school education, and within a range of socio-cultural and religious contexts. In light of my findings, this course should pay special attention to raising teachers' critical awareness within their education and everyday lives. They should be encouraged to question, challenge and not to take things for granted. The inclusion of conception-challenging activities that promote prospective teachers' self-reflection and metacognition will help to achieve this goal (Akerson and Abd El Khalick, 2000; Akerson et al., 2000).

The relationship between the teachers' world and religious views and science should be carefully addressed and clarified. However, we have to keep in mind that the relationship between teachers' views of NOS and their religious beliefs is very complex and depends on the compatibility of their religious beliefs with science (Abd El Khalick and Akerson, 2004), especially in a strongly Muslim society like Palestine, where people give their primary allegiance to their religion and cultural values, and can be very resistant to change. Suitable conceptual change strategies should be implemented so that teachers can strive towards a level of compatibility between their religious beliefs and their scientific views and to reach some state of cognitive equilibrium (Dagher and BouJaoude, 1997). My findings suggest that the key issue to begin with is to try to persuade teachers to look at science and religion as two different belief systems and ways of knowing, and to avoid value judgments about either of them as ways of knowing, as this might negatively influence the teaching of science in Palestine.

In addition, teachers need to be provided with suitable pedagogical strategies on how to address conflicts between scientific and religious issues (Reiss, 2008), and other socio-cultural perspectives surrounding science instruction in the classroom. These strategies might include involving prospective teachers in reflective thinking about the socio-cultural influences of scientific knowledge and endeavours which enable them to see science in its wider societal and cultural spheres. This strategy would be more effective if accompanied by some real practice through action research projects (Fazio, 2005) which the prospective teachers could work on in collaboration with the course lecturers.

My findings suggest that many teachers believe it is their religious responsibility to prove religion through science. By seeking scientific evidence to prove passages recited in the Holy Quran leads to merging science and religion as ways of knowing. I do not think it is going to be easy to persuade teachers to give up this practice. Here, too, we need to build in conceptual change strategies to address this sensitive issue and to encourage teachers to segregate their religious and science beliefs in their teaching. One approach to consider might be to identify scientific evidence that teachers have used in the past to prove certain scripts in the Quran, which was then found to be false. This could be used to support the argument for the separation of the two ways of knowing: the Quran accepted as permanent and correct without any need for evidence; and science knowledge as tentative but with a demand for evidence.

In-service Teacher Education

A similar approach to pre-service teacher development discussed in the previous section should be a feature of in-service training courses. However, as this study and other studies (e.g., Adams, 2000) reveal, the task with in-service teachers is likely to be more challenging. Change can be strongly resisted by experienced teachers. In-service science teacher training and professional development programmes should be revised to facilitate the exploration and promotion of practising teachers' understanding of NOS. However, this initiative is dependent on the in-service teacher trainers' understanding of NOS as well as their pedagogical content knowledge (Shulman, 1986) concerning NOS instruction. As the findings of this study revealed that in-service teacher trainers were not qualified to teach NOS effectively, the priority will be to focus on developing teacher trainers' understanding and expertise. There is also a need to provide the trainers with suitable training materials as this study suggested that there is a lack of appropriate resources in the teacher training department at MoEHE. Again my literature review suggests that this problem is not limited to the Palestinian context, and it is followed up in the later section on areas for future research.

Given the shared issues within the pre- and in-service areas, I believe there is a need for collaboration between teacher trainers in both areas in order to develop a shared understanding of the problems and to generate feasible strategies to address them. Participating in this process will also empower the trainers and encourage them to take ownership of any new initiatives. Research has shown that active participation in the curriculum development process is far more likely to lead to successful implementation than a top-down, imposed model (Connely and Claudinin, 1988). However, the MoEHE should play a facilitatory role and arrange the initial meetings between teacher educators in universities and the in-service teacher trainers who are based in MoEHE. Perhaps a task force could be set up to create links between the universities, MoEHE, and other education development institutions regarding teacher training. Not only would collaboration at this level help in improving teacher efficacy related to NOS, but also at a more general level.

The Palestinian academics, as explained in Chapters 5 and 6, are aware of the reasons for teachers' naïve views of NOS and have suggested possible ways to improve the situation. Likewise, I have made several recommendations emanating from my findings for improving teachers' understanding of NOS and how to teach it. These include offering specialised university and professional courses on NOS, the explicit teaching of NOS in teacher education programmes, providing teachers with suitable strategies and resources to effectively address NOS in their science classrooms, and introducing and facilitating collaboration between educators in different sectors. However, given the lack of any real progress in this area internationally after decades of extensive research in many countries, I am acutely aware of the challenges of implementing these practical recommendations in any country, but particularly in Palestine, given its history and the complexity of the context. I am aware that if the solution was simple it would have been achieved already. So while it is easy for academics, myself included, to make these suggestions, it is more challenging to generate practical ways of actually implementing them. For example, who has the expertise to develop these courses and materials? What should these courses be like and how will agreement be reached? I believe that one of the most challenging tasks for any science educator is to develop an effective curriculum package at any level to develop learners' understanding of the nature of science, and I question whether developing countries have the required human or financial resources. Such is the magnitude of the challenge that perhaps it requires an international research-informed initiative where experts from several countries work collaboratively to take this forward. Generic curriculum approaches and resources could then be tailored to more specific contexts. The implications for future research are addressed in a later section.

7.3.2 Implications for Curriculum Improvement

In response to the findings that teachers rely on the textbook as their only teaching resource, and equate it with the curriculum, and that they never see nor engage with the curriculum document, I recommend that the relationship between the textbook and the curriculum be reconceptualised for teachers. It is important to reach a situation evident in many countries where the curriculum documentation is used as the starting point to inform both teaching and the use and generation of a range curriculum resources and approaches, including textbooks, web-based materials, library books, videos, reference materials, fresh specimens and visiting speakers. The textbook needs to be seen as one of many resources that support the implementation of the curriculum, rather than the curriculum itself.

Palestinian education is just beginning to initiate programmes that connect selected schools with the Internet and provide teachers with other teaching media and well-resourced libraries. However, realistically it is going to take time to get to the stage where teachers utilise the textbook as one of a full range of teaching resources because funding is currently dependent on foreign donations and a stable political situation. In the meanwhile, the development and use of appropriate curriculum resources should be actively promoted among teachers.

Concerning the way the current textbooks present NOS, this study has shown that the current Palestinian textbooks reflect traditional views of NOS by delivering a vast body of content without paying any attention to how this knowledge was generated, stressing absolute objectivity as a core characteristic of science, and presenting scientific knowledge as ultimate , constant and beyond question. Consequently, there is a crucial need to redesign the current science textbooks in a way that incorporates NOS within the content base as a main theme, and represents an informed treatment of NOS. These textbooks should be redesigned to integrate the process of science with the science concepts, despite the challenge that this presents.

It is encouraging that many science textbooks in several countries including the United Kingdom, USA, Australia and South Africa now reflect a more informed view of the nature of science with an integration of content and process. It is vital that Palestinian textbooks now follow suit but this too will take time, so in the interim I suggest that teachers are made aware of the shortcomings of these textbooks so that they can begin to fill the gaps themselves with the support of their trainers and education supervisors and by supplementing the use of textbooks with relevant enrichment materials.

7.3.3 Implications for Policy Making Bodies at MoEHE

The MoEHE is still beginning to develop its administrative system, and thus needs to define clearly its philosophy, policy and implementation processes concerning the teaching profession, teacher education and professional development, and curriculum and assessment. This is a grave responsibility which has to be undertaken in a serious, transparent and professional manner. It cannot be delayed any longer. The first crucial step to be undertaken by the Ministry is to examine its structure and staffing and address shortcomings. This study has revealed that there is a strong belief among academics that there were instances where staff appointments at the upper end of the hierarchical structure of the Ministry were made based on political rather than professional considerations. This situation is not unique to Palestine but every effort should be made to ensure that decisions, performance and recruitment within the Ministry are apolitical and professionally based. It is of concern, although not totally unexpected, that several senior and influential members of the Ministry with responsibilities linked to science teacher education and curriculum development were found to hold naïve views of NOS, and were unaware of the importance of promoting an understanding of the nature of science in school teaching. This surely needs to be addressed before curricular reform can be implemented effectively.

Once they have a professional administrative staff and well qualified leadership, they need to develop the role and capacity of the Ministry in managing, organizing and implementing the teacher education system. They should impose suitable policies that would develop and facilitate the efforts to improve the teaching profession and the quality of teacher education to positively affect teachers' efficiency and promote their views of NOS. In light of the data obtained from interviewing the academics on possible ways of improving teachers' views of NOS, the following practical recommendations are suggested to policy makers and education authorities to consider and develop:

- Begin to decentralize the control of the Ministry to better meet the needs of schools and teachers, and to allow teachers to participate more effectively in identifying their needs and planning the strategies needed for their professional development. Most of the participants interviewed in this study stressed that teachers need to be relieved from the pressure to stick solely to the textbooks in their teaching imposed on them by their supervisors, trainers or other Ministry administrators, who might not be aware of teachers' real needs.
- Improve the financial rewards and working conditions of teachers to increase the attractiveness of the profession, and to improve teachers' commitment towards the job. This would be likely to boost their participation in continuing professional development, which will positively affect their proficiency, including their scientific literacy and understanding of NOS. The vast majority of participants contended that only academically weak and poorly qualified students join the

teaching profession because of its low status. In conjunction with this, school facilities should be improved to create a well-resourced environment suitable for teaching and learning.

- Develop the cadre of professionals at the Ministry who are responsible for teacher education. In light of the findings of this study, much work needs to be carried out in qualifying teacher supervisors, textbook authors and in-service teacher trainers. Similarly, core changes need to take place in the supervision of teachers in schools and in-service training systems to enable them to play an efficient role in improving teachers' understanding of NOS.
- Hold a conference for scientists, philosophers of science, science educators, school teachers, teacher trainers, education supervisors, and curriculum designers that focuses on the NOS issues and generates collaborative and creative partnerships, geared towards enhancing teachers' understanding of the topic.
- Introduce NOS during the selection process of the applicants for the teaching profession, and make potential students aware of the need to develop their understanding in this area. In time it might be useful to give NOS some weight in the qualification exam that the candidates currently have to pass as part of the selection process.

However, I have to acknowledge that these implications for policy, which have arisen in light of the views of academics who characteristically adopt an intellectual and perhaps somewhat idealistic perspective, might be problematic in the eyes of policy makers, who tend to make their decisions on pragmatic grounds based on the current political and financial reality. For example, while academics emphasize the appointing of highly qualified graduate students for teaching, the policy makers are aware that the best qualified students will go for the best paid jobs, and few will enter the teaching profession unless salaries are significantly increased. However, policy makers have restricted budgets that will not allow this in a country with very limited resources that force the politicians to accept barely qualified teachers with limited views of NOS. It seems that there is a policy tension within the system here which demands a level of compromise.

7.3.4 Implications for Methodology

This research has raised methodological issues including specific problems related to the instrument used in the quantitative phase. Although the quantitative and qualitative methods gave broadly similar results, and some discrepancies are to be expected, there were some differences which raise concern. For example, the qualitative survey indicated a more naïve belief-set than did the quantitative survey. Specifically, the qualitative survey indicated that seven of the twelve teachers held naïve beliefs in respect to socio-cultural embeddedness, whereas only 4 % of the 277 teachers in the quantitative sample were in the naïve category for this tenet. This classification, however, in the quantitative survey depended entirely upon the boundaries used for naïve/borderline views, and this, in turn, depended upon the number of items contributing to the tenet. As more items were included within the set contributing to a particular tenet, so the score was likely to regress towards the mean (3), making comparisons between tenets difficult (Coolican, 2004).

Because the items contributing to each tenet are not entirely explicit to the reader, even in Chen's (2006) original VOSE model, and because the interpretation of some items contributing to each tenet is open to question and subject to cultural values, great care is needed to establish the precise boundaries between naïve, borderline and sophisticated views. Even after critique of the survey in a Palestinian context by seven academics, and piloting amongst 35 science teachers, in retrospect it is unclear whether the quantitative survey was unambiguous in use or interpretation. For these reasons, quantitative surveys of the VOSE type should be used with caution, and I do not consider this survey to be as reliable as the qualitative interview format which followed.

In fact, the statistical analysis of questionnaires such as VOSE is not straightforward, and requires great caution in interpretation. In the first place, the variables are treated as pseudo-continuous and are bounded between one and five, making the application of parametric statistical methods inappropriate. More importantly, each tenet is composed of between three and 31 separate items, which are simply averaged to obtain the mean tenet scores for each teacher. This in part contributes to the pseudo-continuous nature of the distributions seen in Figure 4.1, e.g., "The Scientific Method" included six items, divisible by three and giving category increments of 0.33, and "Subjectivity/Objectivity" included the greatest number of items (31), leading to the smallest spread in the data.

Furthermore, perhaps most importantly, although a Likert scale is interpreted by the respondent at the point of completing the questionnaire as ranging from one (total disagreement) to five (total agreement), mean scores cannot be interpreted in this way. An overall mean of 3.5 is a statistical construct indicating that the subject has agreed with slightly more items than they have disagreed with; it does not mean they slightly agree overall. This is not particularly a criticism of the VOSE questionnaire, but of this type of instrument more generally. For example, the interpretation and implementation of student satisfaction or attitudinal surveys needs careful consideration and caution in the interpretation of the data generated.

For these reasons, it would be more meaningful to examine responses to individual items and see the overall naïve pattern of responses of Palestinian science teachers. However, undertaking this analysis and reporting for 55 items is unwieldy, particularly with such a large sample. For this reason it is more appropriate to place greater weight on the responses of the 12 science teachers interviewed in depth. In addition, it is also possible to have confidence in the responses to individual items in the questionnaires. This is because although at the level of individual tenet the quantitative and qualitative findings do not always closely correspond, at an item level findings are virtually identical in the two phases. This indicates that the use of triangulation in this study was successful in improving its validity and reliability.

In fact, from a methodological point of view, the triangulation technique is useful in the sense that it provides the opportunity for the researchers to validate their findings from different perspectives (Creswell, 1998). In this study, Palestinian science teachers' views of NOS were investigated using a quantitative closed questionnaire, a qualitative open-ended questionnaire and a follow up semi-structured interview, an approach termed "multiple methods triangulation" (Branen, 1992). The nature, causes and context of the teachers' views of NOS were investigated using interviews with different groups of stakeholders: academics, curriculum designers, education supervisors and teacher trainers, an approach termed "data source triangulation" (Branen, (1992). Therefore, I can argue that the use of a variety of data collection methods and stakeholders has increased the validity and richness of my data and findings.

7.3.5 Implications for Theoretical Frameworks

The findings of this study concerning teachers' views of NOS revealed that individual participants did not have comprehensive and coherent views and ideas that can fit to a specific philosophy of science such as inductivism, positivism or logical positivism. Rather, each participant was found to have a collection of views and beliefs that might correspond to different philosophical views of science. Consequently, it is not appropriate, and might be misleading, to apply philosophical labels to teachers as empiricists or positivists, for example, in light of their understanding of NOS as has been done in some research (Dibbs, 1982; Chen, 2001). Rather, I argue that this thesis has adopted a successful and productive approach to analyzing teachers' views of NOS in light of the eight tenets of NOS that were used in the second, more specific, tier of the framework of the analysis (Abd El Khalick, 1998). The study was successful in searching for consistencies or inconsistencies between the participants' views on a tenet-by-tenet basis, without labelling participants as affiliated to a certain philosophical view of science, and I would recommend this approach for future research in this topic. I would also encourage researchers of this topic to utilize VNOS-C as an open-ended questionnaire followed by a carefully pre-planned, semi-structured interview, as it worked successfully and enabled me to identify teachers' views of NOS thoroughly and effectively. The combination of VNOS-C and follow-up interviews provided very rich opportunities for the participants to reflect on their understanding and thinking about NOS that allowed me to get to the heart of their views and understanding of the topic.

However, caution should be taken to avoid getting trapped into a rigid theoretical framework that portrays science as subjective, tentative, or culturally/personally/politically/financially motivated, because this will promote the idea that all science knowledge has these features. Rather we want teachers and learners to develop an authentic view of science, recognising its power and its limitations, and that while striving to be objective, permanent and universal well, as a human endeavour, sometimes fall short of these ideals. When establishing a theoretical framework or developing the research instruments to explore stakeholders' conceptions of NOS, more emphasis should be directed toward identifying where the views sit on the continuum; in other words, the extent to which these traits (such as the objective versus subjective, or the tentative versus permanent nature of science) exist in science rather than imposing a "black or white" classification (Millar, 2010, pers.comm).

The above consideration of the implications of my research has illuminated that my thesis has evolved from a specific focus on NOS to an exploration of broader issues that impact, not only on NOS, but on the quality of science education in Palestine more generally. If these significant and broader issues facing education in Palestine are addressed, then an inevitable consequence will be a positive impact on an understanding of NOS.

7.4 Significance and Contribution of the Study

I would argue that it is only when we understand what teachers know and think about their own beliefs and practices in Palestine, can we then design pre- and in-service teacher education programmes to help them question their own beliefs and assumptions, and improve their practices, thereby improving the learning of science in the country. An argument that has been developed through this research is that the main goal of science education in contemporary societies is the preparation of a scientifically literate public who can contribute to society and participate effectively in everyday decision making processes. I strongly believe that scientific literacy is more about an authentic and informed understanding of NOS than about knowing a vast body of facts. Obviously, to achieve this ambitious target of a scientifically literate society, there needs to be a body of qualified and capable teachers who hold mature understanding of the nature of their subject.

The significance and contribution of this research lies in its success in illuminating the nature and likely origins of Palestinian science teachers' views of NOS, and identifying possible ways to advance their understanding. While the focus throughout this study has been on improving understanding of NOS, I believe these insights and particularly the recommendations put forward could have a much broader contribution to the success of pre- and in-service teacher education, and therefore secondary science education in Palestine. The research is a foundation and a starting point for further research in this area, and as such, fills a significant gap in the Palestinian literature as it is the first piece of research in the Palestinian context to address these issues. It lays down a solid foundation for researchers in many interesting and important related areas that might be directed to improve teachers' views of NOS. It creates thoughtful awareness about the vital necessity of advancing teachers' views of NOS, supporting the argument that has been developed through this thesis concerning the essential need to improve teachers' views of NOS in order to develop science teaching in Palestine, and avoid the potential problems resulting from teachers' naïveté of the topic.

The study has revealed beliefs among teachers in the dogmatism of science and the access to a single "reality" through science. A possible relationship between these views of science and a radical political perspective has been questioned by some academics. At worst there is the potential that this position might develop into extremism within Palestinian society. Consequently, the study stresses the necessity to adopt suitable conceptual change strategies to tackle these views of NOS and improve their understanding of the topic.

Another aspect that reflects the significance and contribution of this research for the Palestinian context lies in its attempt to delineate the relationship between teachers' views of NOS and their religious and socio-cultural beliefs. Most interestingly, this study has identified for the first time the motivation of teachers for teaching science in Palestine, which is related to the conflation of religious knowledge and scientific knowledge. A major motivation of many Palestinian teachers to teach science in Palestine is to do their best while teaching to "prove" religion via related science evidence, which suggests to me that, for many of them, NOS is not really part of their mindset, especially because they also believe that all branches of knowledge have their roots in the Quran and have arisen from there. I regard this belief to be dangerous and challenging, because it suggests that science teaching in Palestine is done to reinforce the authority of religion, and that might explain why teachers might reject more sophisticated views of NOS. Traditional views of NOS support their more fundamental belief system.

So while this is a sensitive and challenging issue, I think that understanding how teachers' socio-cultural and religious beliefs and values affect their understanding and viewing of NOS is valuable. Reiss (2010) argues that for people who are religious, which is the case for most Palestinian teachers, their scientific knowledge is a subset of their religious knowledge. Consequently, this science and religion issue must be taken into consideration when designing teacher training programmes or science curricula, as explained earlier in this chapter.

This study plants a seed for more rigorous research into how the socio-cultural beliefs and values teachers hold about science influence their teaching of science in an eastern and predominantly Muslim context, and what (and how) science should be taught in a way to promote harmony between science and religion in such a cultural context.

7.5 Limitations of the Study

As with most research in social science (Strauss and Cobern, 1998), this study is subject to several limitations inherent in the sample selection, methodology and data collection, analysis and interpretations that might have affected the findings. The major limitations of the study include the following:

1. The turbulent and volatile political situation in Palestine prevented me from having access to educators in the Gaza Strip, which would have increased the representativeness of the data.
2. Concerning the sample selection of teachers, there are two issues I regard as potential limitations of the study:
    - The study was conducted on Palestinian in-service science teachers who work in the public sector. Teachers who work in the private sector or with UNRWA schools (about 12 % of the total number of teachers) have been excluded from the study because the policy, supervision, administration, and training followed in these schools are different from those in public schools.
    - When conducting the open-ended questionnaire and the follow-up interviews in the second phase of data collection, teachers whose academic qualification was only a General Science Teaching Diploma (two years of study in a college) were excluded from the study because a decision has been made by MoEHE to qualify these teachers with a Bachelor degree in Science Education within the following three years (MoEHE, 2007). Teachers who had their degree from Al-Quds Open University were also excluded from the study because the teaching/learning process and the curricula utilised in this university are different from those in the traditional universities in Palestine.
3. Given the volatility of the Palestinian political situation, both within the country and with Israel, it is acknowledged that the validity of my

recommendations could be affected by political change. This, however, is the case with research in many countries.

4. The explanation of teachers' views of NOS and the possible ways to improve their understanding of NOS were formulated from the interviews conducted with the academics, teacher supervisors, in-service teacher trainers and textbook authors. These stakeholders were used as the main source to answer two of the research questions. As such, they remain perceptions and views based on their experience and own evidence, rather than on evidence generated in this study. It was beyond the scope of this study to attempt to validate these perceptions. Rather, a detailed description of the roles, qualifications and experience of the participants has been offered to support the reader when considering the validity of these perceptions.
5. As Merriam (1988) asserts, all analyses in qualitative investigations are filtered through the investigator's world views, values and perspectives. I conducted all the interviews, and analysed and interpreted my data. It is likely that my findings were influenced in some way by my beliefs, experiences and biases. I am aware that achieving complete objectivity is difficult, especially as I am part of the context, being a lecturer in teacher training and a devout Muslim. I found it necessary to reflect on, and moderate, my biases and prejudices during all phases of my research. I must also acknowledge that I am very keen to improve views of NOS in Palestine, which might have led to a bias in my reporting.

However, despite the above imitations, I believe my research findings and recommendations have the validity and reliability required to make a significant contribution to the understanding in the area.

7.6 Recommendations for Future Research

This research has established the foundation for many future studies, as several important questions have been raised in the study that merit investigation. In light of the discussion of my findings, I would recommend the following areas for future research.

First, the findings of this study suggest that teachers' socio-cultural and religious beliefs and values affect their understanding and views of NOS. Consequently, an interesting line of research would be to examine in more detail this relationship and the interplay between teachers' views of NOS and their religious and world views, and the extent to which religious and metaphysical concepts promote or impede their understanding of scientific practices. There is also a need to study the extent to which teachers project their religious and socio-cultural understanding of science into classroom discourses, and to what extent their social and cultural values might affect their teaching and the implementation of the curriculum. Future research should continue to investigate what socio-cultural and religious factors significantly influence teachers' interpretation of NOS and drive their teaching.

Second, as an extension of this study to explore possible ways of improving teachers' and learners' understanding of NOS, future research might study the nature and extent of the relationship between teachers' and their learners' views of NOS. This would relate to an exploration of the relationship between the views that teachers hold of NOS and their actual practices in their classrooms, and the factors within the Palestinian context that might affect this relationship translation of teachers' views of NOS and their actual practices.

Third, since the study has raised the issue of the effectiveness of educational leadership and the administrative system, I suggest that the MoEHE, with support from international education organizations who are currently assisting the Ministry financially and with expertise, conducts a review and evaluation of its administrative structures and practices related to teacher education. Similarly, a series of in-depth reviews of the structure and effectiveness (in relation to NOS) of current pre- and in-service teacher training programmes, undergraduate science education, educational supervision, and the school science curriculum would provide the foundation on detailed proposals could be made.

Additionally, the significant gap in the literature on strategies to induce conceptual change within the area of NOS needs to be addressed. In parallel to this research, it seems important in Palestine to study the views of NOS held by undergraduate science teachers, science educators, teacher trainers and education supervisors, because their views of NOS could have a significant impact on the development of teachers' views of the topic.

Finally, further research is needed to investigate teachers' configurations of their views of NOS and the conditions that effectively shape their views.

7.7 Concluding Remark

In conclusion, while I am aware of the extensive body of research in the area of NOS, and the challenges that I have identified, I hope and believe that my study will be a catalyst for real change in science education in Palestine. My research has strengthened my own belief that an area as fundamental as the nature of the subject is the right place to start any serious attempts at curriculum reform in Palestine. I have thoroughly enjoyed my study and am excited about the prospect of taking my recommendations further.

References

Abd El Khalick, F. (1998). *The influence of history of science courses on students' conceptions of the nature of science.* Unpublished PhD Dissertation, Oregon State University, Oregon.

Abd El Khalick, F. (2001). Embedding nature of science instruction in pre-service elementary science courses: Abandoning scientism, but ... *Journal of Science Teacher Education*, 12(3), 215–233.

Abd El Khalick, F. (2005). Developing deeper understandings of nature of science: The impact of a philosophy of science course on pre-service science teachers' views and instructional planning. *International Journal of Science Education*, 27(1), 15-42.

Abd El Khalick, F. (2006). Over and over and over again: College students' views of nature of science. In L. B. Flick and N. G. Lederman (eds). *Scientific Inquiry and Nature of Science*, 389-425. The Netherlands: Kluwer Academic Publishers.

Abd El Khalick, F. and Akerson, V. (2009). The influence of metacognitive training on pre-service elementary teachers' conceptions of nature of science. *International Journal of Science Education*, 31(16), 2161-2184.

Abd El Khalick, F. and Akerson, V. L. (2004). Learning about nature of science as conceptual change: Factors that mediate the development of pre-service elementary teachers' views of nature of science. *Science Education*, 88(5), 785-610.

Abd El Khalick, F. and BouJaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching*, 34(7), 673–699.

Abd El Khalick, F. and Lederman, N. (2000a). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching*, 37(10), 1057–1095.

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

Abd El Khalick, F., Bell, R. and Lederman, N. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, 82(4), 417–437.

Abd El Khalick, F., Waters, M. and Le, A. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, 45(7), 835-855.

Abimbola, I. (1983). The relevance of the "new" philosophy of science for science curriculum. *School Science and Mathematics*, 83(3), 181-193.

Ackay, B. (2007). *The influence of a history of science course on pre-service science teachers' understanding of the nature of science concepts*. Unpublished PhD dissertation, The University of Iowa.

Adams, S. (2000). *The relationship between teachers' understanding of the nature of science and their science practice: Four case studies from urban primary schools*. Unpublished PhD Thesis. University of Plymouth.

Aikenhead, G. (1987a). 'High school graduates' beliefs about science technology- society: Characteristics and limitations of science knowledge'. *Science Education*, (71), 459-487.

Aikenhead, G. (1987b). High-School graduates' beliefs about Science-Technology and Society: Methods and issues in monitoring student views. *Science Education*, 71, 145-161.

Aikenhead, G. and Ryan, A. (1992). The development of a new instrument: "Views on science technology-society" (VOSTS). *Science Education*, (76) 477-491.

Aikenhead, G., Fleming, R. and Ryan, A. G. (1987). High-school graduates beliefs about science-technology-society: Methods and issues in monitoring student views. *Science Education*, 71(2), 145-161.

Akerson, V. and Abd El Khalick, F. (2003). Teaching elements of nature of science: A yearlong case study of a fourth-grade teacher. *Journal of research in science Teaching*, 40(10), 1025-1049.

Akerson, V. and Hanuscin, D. (2007). Teaching nature of science through inquiry: Results of a 3-year professional development programme. *Journal of Research in Science Teaching*, 44(5), 653-680.

Akerson, V., Abd El Khalick, F. and 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.

Al Haq, (2005). *Palestinian education under Israeli occupation*. Paper presented at the conference on International Law in the Shadow of Israeli Occupation. Stockholm, Sweden.

Al Hayani, F. (2005). Islam and science: Contradiction or concordance. *Zygon*, 40 (3), 565-576.

Ali, D. (1998). Scientific literacy in Sudani Year 9 Chemistry curriculum. *Unpublished Masters Dissertation*. Yarmouk University, Irbid.

Allen, N. J. and Crawley, F. E. (1998). Voices from the bridge: Worldview conflicts of Kickapoo students of science. *Journal of Research in Science Teaching*, 35(2), 111-132.

Alters, B. (1997). Whose nature of science? *Journal of Research in Science Teaching*, 34, 39-55.

American Association for the Advancement of Science. (1989). *Project 2061: Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science. (1992). *Up Date, project 2061, Education for A Changing Future*: AAAS publications.

American Association for the Advancement of Science. (1993). *Benchmarks for scientific literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (1997). *Resources for science literacy: Professional development*. New York: Oxford University Press.

American Advancement of Association of Science. (2001). *Atlas of Scientific Literacy*. New York: Oxford University Press.

Anderson, G. and Arsenault, N. (1998). *Fundamentals of Educational Research (2nd ed.)*. London: Falmer Press.

Anderson, H. (1998). *Readings in Science Education in Secondary Schools*. New York: McMillan.

Assessment and Evaluation Department, MoEHE. (2007). *Trends in International Mathematics and Science Study (TIMSS)*. Ramallah, Palestine. (Arabic)

Assessment and Evaluation Department, MoEHE. (2008). *Results of the National Evaluation Study in Arabic, Mathematics, and Science for Tenth Graders in Palestine in the Scholastic Year 2007/2008.* (Arabic)

Ayasreh, M. (1985). *Growth of scientific attitudes and understanding of the nature of science of Jordanian secondary school students*. Unpublished Masters Dissertation, The University of Jordan, Amman. (Arabic)

Badran, N. (1979). *Education and Development in the Arabic Palestinian Community* (1947-1967). Beirut: Research Centre of the Palestinian Liberation Organisation. (Arabic)

Banf, M. (1990). *An examination of social studies pedagogies in terms of the styles of the teacher-pupil intellectual transactions in the secondary schools in plateau state, Nigeria.* Unpublished PhD Dissertation, Nottingham University.

Barufaldi, J., Bethel, L. and Lamb, W. (1977). The effect of science methods course on the philosophical view of science among elementary education majors. *Journal of Research in Science Teaching, 14(4),* 289-294.

Beach, D. M. and Reinhartz, J. (1989). *Supervision: Focus on Instruction,* New York: Harper and Row Publishers.

Behnke, F. (1961). Reactions of scientists and science teachers to statement bearing on certain aspects of science and science teaching. *School Science and Mathematics*, 61, 193-207.

Bell, J. (1999). *Doing Your Research Project (3rd ed.).* Buckingham: Open University Press.

Bell, J., Bush, T., Fox, A., Goodey, J. and Goulding, S. (1984). *Conducting Small Scale Investigations in Educational Management.* London: Harper and Row Publishers.

Bell, R., and Matkins, J. (2003). *Learning about the nature of science in an elementary science methods course: Content vs. context.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Bentley, M., and Garrison, J. W. (1991). The role of philosophy of science in science teacher education. *Journal of Science Teacher Education*, 2(3), 67-71.

Billeh, V. and Hasan, O. (1975). Factors affecting teachers' gain in understanding the nature of science. *Journal of Research in Science Teaching*, 12(3), 209-219.

Black, P. and William, D. (1998). *Inside the black box: raising standards through classroom assessment. Phi Delta Kappan*, 80(2), 130-144.

Blades, W. (1997). *Procedures of Power and Curriculum Change; Foucault and the Quest for Possibilities in Science Education.* New York: Peter Lang Publishing.

Bloom, M. (2008). *The effect of professional development intervention on in-service teachers' conceptions of nature of science.* Unpublished PhD Dissertation. Texas Christian University.

Bogdan, R. and Biklen, S. (1992). *Qualitative Research for Education: an Introduction for Theory and Methods*. Boston: Allyn and Bacon.

BouJaoude, S. (1999). Scientific literacy in the new Lebanese science curriculum. In Fawzi, A. (ed.). *Lebanese New Instructional Curricula: An Evaluative Perspective*. Beirut: Lebanese Committee for Educational Sciences (Arabic).

Brannen, J. (1992). Combining qualitative and quantitative approaches: an overview. In J. Brannen (ed). *Mixing Methods: Qualitative and Quantitative Research*, 3–37. Avebury: Aldershot.

Brickhouse, N. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education,* 41(3), 53-62.

Brickhouse, N. (1998). Feminism(s) and science education. In Fraser, B. J. and Tobin, K. G. (eds.). *International Handbook of Science Education*, 1067-1081. Great Britain: Kluwer Academic Publishers

Brickhouse, N. and Bodner, G. (1992). The beginning science teacher: Classroom narratives of convictions and constraints. *Journal of Research in Science Teaching*, 29, 471-485.

Brooks, K. (2008). *A content analysis of physics science textbooks with regard to the nature of science and ethnic diversity*. Unpublished PhD Dissertation, University of Houston, Houston.

Brown, H. (1977). *Perceptions, Theory and Commitment: The New Philosophy of Science*. Chicago: University of Chicago Press.

Bryman, A. (1994). The mead/freeman controversy: some implications for qualitative researchers. In R. G. Burgess (ed). *Studies in Qualitative Methodology* (Volume 4). Greenwich: Conn, JAI Press.

Bryman, A. (2001). *Social Research Methods.* Oxford: Oxford University press.

Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done?. *Qualitative Research*, 6(1), 97-113.

Bryman, A. and Burgess, R. (1994). Development in qualitative data analysis: an introduction. In A. Bryman and R. G. Burgess (eds). *Analyzing Qualitative Data.* London: Rutledge.

Burbules, N. and Linn, M.C. (1991). Science education and the philosophy of science: Congruence or contradiction? *International Journal of Science Education*, 13(3), 227-242.

Bybee, R. (2000). Teaching science as inquiry. In J. Minstrell and E. van Zee (eds.), *Inquiring into inquiry learning and teaching in science*, 20-46. Washington, DC: American Association for the Advancement of Science.

Bybee, R. and De Boer, G. (1994). Research on goals for the scientific curricula. In D.L. Gabel. *Handbook of Research on Science Teaching and Learning*. New York: McMillan.

Cakir, M. and Crawford, B. (2004). Enhancing prospective science teachers' understandings of scientific inquiry and Mendelian genetics using computer simulation. *Paper presented at the Annual International Conference of the National Association for Research in Science Teaching*, Vancouver.

Campell, D. and Fisk, D. (1959). Convergent and discriminate validation by the multitrait-multimethod matrix. *Psychological Bulletin*, 56, 81-105.

Carey, R. and Stauss, N. G. (1968). An analysis of the understanding of the nature of science by prospective secondary science teachers. *Science Education*, 52(4), 358-363.

Carey, R. L., and Stauss, N. G. (1970). An analysis of experienced science teachers' understanding of the nature of science. *School Science and Mathematics*, 70(5), 366-376

Carey, S., Evans, R., Honda, M., Jay, E. and Unger, C. (1989). An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education*, 11, 514-529.

Chalmers, A. (1999). *What is the Thing Called Science (3rd ed)*. Buckingham: Open University Press.

Cheek, D. W. (1992). *Thinking Constructively about Science, Technology and Society Education*. New York: State University of New York Press.

Chen, S. (2001). *Prospective teachers' views of the nature of science and science teaching*. Unpublished PhD Dissertation, Indiana University.

Chen, S. (2006). Development of an instrument to assess views on nature of science and attitudes toward teaching science. *Science Education*, 90, 803-819.

Chiappetta, E. and Collete, A. (1984). *Science Instruction in the Middle and Secondary Schools*. St. Louis: Times Mirror Mosby.

Chiappetta, E. and Fillman, G. (1987). Curriculum balance in science textbooks, *Texas Science Teacher*, 16 (2), 9-12.

Chiappetta, E. and Fillman, G. (1993a). A Quantitative analysis of high school chemistry textbooks for scientific literacy themes and expository learning aids. *Journal of Research in Science Teaching*, 28, 939-951.

Chiappetta, E. and Fillman, G. (1993b). Do middle school Life science textbooks provide a balance of scientific literacy themes. *Journal of Research in Science Teaching*, 30, 787-797.

Chiappetta, E. and Fillman, G. (2005). *Analysis of five high school Biology textbooks used in the United States for inclusion of the nature of science*. Paper presented at the National Association for Research in Science Teaching meeting. Dallas, TX.

Chiappetta, E. L. Fillman D. and Sethna, G. (1991). *Procedures for Conducting Content Analysis of Science Textbooks*. Houston: Houston University.

Chiappetta, E. L. Fillman D. and Sethna, G. (1993). Do middle school life science textbooks provide a balance of scientific literacy themes, *Journal of research in science Teaching*, 30, 787-797.

Chinn, C. and Malhotra, B. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86, 175-219.*

Chun, S. (2000). *An examination of the relationship among science teaching actions, beliefs and knowledge of the nature of science.* Unpublished PhD Dissertation. University of Georgia.

Cimer, A. (2004). *A study of Turkish biology teachers' and students' views of effective teaching for improving teaching in schools and teachers education*. Unpublished PhD Thesis, University of Nottingham.

Clandinin , D. and Connelly, F. (1987). Teachers' personal knowledge: What counts as 'personal' in the studies of the personal?. *Journal of Curriculum Studies*, 19, 487-500.

Clement, J. (1988). Observed methods for generating analogies in scientific problem solving. *Cognitive Science, 12*, 563-586.

Clement, J. (1989). Learning via model construction and criticism: Protocol evidence on sources of creativity in science. In Glover, J., Ronning, R., and Reynolds, C. (ed.), *Handbook of Creativity Assessment: Theory and Research*, 341-381. Plenum: NY.

Cobb, B. (1994). Constructivism in mathematics and science education. *Educational Researcher*, 23(7), 4-7.

Cobern, W. and Loving, C. (2000). Scientific worldviews: A case study of four high school science teachers. *Electronic Journal of Science Education*, 5(2), 1–26.

Cohen, L. and Manion, L. (2000). *Research Methods in Education*. New York: Roultedge.

Connely, F. and Claudinin, D. (1988). *Teachers as Curriculum Planners*, New York: Teachers College Press.

Cooley, W. and Klopfer, L. (1961). *Test on Understanding Science, Form W, Princeton*. NJ: Educational Testing Service.

Coolican, H. (2004). *Research Methods and Statistics in Psychology* (4th ed). London: Hodder Headline.

Creswell, J. (1994). *Research Design: Qualitative and Quantitative Approaches*, Thousand Oakes CA: Sage.

Creswell, J. (2003). *Research Design: Quantitative ,Qualitative, and Mixed Methods* (2nd ed). London: Sage.

Creswell, J. and Clark, V. (2006). *Designing and Conducting Mixed Methods Research*. Thousand Oakes: Sage.

Cunningham, J. and Fitzgerald, J. (1996). Epistemology and reading. *Reading Research Quarterly*, 31(1), 36-60.

Curd, M. and Cover, J. (eds). (1998). *Philosophy of Science: The Central Issues*. New York: W.W. Norton.

Dagher, Z. And BouJaoude, S. (1997). Scientific views and religious beliefs of college students: The case of biological evolution. *Journal of Research in Science Teaching*, 34(5), 429-445.

DCSF, (2004). *The Science National Curriculum for England*. London.

DCSF, (2008). *The Science National Curriculum for England*. London.

Deboer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, 37(6), 582-601.

Dennis, L. and Thomas J. (1994). Analyzing data measured by individual Likert-type items, *Journal of Agricultural Education*, 35(4), 437-440.

Denzin, N. and Lincoln (2000). *Handbook of Qualitative Research* (2nd ed). London: Sage.

DfES/QCA . (2004). *The Science National Curriculum for England*. London.

DfES/QCA. (1995). *The Science National Curriculum for England*. London.

Dibbs, D. (1982). *An investigation into the nature and consequences of teachers' implicit philosophies of science*. Unpublished PhD Thesis, University of Birmingham.

Dinc, E. (2005). *The European Dimension in the Turkish History Curriculum: An Investigation*. Unpublished PhD Thesis, University of Nottingham.

Discenna, J. L. and Howse, M. A. (1998). *Biology and physics students' beliefs about science and science learning in non-traditional classrooms*. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.

Dogan, N. and 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, E. (1995). *Using Semi-Structured Interviews in Small Scale Research*. Edinburgh: The Scottish Council for Research in Education.

Driver, R. (1986). Pupils' alternative frameworks in science. *Science in Schools*, 56(4), 286-278.

Driver, R. and Bell, B. (1986). Students' thinking and the learning of science: a constructivist view. *School Science Review*, 67:434-456.

Driver, R., Asoko, H., Leach. J., Mortimer, E. and Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5-12.

Driver, R., Leach, J., Millar, R. and Scott, P. (1996). *Young People's Images of Science*. Buckingham: Open University Press.

Duell, O. and Schommer, M. (2001). Measures of people's beliefs about knowledge and learning. *Education Psychology Review*, 13(4), 419-449.

Duit, R. (1994). *The constructivist view in science education: what it has to offer and what shouldn't be expected from it*. Paper presented at the Science and Mathematics for the 21st Century: Towards Innovatory Approaches, Chile.

Dunbar, K. (2001). What scientific thinking reveals about the nature of cognition. In K. Crowley, C. Shunn, and T. Okada (eds.), *Designing for Science: Implications from Everyday Classroom and Professional Settings*. Mahwah, NJ: Lawrence Erlbaum Associations, Inc.

Durkee, P. (1974). An analysis of the appropriateness and utilization of TOUS with special reference to high-ability students studying physics. *Science Education*, 58(3), 343–356.

Durkee, P. and Cossman, G. (1976). *Views on the nature of science among college science faculty*. Paper presented at the 49th annual meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Duschl, R. (1990). *Restructuring Science Education: The Importance of Theories and Their Development*. New York: Teacher College.

Duschl, R. and Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of Research in Science Teaching*, 262, 467-501.

Dzama, E. and Osborne, J. (1999). Poor performance in science among African students: An alternative explanation to the African worldview thesis. *Journal of Research in Science Teaching*, 36(3), 387–405.

Educational Network (1990). The Situation of Palestinian schools under occupation. *Educational Network Report*. Ramallah. (Arabic)

Eick, C. (2000). Inquiry, nature of science, and evolution: the need for a more complex pedagogical content knowledge in science teaching. *Electronic Journal of Science Education,* 4(3). Retrieved from http://unr.edu/homepage/crowther/esje

El Muhtaseb, S. (1994). *A training program for science teachers at the basic educational stage in Jordan for improving their classroom performance within the light of the conceptions of the nature of science and its process*. Unpublished PhD Thesis. The University of Jordan, Amman. (Arabic)

El Sheikh, O. (2002). Elementary school students' epistemological beliefs of science in Jordan. *The Teacher Mission*, 16(1): 43-58. (Arabic)

Fazio, X. (2005). *Exploring teachers' beliefs and knowledge about scientific inquiry and the nature of science: A collaborative action research project*. Unpublished PhD Dissertation, University of Toronto.

Fazio, X. and Melvilleb, W. (2008). Science teacher development through collaborative action research, *Teacher Development,* 12(3), 193-209.

Fenstermacher, G. D. (1986). Philosophy of research in teaching: three aspects. In M. C. Wittrock (ed). *Handbook of Research on Teaching,* New York: MacMillan.

Feyerabend (1975). *Against Method.* New York: Verso.

Fielding, N. and Fielding, J. (1986). *Linking Data: The Articulation of Qualitative and Quantitative Methods in Social Research.* Beverly Hills, CA: Sage.

Freire, P. (1970). *Pedagogy of the Oppressed.* New York: Continuum.

Gabel, D. L., Rubba, P. A., and Franz, J. R. (1977). The effect of early teaching and training experiences on physics achievement, attitude toward science and science teaching, and process skill proficiency. *Science Education*, 61, 503-511.

Gallagher, J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the history and philosophy of science, *Science Education*, 75(1), 121-134.

Galton, M., Simon, B. and Croll, P. (1980). *Inside Primary Classrooms.* London: Routledge.

Gao. L. and Watkins, D. (2002). Conceptions of teaching held by school science teachers in China: identification and cross-cultural comparisons, *International Journal of Science Education*, 24(1), 61-79.

Garcia, T. D. (1985). *An analysis of earth science textbooks for presentation of aspects of scientific literacy.* Unpublished Doctoral Dissertation, University of Houston.

Gess-Newsome, J. (2002). The use and impact of explicit instruction about the nature of science and science inquiry in an elementary science methods course. *Science Education*, 11, 55-67.

Giacaman, R. Abdullah, A. Abu Safieh, R. and Shamieh, L. (2002). *Schooling at Gunpoint: Palestinian Children's Learning Environment in War Like Conditions*. Palestine: Birzeit University.

Giddens, A. (1990). The Consequences of Modernity. Cambridge: Polity Press.

Glaser, B. and Strauss, A. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research.* New York: Aldine De Gruyter.

Gobrium, J. and Holstein, J. A. (1997). *The New Language of Qualitative* Method. New York: Oxford University Press.

Good and McCaslin, M. M. (1992). Teacher effectiveness. *Encyclopaedia of Educational Research.* New York, Volume 4, 137-186.

Good, R., Anderson, O.R., Chiappetta, E.L., Cummins, C.L., DeBoer, G.E., Felske, D., Gess-Newsome, J., Lawson, A., Lederman, N.G., McComas, W.F., Smith, M.U. and Staver, J. (2000). *Guidelines for nature of science (NOS) researchers*. Symposium conducted at the annual meeting of the National Association for Research in Science Teaching. New Orleans, LA.

Good, R., Lederman, N., Gess-Newsome, J., McComas,W. and Cummins, C. (2000). *Nature of science: Implications for research, assessment, and teacher education*. A symposium paper presented at the annual international meeting of the Association for the Education of Teachers in Science. Akron, OH.

Greelan, D. (1997). Epistemological anarchy and the many forms of constructivism. *Science and Education*, 6, 15-28.

Greene, J. C., Caracelli, V. J. and Graham, W. (1989). Toward a conceptual framework for mixed method evaluation designs. *Educational Evaluation and Policy Analysis*, 11, 255-274.

Griffiths, A. and Barry, M. (1993). High school students' views about the NOS. *School Science and Mathematics*, 93(1), 35-37.

Gronlund, N. (1981). *Measurement and Evaluation in Teaching.* New York: MacMillan.

Guba, E. and Lincoln, Y. (1982). Epistemological and methodological bases of naturalistic enquiry. *Educational Communication and Technology Journal*, 30, 233-252.

Hacking, I. (1983). *Representing and Intervening*. New York: Cambridge University.

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

Halai, N. and McNicholl, J. (2004). Teachers' conceptions of the nature of science: a comparative study for Pakistan and England. *School Science Review*, 86 (314), 93-99.

Hammersley, M. (1992). *What's Wrong with Ethnography: Methodological Explorations.* London: Routledge.

Hammersley, M. (1993). *Educational research: Current Issues*. London: Open University.

Hammersley, M. (1995). Opening up the qualitative-quantitative divide. *Education Section Review*, 19 (1), 2-29.

Hammersley, M. and Atkinson, P. (1995). *Ethnography: Principles in Practice* (2nd ed). London: Routledge.

Hand, R. J. (1999). Hard questions-easy science? Or why do scientists not teach philosophy?. *Teaching in Higher Education*, 4, 121-124.

Harms, N., and Yager, R. (eds.). (1981). *What Research Says to the Science Teacher*. Washington, DC: National Science Teachers Association.

Harris, B. (1980). *Improving Staff Performance Through In-service Education*. Boston: Allyn and Bacon.

Harris, K. (1979). *Education and Knowledge: The Structured Representation of Reality*. London: Routledge and Kegan Paul.

Harris, K. and Taylor (1983). Discovery learning in school science: the myth and reality. *Journal of Curriculum Studies*, 15 (3), 277-289.

Hashweh, M. (1986). Toward an explanation of conceptual change. *European Journal of Science Education*, 8(3), 229-249.

Hashweh, M. (1996). Palestinian science teachers' epistemological beliefs: A preliminary survey. *Research in Science Education*, 26(1), 89-102.

Hashweh, M. (2009). *University Education as a Conceptual Change Process*. Paper presented in the Ibin Rushd Educational Centre Conference, 'Future Higher Education in Palestine'. Birzeit University, Palestine.

Hashweh, M. and Hashweh, M. (1999) Higher education in Palestine: current status and recent developments. *Mediterranean Journal of Educational Studies*, 4 (2), 221-227.

Hashweh, M. et al., (2008). *Teacher Education Strategy in Palestine*. Ramallah: MoEHE.

Hashweh, M., Khaldi, M. and Mas'ad, F. (2004). *Report of the evaluation study of the Italian-funded project 181-ITA-33 (Strengthening the Ministry of Education of the Palestinian Authority Through the Use of Teaching Materials for Basic Education and the Training of Teachers).* International Institute of Educational Planning of UNESCO, Paris.

Hempel, C. (1966). Philosophy *of Natural Science*. USA: Prentice-Hall.

Henson, K. T. and Eller, B. F. (1999). *Educational Psychology for Effective Teaching*. Belmont: Wadsworth Publishing.

Herbert, M. (1990). *Planning a research project*. London: Cassel Education Limited.

Hewson, P. and Hewson, M. (1989). Analysis and use of a task for identifying conceptions of teaching science. *Journal of Education for Teaching*, 15(3), 191-209.

Hewson, P.W. (1981). A conceptual change approach to learning science. *European Journal of Science Education*, 3(4), 383–396.

Hockey, J. (1993). Research methods: Researching peers and familiar settings. *Research Papers in Education, 8*(2), 199 - 225.

Hodson, D. (1993a). Philosophic stance of secondary school science teachers, curriculum experiences, and children's understanding of science: Some preliminary findings. *Interchange*, 24, 41-52.

Hodson, D. (1993b). In search of a rationale for multicultural science education. *Science Education*, 77 (6), 685–711.

Hodson, D. (1998). *Teaching and Learning Science: Towards a Personalized Approach.* Philadelphia, PA: Open University Press.

Hofer, B. (2002). Personal epistemology as a psychological and educational construct: An introduction. In Hofer, B and Pintrich, P. (eds) *Personal Epistemology*, 3-14. Mahwah: Lawrence Earlbaum Association.

Hofer, B. K. and Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research,* 67, 88–140.

Holloway, I. (1997). *Basic Concepts for Qualitative Research*. Oxford: Blackwell Science.

Hurd, P. (1960). *Biological Education in American Secondary Schools, 1890-1960.* Washington: Rand-McNally.

Husen, T. (1997). Research paradigms in education. In J. P. Keeves (ed). *Educational Research: Methodology and Measurement: an International Handbook* (2nd ed), 16-21. Oxford: Pergamon.

Irwin, A. (2000). Historical case studies: Teaching the nature of science in context. *Science Education*, 84, 5-26.

Jegede, O., and Okebukola, P. (1991). The effect of instruction on socio-cultural beliefs hindering the learning of science. *Journal of Research in Science Teaching*, 28, 275-285.

Jenkins, E. (1997). Scientific and technological literacy for citizenship: What can we learn from the research and other evidence. In s. Sjoberg and E. Kallerud (eds). *Science, technology and Citizenship: The Public Understanding of Science and Technology in Science Education and Research Policy*, 29-50. Oslo: Norwegian Institute for Studies in Research and Higher Education.

Johnson, R. B. and Onwueghuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33 (3), 14-26.

Joyce, B., Weil, M. and Calhoun, E. (2000). *Models of Teaching*. Boston: Allyn and Bacon.

Kabaha, A. (2005). *A critical assessment of Palestinian higher education: current status and future prospective*. Unpublished PhD Thesis, University of Nottingham.

Kang, N. (2005). *Learning to teach science: Personal epistemologies, teaching goals, and practices of teaching*. Paper Presented at the American Educational Research Association, Montreal, Canada.

Kang, S., Scharmann, L., and Noh, T. (2004). Examining students' views on the nature of science: Results from Korean 6th, 8th, and 10th graders. *Science Education*, 89(2), 314–334.

Kattoula, E. (2007). *Conceptual change in pre-service science teachers' views on nature of science when learning a unit on the physics of waves,* Unpublished PhD Dissertation, University of Georgia State.

Khaldi, M. (1998). *The alternative conceptions held by grade-11 students in the topic chemical bonding*. Unpublished Masters Dissertation, Birzeit University. (Arabic)

Khaldi, M. (2004). Scientific literacy in the new Palestinian science curricula: An analytical and critical study. *Bethlehem University Research Journal*, 23, 8-38 (Arabic)

Khaldi, M. and Wahbeh, N. (2000). Teacher education in Palestine: Understanding teachers' realities and development through action research. In Ronald Sultana (edt), *Teacher Education in the Euro-Mediterranean Region*, 193-212. London. Peter Lang.

Khaldi, M. and Wahbeh, N. (2002). Teacher education in Palestine. In *Human Development Report: Palestine 2002*. Ramallah: Development Studies Program at Birzeit University. (Arabic)

Khaldi, M. and Wahbeh, N. (2003). *Current Situation of Educational Supervision in the Palestinian Schools.* Ramallah: Qattan Centre for Research and Development (Arabic).

Khishfe, R., and Abd El Khalick, F. (2002). The influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching,* 39(7), 551-578.

Khishfe, R. and Lederman, N. G. (2006). Teaching nature of science within a controversial topic: Integrated versus non-integrated. *Journal of Research in Science Teaching*, 43(4), 377–3 94.

Khishfe, R. and Lederman, N. (2007). Relationship between instructional context and views of nature of science. *International Journal of Science Education*, 29(8), 939-961.

Kim, S. (2007). *Genetics instruction with history of science: nature of science learning*. Unpublished PhD Dissertation, Ohio State University.

Kimball, M. E. (1967). Understanding the nature of science: A comparison of scientists and science teachers. *Journal of Research in Science Teaching*, 5 , 110-120.

Kinnear, P and Gray, C. (2006). *SPSS 14 Made Simple*. Sussex: Psychology Press.

Klopfer, L. and Cooley, W. (1963). The history of science cases for high schools in the development of student understanding of science and scientists. *Journal of Research in Science Teaching*, 1(1), 33–47.

Knorr-Cetina, K. (1999). *Epistemic Cultures: How the Sciences Make Knowledge*. Cambridge: Harvard University Press.

Kuhn, T. (1962). *The Structure of Scientific Revolutions* (2^{nd} ed). Chicago: The University of Chicago Press.

Kuhn, T. (1977). Objectivity, value judgment, and theory choice. In M. Curd and J. A. Cover (Eds.) (1998), *Philosophy of Science: The Central Issues,* 102-118. New York: W.W. Norton.

Kvale, S. (1996). *Interviews.* London: Sage.

Lakin, S. and Wellington, J. (1994). Who will teach the "nature of science"?: Teachers' views of science and their implications for science education. *International Journal of Science Education*, 16, 175-190.

Lankashear, C. and Knobel, M. (2004). *Teacher Research*. Maidenhead: Open University Press.

Lantz, O. and Kass, H. (1987). Chemistry teachers' functional paradigms. *Science Education*, 71, 117-134.

Laudan, L. (1984). Dissecting the holist picture of scientific change. In M. Curd and J. A. Cover (Eds.) (1998), *Philosophy of Science: The Central Issues*, 139-169. New York: W.W. Norton.

Lawson, A. E. (1982). The nature of advanced reasoning and science instruction. *Journal of Research in Science Teaching*, 19, 743-760.

Layder, D. (1993). *New Strategies in Social Research*. Cambridge: Polity.

Leach, J. Millar, R., Ryder, J. and Sere, M. (2000). Epistemological understanding in science teaching: The consistency of representations across contexts. *Learning and Instruction*, 10 (6), 497-527.

LeCompte, M. and Goetz, J. (1982). Problems of reliability and validity in ethnographic research. *Review of Educational Research*, 52(1), 30-42.

Lederman, J. S. and Ko, E. K. (2004). *Views of Nature of Science, Form E.* Unpublished Paper. Illinois Institute of Technology, Chicago IL.

Lederman, N. G. (1986). Relating teaching behaviour and classroom climate to changes in students' conceptions of the nature of science. *Science Education*, 70, 3-19

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching,* 29, 331-359.

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, 916-929.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell and N. G. Lederman (Eds.), *Handbook of Research in Science Education*. Englewood cliffs, NJ: Erlbaum Publishers.

Lederman, N. G. and Druger, M. (1985). Classroom factors related to changes in students' conceptions of the nature of science. *Journal of Research in Science Teaching*, 22, 649-662.

Lederman, N. G. and Lederman, J. S. (2004). Revising instruction to teach nature of science. *The Science Teacher*, 71(9), 36-39.

Lederman, N. G. and Lederman, J. S. (2006). *Teachers' professional development related to NOS and their students' understanding: closing the circle in explicit, reflective instruction about NOS*. Paper presented at the annual meeting of the National Association for Research in Science Teaching. San Francisco, CA.

Lederman, N. G. and O'Malley, M. (1990). Students' perceptions of tentativeness in science: Development, use, and sources of change. *Science Education*, 74, 225-239.

Lederman, N. G. and Zeidler, D. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behaviour?. *Science Education*, 71, 721-734.

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

Lederman, N. G., Wade, P. and Bell, R. (1998). Assessing understanding of the nature of science: A historical perspective. In McComas, W. (Ed.), *The Nature of Science in Science Education: Rationales and Strategies,* 331–350. The Netherlands: Kluwer Academic.

Lederman, N.G., Abd El Khalick, F., Bell, B. and Schwartz, R. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39, 497 - 521.

Liang, L. (2006). *Student understanding of science and scientific inquiry (SUSSI): Revision and further validation of an assessment instrument.* Paper presented in the 2006 annual conference of the NARST. San Francisco.

Liang, L., Chen, S., Chen, X., Kaya, O., Adams, A. , Macklin, M. and Ebenezer, J. (2008). *Assessing pre-service elementary teachers' views on the nature of scientific knowledge: a dual-response instrument.* Asia-Pacific Forum on Science Learning and Teaching.

Liang, L., Chen, S., Chen, X., Kaya, O., Adams, A., Macklin, M. and Ebenezer, J. (2009). Pre-service teachers' views about nature of scientific knowledge development: An international collaborative study. *International Journal of Science and Mathematics Education*, 7 (5), 987-1012.

Limon, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: a critical appraisal. *Learning and Instruction*, 11, 357-380.

Lin, H. and Chen, C. (2002). Promoting pre-service chemistry teachers' understanding about the nature of science through history. *Journal of Research in Science Teaching*, 39(9), 773-792.

Littledyke, M. (1998a). Constructivist ideas about learning. In M. littledyke and L. Huxford (eds). *Teaching the primary Curriculum for Constructive learning*, 1-16. London: David-Fulton Publishers.

Littledyke, M. (1998b). Teaching for constructive learning. In M. Littledyke and L. Huxford (eds). *Teaching the primary Curriculum for Constructive learning*. London: David Fulton Publishers.

Liu, S and Lederman, N. (2007). Exploring prospective teachers' worldviews and conceptions of nature of science. *International Journal of Science Education*, 29(10), 1281-1207.

Liu, S. (2003). *Conceptions of the nature of science and worldviews of pre-service elementary science teachers in Taiwan*. Unpublished PhD Dissertation, Oregon State University.

Liu, S. and Lederman, N. G. (2002). Taiwanese gifted students' views of nature of science. *School Science and Mathematics*, 102(3), 114-123.

Longino, H. (1990). Values and Objectivity. In M. Curd and J. A. Cover (Eds.), *Philosophy of Science: The Central Issues*, 170-191. New York: W.W. Norton.

Loving, C. (1991). The scientific theory profile: A philosophy of science model for science teachers. *Journal of Research in Science Teaching*, 28(9):823-838.

Lunn, S. (2000). *Primary Teachers' Understanding of the Nature f Science and the Purposes of Science Education*. Unpublished PhD Thesis, Open University, England.

Mackay, L. (1971). Development of understanding about the nature of science. *Journal of Research in Science Teaching*, 8(1), 57-66.

Mansour, N. (2007). The experiences and personal religious beliefs of Egyptian science teachers as a framework for understanding the shaping and reshaping of their beliefs and practices about Science-Technology-Society (STS). *International Journal of Science Education*, 1-30.

Mansour, N. (2010). Science teachers' interpretations of Islamic culture related to science education versus the Islamic epistemology and ontology of science. *Cultural Studies of Science Education*, 5, 127-140.

Matthews, M. (1993). Constructivism and science education: Some epistemological problems. *Journal of Science Education and Technology*, 1(2), 359-370.

Matthews, M. (1994). *Science Teaching: the Role of History and Philosophy of Science*. New York: Roultedge.

Mazawi, A.E. (1994). Teachers role pattern and the mediation of socio-political change: The Case of Palestinian Arab school teachers. *British Journal of Sociology of Education*, 15 (4) 497-514.

McCarthy, S. and Sanders, M. (2007). Issues relating to broad classification and the provisional nature of science in biology education. *Journal of Biological Education*, 41(3), 123-130.

McCarthy, S. and Youens, B. (2005). Strategies used by science student teachers for subject knowledge development: a focus on peer support. *Research in Science and Technological Education*, 23(2), 149-162.

McCarthy, S., Sorensen, P. and Newton, L. (2010). *Secondary science student teachers' understanding of the nature of science: their starting point*. Paper presented at ASE 2010 Symposium, Nottingham.

McComas, W. (1998). The principle elements of the nature of science: Dispelling the myths. In W. F. McComas(ed). *The Nature of Science in Science Education: Rationales and Strategies*, 53-70. Boston: Kluwer Academic Publishers

McComas, W. and Oslon, J. (1998). The nature of science in international science education standards documents. In W. F. McComas (ed), *The Nature of Science in Science Education: Rationales and Strategies,* 41-52. Boston: Kluwer Academics Publishers.

McComas, W. F., Clough, M.P. and Almazroa, H. A. (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,* 3-39. Boston: Kluwer Academic Publishers.

McGinn, R. E. (1991). *Science, Technology and Society*. New Jersey: Prentice Hall.

McIntyre, D. (1997). *Teacher Education Research in a New Context: The Oxford Internship Scheme*. London: Paul Chapman.

McMullin, E. (1993) Rationality and paradigm change in science. In M. Curd and J. A. Cover (eds). *Philosophy of Science: The Central Issues,* 119-138. New York: W.W. Norton.

McNiff, J. L. Lomax, P. and Whitehead, J. (1996). You and Your Action Research. London: Routledge Hyde Publications.

Meichtry, Y.G. (1993). The impact of science on student views about the nature of science. *Journal of Research in Science Teaching*, 30 (5): 429-443.

Mellado, V. (1997). Pre-service teachers' classroom practice and their conceptions of the nature of science. *Science and Education*, 6, 331-354.

Mellado, V. (1998). The classroom practice of pre-service teachers and their conceptions of teaching and learning science. *Science Education*, 82, 197-214.

Mercer, J. (2007). The challenges of insider research in educational institutions: wielding a double-edged sword and resolving delicate dilemmas. *Oxford Review of Education, 33* (1), 1-17.

Merriam, S. (1988). *Case Study Research in Education*. Jossey-Bass: San Francisco.

Michael, M. (1992). Lay discourses of science: science-in-general science-in- particular and self. *Science, Technology and Human Values*, 17(3), 270-286.

Miles, S. and Huberman, M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook (*2nd ed). Thousand Oaks: Sage.

Millar, R. (2010). *Personal communication* via the (ASE) 2010 Annual Symposium, Nottingham, January, 2010.

Millar, R. and Wynne, B. (1988). Public understanding of science: from contents to processes. *International Journal of Science Education*, 10(4), 388-398.

Milne, C. and Taylor, P. (1995). Metaphors as global makers for teachers' beliefs about the nature of science. *Research in Science Education*, 25, 39-49.

Milne, E. and Taylor, C. (1998). Critical theory to science education. In Cobern, W. W. (Ed.), *Socio-cultural Perspectives on Science Education*, 25-48. Netherlands: Kluwer Academic Publishers.

Ministry of Education (1999). *Five-Year Education Development Plan 2001-2005*. Palestinian National Authority, Palestine.

Ministry of Education (MoE), (1998). *General Outline for Science Curriculum*. Ramallah: Curriculum Development Centre. (Arabic)

Ministry of Education and Higher Education (2007). *Statistical manual of the Palestinian higher education institutions (2007-2008*), Ramallah. (Arabic)

Ministry of Education and Higher Education (2008). *Education Development Strategic Plan 2008-2012*. Palestinian National Authority, Ramallah.

Monk, M., and Osborne, J. (1997). Placing the history and philosophy of science on the curriculum: A model for the development of pedagogy. *Science Education*, 81, 405-424.

Morrison, J., Raab, F., and Ingram, D. (2008). Factors influencing elementary and secondary teachers' views on the nature of science. *Journal of Research in Science Teaching*, 46(4), 384-403.

Morrison, K. (1993). *Planning and Accomplishing School Centred Evaluation*. Norfolk: Peter Francis Publishers.

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

Munby, H. (1983). *An Investigation into the Measurement of Attitudes in Science Education*. Columbus: SMEAC Information Reference Centre.

Munro, J. (1999). Learning more about learning improves teacher effectiveness. *School Effectiveness and School Improvement*, 10(2), 151-171.

Musgrave, A. (1985). Realism versus constructive empiricism. In M. Curd and J. A. Cover (eds.) (1998*), Philosophy of Science: The Central Issues*, 1088-1113. New York: W.W. Norton.

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

National Research Council. (2000). *Inquiry and the National Science Education Standards.* Washington, DC: National Academic Press.

National Science Teacher Association (1982). Science- technology-society: Science education for the 1980s. Washington, DC.

National Science Teacher Association (2000). NSTA Position Paper: *Understanding the True Meaning of the Nature of Science*. Retrieved on 10 March 2008 from http://www. nsta.org/positionstatement&psid=22.

Neale, D. C., Smith D. and Johnson, V. G. (1990). Implementing conceptual change teaching in primary science. *The Elementary School Journal*, 91(2), 109-132.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19(4), 317- 328.

Norman, D. (1980). What goes in the mind of the learner?. *New Directions for Teaching and Learning*, 2, 35-49.

Nott, M. and Wellington, J. (1995). *'Probing teachers' views of the nature of science: How should we do it and where should we be looking?.* Proceedings of the Third International History, Philosophy, and Science Teaching Conference, 864-872.

Ochanji, M. B. (2003). *Learning to teach the nature of science: A study of pre-service teachers.* Unpublished PhD Dissertation, Syracuse University.

Odwan, A. (2000). Current reality of educational supervision in Jerusalem area in light of some new approaches and models in supervision. *Unpublished Masters Dissertation*, Al Quds University. (Arabic)

Ogunniyi, M. (1983). Relative effects of a history/philosophy of science course on student teachers' performance on two models of science. *Research in Science and Technological Education*, 1(2), 193-199.

Ogunniyi, M. B., Jegede, O. J., Ogawa, M., Yandila, C. D. and Oladele, F. K. (1995).Nature of worldview presuppositions among science teachers in Botswana, Indonesia, Japan, Nigeria, and the Philippines. *Journal of Research in Science Teaching*, 32(8), 817–831.

Omari, A. (2006). *Science teachers' beliefs about the nature of science, teaching, and learning and their relationship to classroom practice.* Unpublished PhD Dissertation, Arabic University of Amman. (Arabic)

Pajares, M. (1992). Teachers' Beliefs and Educational Research: Cleaning up a messy construct. *Review of Educational Research*, 62(3), 307-332.

Palestine Economic Policy Research Institute-MAS (2002). *Social Monitor*, 5, Ramallah. (Arabic)

Palestinian Curriculum Development Centre (1998). *The First Palestinian Curriculum Plan.* Jerusalem: Al Ma'aref Press.

Patton, M. (1990). *Qualitative Evaluation Methods.* London :Sage.

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. *Science Education*, 77, 261-278

Poole, M. (1995). *What Science Cannot Discover, Mankind cannot Know?-Beliefs and Values about Science.* Buckingham: Open University Press.

Popper, K. (1963). *Conjectures and Refutations.* London: Rutledge.

Popper, K. (1965). Normal science and its dangers. In I. L. Musgrave (ed), *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.

Popper, K. (1968). *The Logic of Scientific Discovery*. London: Hutchinson.

Potter, (2000). *The Philosophy of Social Science: New Perspectives*. Essex: Pearson Education Limited.

Radcliffe, R. Caverly, D., Peterson, C. and Emmons, M. (2004). Improving textbook reading in a middle school science classroom. *Reading Improvement*, 41, 145- 156.

Ramsey, J. (1993). The science education reform movement: Implications for social responsibility. *Science Education*, 77(2), 235-258.

Reiss, M. (2009). Imagining the world: the significance of religious worldviews for science education. *Science and Education*, 18, 783-796.

Reiss, M. (2010). Science and religion: Implications for science educators, *Cultural Studies of Science Education*, 5, 91–101.

Richards, S. (1987). *Philosophy and Sociology of Science: An Introduction* (2nd ed.), Basil: Blackwell.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (ed). *Handbook of Research on Teacher Education* (2nd ed), 102-119. New York: Macmillan.

Rigby, A. (1995). *Palestinian Education: The Future Challenge*. Jerusalem: Palestinian Academic Society for the Study of International Affairs (PASSIA).

Rihan, R. (1999). Reflections on Palestinian education in the twenty first century. *In Educational Development First Five-Year Plan for the Period 2000-2004*. MoEHE, Ramallah. (Arabic)

Rihan, R. (2001). The Palestinian educational development plan: Promise for the future. *Palestine-Israel Journal of Politics*, 3(2), 19-34.

Riley, J. (1979). The influence of hands-on science process training on pre-service teachers' acquisition of process skills and attitude toward science and science teaching. *Journal of Research in Science Teaching*, 16, 373-3 84.

Robson, C. (1993). *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*. Oxford: Blackwell.

Rose, D. and Sullivan, O. (1996). *Introducing Data Analysis for Social Scientists*. Buckingham: Open University Press.

Rowe, M. (1974). A humanistic intent: The program of pre-service elementary education at the University of Florida. *Science Education*, 58, 369-376.

Rubba, P. (1976). Nature of scientific knowledge scale. Bloomington: *Indiana University.*

Rubba, P. A., Horner, J. K. and Smith, J. M. (1981). A study of two misconceptions about the nature of science among junior high school students. *School Science and Mathematics*, 81, 221-226.

Rubba, P. and Anderson, H. (1978). Development of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. *Science Education*, 62(4), 449-458.

Rubin, H. and Rubin, I. (1995). *Qualitative Interviewing: The Art of Hearing Data*. Thousand Oaks, Calif: Sage Publications.

Ryan, A. and Aikenhead, G. (1992). Students' preconceptions about the epistemology of science. *Science Education*, 76(6), 559-580.

Ryder, J., Leach, J. and Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching*, 36(2), 201–220.

Said, E. (2001). Palestinians under siege. In R. Carey (Ed.), *The new Intifada: Resisting Israel's Apartheid*, 27-42. New York: Verso

Sanger, M. and Greenbowe, T. (1999). An analysis of college chemistry textbooks as sources of misconceptions and errors in electrochemistry, *Journal of Chemical Education*, 76(6), 853-860.

Sapsford, R. and Abbott, P. (1998). Ethics, politics and research. In R. Sapsford and V. Jupp (eds.). *Data Collection and Analysis*, 317-341. London: Sage.

Sarantakos, S. (2005). *Social Research* (3rd ed). Basingstoke: Palgrave Macmillan.

Scharmann, L. and Harris, W. (1992). Teaching evolution: Understanding and applying the nature of science. *Journal of Research in Science Teaching*, 29, 375-388.

Schmidt, D. (1967). Test on understanding science: A comparison among several groups. *Journal of Research in Science Teaching*, 5(6), 365-366.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, 82, 498-504.

Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review*, 6, 293–319.

Schraw, G. (2002). Teachers' epistemological world views and educational practices. *Issues in Education*, 8 (2), 99-149.

Schwab, J. (1962). *The Teaching of Science: The Teaching of Science as Enquiry*. Cambridge: Harvard University Press.

Schwartz, R. (2004). *Epistemological views in authentic science practices: A cross discipline comparison of scientists' views of nature of science and scientific inquiry*. Unpublished PhD Dissertation, Oregon State University.

Schwartz, R. and 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, 205–236.

Schwartz, R. and Lederman, N. (2006). *Exploring contextually-based views of NOS and scientific literacy: What scientists say*. Paper presented at the annual meeting of the National Association for Research in Science Teaching. San Francisco.

Schwartz, R., Lederman, N. and Crawford, B. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88,* 610-645.

Segerstrale, U. (2000). Science and science studies: Enemies or allies? In U. Segerstrale (Ed.), *Beyond the Science Wars: The Missing Discourse about Science and Technology*, 1-40. Albany: State University of New York Press.

Sergiovani, T. and Starratt, R. (1988). *Supervision Human Perspectives*. New York: McGraw Hill Book Company.

Shapiro, B. L. (1996). A case study of change in elementary student teacher thinking during an independent investigation in science: learning about the "face of science that does not yet know". *Science Education, 80,* 535-560.

Sharabi, H. (1975). *Introductions to Social Arab Studies*. Jerusalem: Salah Al-Dien Publishing. (Arabic)

Shawabkeh, A. et al., (2006). *Palestinian Science Textbook Year 9* (1st Volume). Ramallah, MoEHE, 2-15. (Arabic)

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.

Shumba, O. (1999). Relationship between secondary science teachers' orientation to traditional culture and beliefs concerning science instructional ideology. *Journal of Research in Science Teaching*, 36(3), 333-355.

Shymansky, J., Kyle, W. and Alport, J. (1983). The teacher crises in secondary school science and mathematics. *Educational Leadership*, 40, 63-67.

Siegel, H. (1982). On the parallel between Piagetian cognitive development and the history of science. *Philosophy and Sociology of Science*, 12(4), 375-386.

Siegel, H. (1991). Conceptual change in science and science education. In M. R .Mathews (ed.). *History, Philosophy, and Science Teaching: Selected Readings*, 133-148. New York: Teachers College Press.

Siegel, S. And Castellan, N. (1988). *Nonparametric Statistics for the Social Sciences* (2nd ed). New York: McGraw-Hill.

Silverman, D. (1985). *Qualitative Methodology and Sociology: Describing the Social World.* Aldershot: Gower.

Simon, M. (2000). Constructivism, mathematics teacher education, and research in mathematics teacher development. In L. P. Steffe and P. W. Thompson (eds.). *Radical Constructivism in Action: Building on the Pioneering work of Ernst von Glaserfeld*, 213-230. London: Rutledge Falmer.

Slaven, R. (1994). *Educational Psychology: Theory and Practice* (4th ed). USA: Allyn and Bacon.

Solomon, J. (1992). The classroom discussion of science-based social issues presented on television: Knowledge, attitudes and values. *International Journal of Science Education*, 14, 431 - 444.

Solomon, J. (1993). *Teaching Science Technology and Society*. Buckingham: Open University.

Solomon, J., Duveen, J., Scot, L. and McCarthy, S. (1992). Teaching about the nature of science through history: Action research in the classroom. *Journal of Research in Science Teaching*, 29(4), 409–421.

Sorsby, B. (2000). The irresistible rise of the nature of science in science curricular. In J. Sears and P. Sorensen, (eds.). *Issues in Science Teaching*, 23-30. New York: Rutledge.

Stinner, A. (1992). Science textbooks and science teaching: From logic to evidence. *Science Education*, 76(1), 1-16.

Strauss, A. and Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques.* Berkeley, CA: Sage.

Strauss, A. and Corbin, J. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* Thousand Oaks: Sage.

Strike, K. A. and Posner, G. J. (1982). Conceptual change and science teaching. *European Journal of Science Education*, 4 (3), 231-240.

Strike, K. A. and Posner, G. J. (1985). A conceptual change view of learning and understanding. In L H. West and A. L. Pines (eds), *Cognitive Structure and Conceptual Change*. New York: Academic Press.

Strike, K. A., Bosner, G. J. Hewson, P. W. and Gertsog, W. A. (1992). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66 (2), 211-227.

Strike, K. and Posner, G. (1992). A revisionist theory of conceptual change. In R. Duschl and R. Hamilton (eds). *Philosophy of Science, Cognitive Psychology, and Educational Theory and Practice*. Albany, NY: State University of New York.

Stumpf, S. E. (1966). *Socrates to Sartre: A History of Philosophy*. New York: McGraw-Hill.

Tairab, H. (2001). Pre-service teachers' views of the nature of science and technology before and after a science teaching methods course, *Research in Education*, 65, 81-87.

Tamir, P., and Zohar, A. (1991). Anthropomorphism and teleology in reasoning about biological phenomena. *Science Education*, 75(1), 57-68.

Tashakkori, A. and Teddlie, C. (1998). *Mixed Methodology: Combining Qualitative and Quantitative Approaches*. Thousand Oaks: Sage.

Tashakkori, A. and Teddlie, C. (2003). *Handbook of Mixed Methods in Social and Behavioural Research*. Thousand Oaks: Sage.

Taylor, P. (1993). Collaborating to reconstruct teaching: the influence of researcher beliefs. In K. Tobin (ed). *The Practice of Constructivism in Science Education*, 267-297. Washington, DC: AAAS Press.

Thabyan, S. (1994). An analysis of Saudi Arabian Year 9 science textbook in light of scientific literacy. *King Faisal University Research Journal* , 1, 40-65.

Theobold, D. W. (1968). *An Introduction to the Philosophy of Science*. London: Methuen Co. Ltd.

Tibawi, A. L. (1956). *Arab Education in Mandatory Palestine: A Study of Three Decades of British Administration*. London: Luzac.

Tobin, K. and McRobbie, C. J. (1997). Beliefs about the nature of science and the enacted science curriculum. *Science and Education*, 6, 355-371.

Tobin, K., Tippins, D. and Hook, K. (1994). Referents for changing a science curriculum: A case study of one Teacher's change in beliefs, *Science and Education*, 3, 245-264.

Trembath, R.J. (1972). The structure of science. *The Australian Science Teachers Journal*, 18, 59-63.

Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*, 24(8), 771–783

Turner S. and Sullenger, K. (1999). Kuhn in the classroom, Lakatos in the lab: Science educators confront the nature-of-science debate. *Science, Technology, and Human Values*, 24(1), 5-30.

Tytler, R. (2002). Teaching for understanding in science: Constructivist/conceptual change teaching approaches. *Australian Science Teachers Journal*, 48(4), 30-35.

UNESCO (2002). Developing education in Palestine: A continuing Challenge. Ramallah: UNESCO.

UNRWA (2004). *The Impact of Israeli Aggression on Education*. Jerusalem: UNRWA.

Van Frassen, B. (1980). Arguments concerning scientific realism. In M. Curd and J. A. Cover (eds.) (1998), *Philosophy of Science: The Central Issues*, 1064-1087. New York: W.W. Norton.

Verma, G. and Malick, K. (1999). *Researching Education: Perspectives and Techniques*. Britain: Falmer Press.

Von Glaserfeld, V. (1989). Constructivism in Education. In T. Husen and R. T. Neville. *The International Encyclopaedia of Education*. Volume 1, New York: Peragman Press.

Von Glaserfeld, V. (1993). Questions and answers about radical constructivism. In K. Tobin (ed). *The Practice of Constructivism in Science Education*. Washington, DC: American Association for the Advancement of Science Education Press.

Vosniadou, S. and Brewer, W.F. (1987). Theories of knowledge restructuring in development. *Review of Educational Research*, 57(1), 51-67.

Wahbeh, N. (2003). Teaching and learning science in Palestine: Dealing with the new Palestinian science curriculum. *Mediterranean Journal of Educational Studies*, 8(1), 135-159.

Wahbeh, N. (2009). *The effect of a content-embedded explicit-reflective approach on in-service teachers' views and practices related to nature of science.* Unpublished PhD Dissertation, University of Illinois at Urbana-Champaign.

Waldrip, B. and Taylor, P. (1999). Permeability of students' worldviews to their school views in a non-western developing country, *Journal of Research in Science teaching*, 36(3), 289-303.

Wandersee, J. Mintez, J. and Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (ed). Handbook of Research in Science Teaching and Learning. New York: Macmillan.

Watkins, J. (1965). Against normal science. In I. L. A. Musgrave (ed.), *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.

Weinberg, S. (2001). *Facing up Science and its Cultural Adversaries*. Cambridge: Harvard University Press.

Weiss, I. R. (1993). Science teachers rely on the textbook. In R. E. Yager (ed). What Research Says to the Science Teacher: The Science, Technology, Society Movement, 35-41. Washington, DC: National Science Teachers Association.

Welch, W. (1966). *Science Process Inventory*. Cambridge, MA: Harvard University Press.

Welzel, M. and Roth, W. M. (1998). Do interviews really assess students' knowledge?. *International Journal of Science Education*, 20, 25 - 44.

Wertsch, J. V. (1998). *Mind as Action*. New York: Oxford University Press.

Williams, M. (2000). Interpretivism and generalisation. *Sociology, 34*, 209-224.

Wright, B. and Masters, G. (1982). *Rating Scale Analysis*. Chicago: Measurement, Evaluation, Statistics, and Assessment Press.

Yager, R. E. (1990). The science- technology- society movement in the United States: Its origin, evolution and rationale. *Social Education*, 54(4), 198-201.

Yalvac, B. (2005). On-line peer review and students' understanding of the nature of science. *Unpublished PhD Dissertation*, Pennsylvania State University.

Yalvac, B. and Crawford, B. A. (2002). *Eliciting prospective science teachers' conceptions of the nature of science in Middle East Technical University (METU) in Ankara.* Paper Presented at the Annual International Conference of the Association for the Education of Teachers in Science. Charlotte, NC.

Yusuf, F. (2000). *An analytical study of the chemistry textbook of the 1st scientific secondary class in light of the nature of science.* Unpublished Masters Dissertation, Al Quds University. (Arabic)

Zimmerman, E. and Gilbert, J. (1998). Contradictory views of the nature of science held by Brazilian secondary school physics teacher: Educational value of interview, *Education Research and Evaluation*, 4(3), 213-234.

Appendices

Appendix 1[1]: Explanation of the Main Aspects of NOS that Served as the Theoretical Framework for Analysis

NOS aspect	Relevant dimensions
Empirical	Scientific claims are derived from, and/or consistent with, observations of natural phenomena. Scientists, however, do not have "direct" access to most natural phenomena: Their observations are almost always filtered through the human perceptual apparatus, mediated by the assumptions underlying the functioning of "scientific" instruments, and/or interpreted from within elaborate theoretical frameworks.
Inferential	There is a crucial distinction between observations and inferences. Observations are descriptive statements about natural phenomena that are accessible to the senses (or extensions of the senses) and about which observers can reach consensus with relative ease (e.g., objects released above ground level tend to fall to the ground). Inferences, on the other hand, are statements about phenomena that are not directly accessible to the senses (e.g., objects tend to fall to the ground because of "gravity"). Scientific constructs, such as gravity, are inferential in the sense that they can only be accessed and/or measured through their manifestations or effects.
Creative	Science is not an entirely rational or systematic activity. Generating scientific knowledge involves human creativity in the sense of scientists inventing explanations and theoretical entities. The creative NOS, coupled with its inferential nature, entail that scientific entities (atoms, force fields, species, etc.) are functional theoretical models rather than faithful copies of "reality."
Theory-driven	Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, and expectations influence their work. These background factors affect scientists' choice of problems to investigate and methods of investigations, observations (both in terms of what is and is not observed), and interpretation of these observations. This (sometimes collective) individuality or mind-set accounts for the role of theory in generating scientific knowledge. Contrary to common belief, science never starts with neutral observations. Like investigations, observations are always motivated and guided by, and acquire meaning in light of questions and problems derived from, certain theoretical perspectives.
Tentative	Scientific knowledge is reliable and durable, but never absolute or certain. All categories of knowledge ("facts," theories, laws, etc.) are subject to change. Scientific claims change as new evidence, made possible through conceptual and technological advances, is brought to bear; as extant evidence is reinterpreted in light of new or revised theoretical ideas; or due to changes in the cultural and social spheres or shifts in the directions of established research programmes.

Myth of "The Scientific Method"	This myth is often manifested in the belief that there is a recipe-like stepwise procedure that typifies all scientific practice. This notion is erroneous: There is no single "Scientific Method" that would guarantee the development of infallible knowledge. Scientists do observe, compare, measure, test, speculate, hypothesize, debate, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of (practical, conceptual, or logical) activities that will unerringly lead them to valid claims, let alone "certain" knowledge.
Scientific theories	Scientific theories are well-established, highly substantiated, internally consistent systems of explanations, which (a) account for large sets of seemingly unrelated observations in several fields of investigation, (b) generate research questions and problems, and (c) guide future investigations. Theories are often based on assumptions or axioms and posit the existence of non-observable entities. Thus, direct testing is untenable. Only indirect evidence supports and validates theories: Scientists derive specific testable predictions from theories and check them against observations. An agreement between predictions and observations increases confidence in the tested theory.
Scientific laws	In general, laws are descriptive statements of relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. Contrary to common belief, theories and laws are not hierarchically related (the naïve view that theories become laws when "enough" supporting evidence is garnered, or that laws have a higher status than theories). Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws.
Social dimensions of science	Scientific knowledge is socially negotiated. This should not be confused with relativistic notions of science. This dimension specifically refers to the constitutive values associated with established venues for communication and criticism within the scientific enterprise, which serve to enhance the objectivity of collectively scrutinized scientific knowledge through decreasing the impact of individual scientists' idiosyncrasies and subjectivities. The double-blind peer-review process used by scientific journals is one aspect of the enactment of NOS dimensions under this aspect.
Social and cultural embedded-ness of science	Science is a human enterprise embedded and practiced in the context of a larger cultural milieu. Thus, science affects and is affected by various cultural elements and spheres, including social fabric, worldview, power structures, philosophy, religion, and political and economic factors. Such effects are manifested, among other things, through public funding for scientific research and, in some cases, in the very nature of "acceptable" explanations of natural phenomena (e.g., differing stories of hominid evolution have resulted from the advent of feminist perspectives brought about by increased access, participation, and leadership of females in the biosocial sciences).

[1] Adopted from Abd El Khalick, Waters and Le (2008:238-239).

Appendix 2: A Questionnaire to Explore Views of the Nature of Science

Dear Teachers,

I am conducting a study to explore the relationship between Palestinian science teachers' views of the nature of science and their classroom practices.

I would really appreciate your participation by responding to the following questionnaire which was designed to measure Palestinian teachers' views and conceptualizations of the nature of science. All the information I am collecting for this study is confidential and will only be used for research purposes.

Your participation is much appreciated,

Mousa Khaldi
Lecturer, Education and Psychology Department -Birzeit University.
PhD student, Nottingham University, England

****

Part 1: General background

Name:
Gender:
Degree and field of specialization:

School:
Teaching experience:
Teaching certification (if any):

What classes are you teaching this year?

Part 2: The questionnaire items.

General Directions: This questionnaire consists of ten questions. Each one is followed by a group of statements that adopt a specific perspective about the nature of science. Perhaps you agree or disagree with these points of views; you might even have a different perspective. Please read all the statements that follow each question, and then circle the appropriate number (1, 2, 3, 4, 5) from the columns on the right. These numbers have specific meanings as follows:

5: Strongly agree.
4: Agree.
3: Uncertain.
2: Disagree.
1: Strongly disagree.

Please keep in mind that there is no right or wrong answers for these questions. We are only interested in your beliefs about some aspects of science.

1. When two different theories arise to explain the same scientific phenomenon (such as the fossils of dinosaurs), would scientists accept both of them at the same time?						
1-1	Yes, scientists cannot objectively compare the two theories, thus they should temporarily accept both of them.	5	4	3	2	1
1-2	Yes, each theory could introduce different explanation.	5	4	3	2	1
1-3	No, scientists accept the theory that they know better.	5	4	3	2	1
1-4	No, scientists accept simple theories and avoid complex ones.	5	4	3	2	1
1-5	No, the authoritative position of the scientists who develop the theory affects others in accepting it.	5	4	3	2	1
1-6	No, scientists tend to accept new theories that are consistent with recent theories.	5	4	3	2	1
1-7	No, scientists select one of the theories by intuition.	5	4	3	2	1
1-8	No, there is only one truth, so scientists may not accept a theory without making sure that it is the most accurate one.	5	4	3	2	1
2. Do you think that research is influenced by social and cultural values? (i.e. the system of values and beliefs in the society)						
2-1	Yes, research approaches are usually influenced by the social and cultural values in a society.	5	4	3	2	1
2-2	Yes, because social and cultural values affect scientists who conduct these research.	5	4	3	2	1
2-3	No, experienced scientists are not affected by social values while doing research.	5	4	3	2	1
2-4	No, science requires objectivity, and this cannot relate to social norms, which are sometimes subjective.	5	4	3	2	1
3. While doing research, can scientists use imagination?						
3-1	Yes, imagination is a basic source for creativity.	5	4	3	2	1
3-2	Yes, scientists use imagination in one way or another when they do research.	5	4	3	2	1
3-3	No, imagination is not consistent with the logic of science.	5	4	3	2	1
3-4	No, because imagination could be used by a scientist to prove his/her point of view.	5	4	3	2	1
3-5	No, imagination lacks reliability.	5	4	3	2	1
4. Although scientists conduct research properly, the theory produced might be disproved in the future:						
4-1	Scientific research faces evolutional changes, thus a new theory can replace a former one.	5	4	3	2	1
4-2	Scientific progress/ developments take place through an accumulative process, so the old theories are still preserved.	5	4	3	2	1
4-3	As data and information about a theory are accumulated, scientists build on it instead of disproving it.	5	4	3	2	1

5. Do you think that theories are invented or discovered by scientists?						
5-1	Discovered, the main idea is available in nature and we just have to discover it.	5	4	3	2	1
5-2	Discovered, because theory is built on facts that could be tested empirically.	5	4	3	2	1
5-3	Some scientists accidentally discover theories; others invent theories from available facts.	5	4	3	2	1
5-4	Invented, because theory explains the empirical facts, which are usually discovered by scientists.	5	4	3	2	1
5-5	Invented, scientists produce theories and develop them.	5	4	3	2	1
5-6	Invented, because theory could be disproved.	5	4	3	2	1
6. Are scientific laws (such as gravitation law) invented or discovered?						
6-1	Discovered, scientific laws exist in nature, scientists just have to discover them.	5	4	3	2	1
6-2	Discovered, because scientific laws depend on empirical facts.	5	4	3	2	1
6-3	Some scientists accidentally discover science laws; others invent laws using the facts they have.	5	4	3	2	1
6-4	Invented, scientists invent laws to explain facts that were discovered by experimentation.	5	4	3	2	1
6-5	Invented, there are no absolutes in nature, law is invented by scientists.	5	4	3	2	1
7. Compared to scientific laws, do theories lack evidence that support them?						
7-1	Yes, theories are not determined like laws.	5	4	3	2	1
7-2	Yes, if a theory is proved it becomes a law, scientific law usually has more evidence.	5	4	3	2	1
7-3	Not necessarily, some theories have more evidence than some laws.	5	4	3	2	1
7-4	No, because theories and laws are different forms of ideas, thus we can't compare them.	5	4	3	2	1
8. Observation might be influenced by scientists' personal beliefs, their experience, and assumptions. Thus, their observation could be different about the same experiment.						
8-1	Observation will be different since difference in beliefs will lead to different expectations.	5	4	3	2	1
8-2	Observation will be similar because scientists from the same field hold similar ideas.	5	4	3	2	1
8-3	Observation will be similar because scientists practice in advance how to avoid personal opinions in order to reach objective results.	5	4	3	2	1
8-4	Observation will be similar because it reflects only what we see; explanations might vary from one person to another.	5	4	3	2	1
8-5	Observations will be the same, although subjectivity could not be neglected totally, scientists use different methods to increase objectivity.	5	4	3	2	1
9. Most scientists follow the "scientific method" step by step to conduct their research (observation, hypotheses, experiment design, data collection, and drawing conclusions).						

9-1	Most scientists use the scientific method because it guarantees reliable and correct results.	5	4	3	2	1
9-2	Most scientists follow it because it depends on logical steps.	5	4	3	2	1
9-3	Scientific method is useful in most cases, however it does not guarantee the results and thus new approaches need to be invented.	5	4	3	2	1
9-4	In reality, there is nothing called "scientific method," scientists use any methodology to reach the results they want.	5	4	3	2	1
9-5	There is no particular "scientific method," sometimes knowledge could be discovered accidentally.	5	4	3	2	1
9-6	Regardless of the way they reach results, scientists use the "scientific method" to test them.	5	4	3	2	1

****

Please read the following story and then answer the questions that follow.

Imagine that we are in the year 2016, A and B are scientists conducting biological research about gene selection and transformation at one of the biology technological centres. If they succeed, their research will have huge positive impact on humanity and the science of heredity. In addition to protecting people from transferred diseases, selecting specific kinds of genes will be possible and people will not suffer anymore from these kinds of diseases. In spite of the fact that the project is about to reach its final stages, some objections started to appear. The budget of the project might be terminated because of some public objections raised against the project approach. In fact, scientist A started to complain he may quit the project because he is religious and he believes that God has created all people and he will facilitate their lives. Furthermore, he believes that human diversity is essential in human history, thus there is nobody who has the right to make any changes to what God has created in spite of the transferred diseases. He believes that research and science development should not negatively affect human beings. Thus, whenever there is a conflict between science and socio-cultural values, scientists should take into consideration these moral values as the ultimate goal of science should be to improve peoples' lives.

However, scientist B has a different opinion. He believes that science has absolute objectivity, while socio-cultural norms are a public issue and usually associated with the local society, so they lack objectivity. In other words, some research that we oppose today might become highly recognized in the future. Thus, personal values should not determine the direction of objective scientific developments. Finally, scientist A decided to withdraw from the project as a result of the disagreement between them. However, scientist B continued working on the project. He thinks that stopping such a developed project would be regrettable. Scientist A changed his approach focusing on gene transfer in plants because he believes that this approach is still consistent with the value system in his society. Recently, he succeeded in developing some kinds of anti-cancer medicines using his research on plants. He does not feel sorry for leaving the original project because he believes that although science might be objective, social values and ideals are much more important for humanity. Scientist B decided to continue the original project and was successful in this research using animals. He is planning to do more research on human beings. He does not feel sorry because he continued the same approach. He thinks that his research will finally succeed. According to him, history will be the judge of the significance of his work, not the cultural and social norms.

10. Depending on your own opinion about the nature of science, do you agree with A or B?						
10-1	A: scientist should have "values" when doing research.	5	4	3	2	1
10-2	A: Scientist should take into consideration both the importance of the research and the socio-cultural values.	5	4	3	2	1
10-3	A: Conducting research with total ignorance of the social values is impossible.	5	4	3	2	1
10-4	A: Scientists should respect human diversity	5	4	3	2	1
10-5	B: Ignoring personal beliefs while conducting research is necessary.	5	4	3	2	1
10-6	B: Scientific research should not be influenced by personal values.	5	4	3	2	1
10-7	B: High values of science, which include seeking truth, should be respected.	5	4	3	2	1
10-8	Both of them, because each one has the spirit of science in spite of the fact they are both influenced by their personal values.	5	4	3	2	1
10-9	Neither one, because neither of them has enough objectivity and each one is influenced by his own beliefs and values.	5	4	3	2	1

Appendix 3: Open-Ended Questionnaire to Assess Teachers' Views of the Nature of Science

Dear Teacher,

My name is Mousa Khaldi and I am a PhD student at School of Education, University of Nottingham. I am conducting a study to explore **Palestinian Science Teachers' Views of the Nature of Science** as a partial requirement for my PhD degree.

I really appreciate your participation by responding to the following questionnaire and a follow up semi-structured interview. The questionnaire contains open-ended questions that aim to probe your views related to the nature of science. It is expected to take you about 45 minutes to complete it. The interview will focus on your responses to the questionnaire, and will last approximately one hour. The interview will be audio taped, and these tapes will then be transcribed. Confidentiality will be maintained through the use of codes rather than names on all data sources. The only people who will have access to the data will be my supervisors and me. Any publications that result from this study will use pseudonyms to maintain your anonymity.

There are no foreseeable risks to your participation in this study. Rather, you will be making a valuable contribution towards the improvement of science education in Palestine. Your participation is much appreciated.

Yours sincerely,

Mousa M. M. Khaldi
Lecturer,
Education and Psychology Department, Birzeit University.
PhD student,
University of Nottingham, England

Part 1: General Background and Biographical Data

Name:
Phone number:
School:
Gender:
Degree/s:
Source of last degree (university):
Specialism:
Years of teaching experience:
Teaching qualification (if any):
Grades and subjects currently teaching:
Grades and subjects previously taught:
Religion:

Do you have any research experience? If yes, briefly describe, please.
Do you have any work or career other than teaching? If yes, briefly describe.

Part 2: The questionnaire Items

Instructions:

- Please answer each of the following questions. Include relevant examples whenever possible. You can use the back of the page if you need more space.

- There are no 'right' or 'wrong' answers to the following questions. I am interested only in your views about some aspects of the nature of science.

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments?
   If yes, explain why. Give an example to defend your position.
   If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g. atomic theory, evolution theory), does the theory ever change?
   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change:
     (a). Explain why theories change.
     (b). Explain why we bother to learn scientific theories. Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are

scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom is like?

7. Science textbooks often define a species as a group of organisms that share characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

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

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.

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

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

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

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

11. What do you want your students to know about the nature of science?

12. Do you feel your views about NOS are influenced by your religious beliefs and/or cultural and social norms? Explain and give examples.

Appendix 4: Semi–Structured Interview with Teachers

The main aims of this interview are to clarify and discuss your answers to the questionnaire and to explore your answers in more depth.

Please ask for clarification of questions should you need it at any point. As I mentioned in the covering letter, your confidentiality will be maintained throughout the research process.

The interview consists of three main parts. The first part aims to check the clarity of the respondents' answers, any lack of detail in the answers or any conflict in their responses. The second part (adopted from Abd El Khalick, 2006) consists of follow up questions to the different scenarios of naïve responses that might be obtained on each item of VNOS-C. These questions, where necessary, will be asked to respondents with naïve views to comment and reconsider any conflicts in their answers on the questionnaire items. The third part consists of five additional open-ended questions that aim to elaborate and integrate with the original VNOS-C items to enrich the data, and get to the heart of teachers' views of NOS in a holistic and deep manner.
The general format of the follow up interview for the three parts will go as follows:

Part One

Different approaches were adopted, depending on the nature of the answers to the questions. The following are examples:

- In Question 1 you said that you believed science to be an objective body of knowledge. Could you please explain what you mean by this.

- Please read your answer to Question 1 and elaborate.

- Could you explain to me what you mean by ... ?
- Could you give an example of what you meant by ...?

- How does your response to Question x relate to what you said in response to Question y?

- How can you explain your answer on Item x that conflicts with what you said in your response to Item y?

Part Two (Adopted from Abd El Khalick, 2006: 394-395)

These follow-up questions consist of different scenarios of naïve responses to VNOS-C questions that were conducted at appropriate points when the participants expressed certain naïve views.

For Question 1, if the teacher responded that "science is characterized by the scientific method," he will be asked:
- Do all scientists use a specific method, in terms of a certain stepwise procedure, when they do science? Can you elaborate?" (p.394)

For Question 2, if teachers "defined the scientific experiment very broadly as procedures used to answer scientific questions", they will be asked:

- Are you thinking of an experiment in a sense of manipulating variables or are you thinking of more general procedures? Can you elaborate?" (p.394).

For Questions 1 and 2, if teachers noted that "scientific knowledge is 'proven' knowledge or that scientific experiments aim to 'prove' hypotheses or theories", they will be asked:

- How would you "prove" a theory or hypothesis?
- How much evidence or how many experiments does it take to "prove" a scientific claim?" Or "how much evidence or/and how many experiments are "enough" to prove a scientific claim?

For Question 3, if teachers responded that "developing scientific knowledge requires manipulative experiments," they will be asked:

- Let's consider a science like astronomy (or anatomy). Can we (or do we) do manipulative experiments in astronomy (or anatomy)? If the teacher answered positively then he will be asked: Can you elaborate/or explain more?
- If the teacher answered negatively then he will be asked: But we still consider astronomy (or anatomy) a science. What are your ideas about that?" (p.394 – 395)

For Question 4, if the teachers answered that scientific theories change, they will be asked:

- Then they will be asked: "the history of science is full with examples of scientific theories that have been discarded or greatly changed. The life spans of scientific theory, if you will, vary greatly, but theories seem to change at one point or another. And there is no reason to believe that the scientific theories we have today will not change in the future. Why do we bother learn about theories? Why do we invest time and energy to grasp these theories?" (p.395)
- Which comes first when scientists conduct scientific investigations, theory or observation?

For Question 5, teachers will be asked:

- "In terms of status and significance as products of science, would you rank scientific theories and laws? And if you choose to rank them, how would you rank them?" (p.395)

For Question 6, Teachers will be asked:

- "Have scientists ever seen an atom?
- If they responded the negative, they will be asked: So where do scientists come up with this elaborated structure of atom? Would you elaborate?" (p.395)

For Question 7, If teachers answered that scientists are very certain about the notion of species, they will be asked:

- There are certain species of wolves and dogs that are known to interbreed and produce fertile offspring. How does this fit into the notion of species, knowing that the aforementioned species are "different" species and have been given different scientific names?" (p.395)

For Question 9, if the teacher responded that "the dinosaur extinction controversy is justified given that the available evidence supports both hypotheses, he will be asked

- It is very reasonable to say that the data is scarce and that the available evidence supports both hypotheses equally well. However, scientists in the different groups are very adamant about their own position and they publish very pointed papers in this regard. Why is that?" (p.395)

Part Three

These additional questions were conducted at appropriate points in the interview, to enrich the data and explore areas that I believed were not fully addressed in the original VNOS-C questionnaire.

- Is there a difference between scientific knowledge and opinion? Explain your view using an example.

- Explain with examples whether scientists follow a single universal scientific method or use different types of methods.

- Explain with examples why you think scientists' observations and interpretations are the same or different?

- One might argue that science achieves objectivity by using methods that eliminate the impact of scientists' values, beliefs and commitments. Do you agree with this view? Explain why.

- Do you think your background as a Muslim/Christian, eastern, conservative, and/or your culture and the way you were brought up influence your views of NOS?
  Or is it only the academic factors that shape your views of NOS? If yes, what are these academic factors and in what way did they affect your views? Explain in detail.

Appendix 5: Semi-Structured Interview with the Palestinian Academics

Biographical data

Name:	Gender:
University:	
Source of last degree:	Specialism:
Experience:	Current role in teacher education:

Interview Questions

1. How important do you believe it is for learners and teachers to have an informed view of NOS? Explain.

2. Provided this brief description of science teachers' views/understanding of NOS, how would you explain these findings?

3. What are the reasons behind these traditional/ naïve system of beliefs held by many teachers?

4. To what extent do you think each of the following have had an effect on shaping teachers' views?
   - the available resources/facilities
   - structure of the educational system
   - their teacher training, including science education programmes at the university level
   - their school-based supervision
   - the curriculum

5. What should be done to improve teachers' views of NOS? How feasible are these options?

6. Suppose you are the director of a project that is very well funded, and you have all the resources you need to improve teachers' views of NOS. What will you do? Where are you going to spend the money and other available resources?

7. Suppose you are a decision maker at the top of the Ministry of Education and Higher Education (MoEHE), what policies would you implement to address this issue?

8. What aspects within Palestinian context might support the development of teacher's understanding of NOS?

9. What challenges need to be overcome in Palestine in order to improve teachers' understanding of NOS?

10. To what extent do you think that the structure of the society and culture shapes teachers' views of NOS? What about the effect of religion? What are the aspects that are more affected by the religious and socio-cultural factors?

Appendix 6: Semi-Structured Interview with the Science Textbook Authors

Biographical data

Gender:	Teaching experience:
Degree:	Source of last degree (university):
Specialism:	Teaching qualification (if any):

Interview Questions

1. What is your conceptualization of the nature of science? What are its main tenets?

2. Do you feel confident in this area? Have you got any training concerning this issue on the conceptual level?

3. Have you had any training on how to include NOS in the curriculum and textbooks? If yes, give details of the training, and the approach adopted? What was recommended to be included in terms of NOS? Was a balanced focus on all the tenets recommended? If not, which tenets received a greater focus? Why?

4. Do you think it is important that pupils/teachers have a sound understanding of NOS? Why?

5. Have you worked on including the NOS within the science curriculum? If yes, how? What approach did you adopt? Give examples.
    a. If no, why?

6. Have the aims concerning NOS that were raised in the curriculum main documents (broad aims) been translated in the textbooks? If no, Why? Give examples.

7. Did the science teachers who teach the curriculum receive any training on how to address the issues of NOS that were included in the textbooks? If yes, could you describe that training?

8. In your opinion is it possible for the Palestinian Science Curriculum Development Unit to design a science curriculum that includes the contemporary NOS features in a relevant and balanced manner? How? What aspects would facilitate a successful programme and what are potential barriers?

Appendix 7: Semi-Structured Interview with Science Teachers' Supervisors

Biographical data

Gender:	Teaching experience:
Degree:	Source of last degree (university):
Specialism:	Teaching qualification (if any):

Interview Questions

1. Would you please describe how a typical supervision session takes place? What are the specific aspects of teachers' knowledge and behaviours that you focus on? Are you satisfied with the way this supervision process takes place? If no, why? What aspects are you not happy about?

2. What is your conceptualization of NOS? What are its main tenets?

3. Do you think it is important that pupils/teachers have a sound understanding of NOS? Why? Which of these tenets do you think are the most important for school pupils to understand?

4. Do you think teachers possess an adequate view and understanding of NOS? If no, what do you believe are the causes? Explain in detail.

5. In the cases when you realize that the teacher you are supervising holds a traditional/naïve view of NOS, what do you do?

6. To what extent do you stress the teaching of NOS by the teachers you supervise? How? What aspects do you prioritise?

7. To what extent do you think Palestinian teachers are qualified to effectively teach the NOS?

8. Is the current science curriculum we have helpful for teachers to effectively teach NOS? Explain and give examples?

9. To what extent do you think it is possible to improve teachers' views of NOS? What aspects would facilitate a successful programme and what are potential barriers?

10. In what way could the supervision process be used to improve teachers' views of NOS? What changes need to take place for supervision to play an effective role in this area?

Appendix 8: Semi-Structured Interview with the In-service Teacher Trainers

Biographical data

Gender:	Teaching experience:
Degree:	Source of last degree (university):
Specialism:	Teaching qualification (if any):

Interview Questions

1. Would you please tell me when and how you became qualified as an in-service teacher trainer? Have you got any formal qualification in teacher training? Did this training focus on NOS?

2. What is your conceptualization of NOS? What are its main tenets?

3. Do you think it is important that pupils/teachers have a sound understanding of NOS? Why?

4. Do you think there is a problem in schools with the teaching of NOS? Explain.

5. Do you think teachers do possess an adequate understanding of NOS?
   If yes, which aspects of NOS do they understand particularly well? Do they translate their understanding into their teaching? Give examples. If no, why? Explain in detail.

6. To what extent do you pay attention to NOS in your training courses? How? Give examples, please.

7. Are there any training courses that aim specifically at improving teachers' views of NOS? If yes, describe them.

8. Do you think is it possible to improve teachers' views of NOS?
   If yes, in what way? What are the factors that exist and would facilitate achieving this goal?
   If no, why? What are the factors that exist and would make it difficult to achieve this goal?

9. What role can teacher training can play in the development of teachers' views of NOS? How? Give examples