THE INFLUENCE OF TEACHERS’ CONCEPTIONS OF THE NATURE OF SCIENCE ON CLASSROOM PRACTICE

by

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AN ABSTRACT OF THE THESIS

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Developing scientifically literate individuals has become one of the important goals of science education. A scientifically literate individual is one who appreciates scientific knowledge, differentiates between evidence and opinion, is capable of understanding and using science to solve personal and societal problems, and understands the nature of science (NOS) (Lederman, 1992). Research has established that many teachers and students possess inadequate understandings of NOS. However, whether teachers’ conceptions of NOS are reflected in their instructional planning and classroom practice remains an important academic research area, even though some research has been done on this topic. Consequently, the purpose of this study is to investigate teachers’ conceptions of NOS and to determine the relationship between these conceptions and their classroom practice as well as to delineate the factors that facilitate or impede this relationship. To achieve this, a sample of seven high school biology teachers, with a science teaching diploma, was selected to participate in this study. These teachers filled out an open-ended questionnaire entitled “Views of the Nature of Science Questionnaire - form C (VNOS-C)” to gauge their NOS conceptions. In addition, they participated in semi-structured interviews to validate the results of the Questionnaire and investigate the factors enhancing or impeding relationships between conceptions and practice. Finally, teacher’s classrooms were videotaped and their lesson plans were analyzed to identify evidence for NOS. Data was analyzed using a qualitative interpretive method. Results from the questionnaire and the interviews showed that most teachers do not possess appropriate views of NOS. Similarly, lesson plans, lacked any planning for teaching NOS aspects and analysis of classroom videotapes showed that teachers’ practices lacked any explicit reference to the aspects of NOS. Despite the fact that teachers who participated in this study had studied NOS in their teacher education programs, it seems that NOS is absent from all their teaching related activities. On the other hand, various factors seem to mediate the translation of teachers’ views into practices such as the curriculum teachers’ experience, time constraints, and classroom management problems.
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Science educators and organizations are increasingly advocating the reform of science education in general and science curricula more specifically (e.g. American Association for the Advancement of Science [AAAS], 1990, 1993; National Science Research Council [NRC], 1996). Developing scientifically literate individuals has become one of the most important goals in these reform efforts and thus, a central component of science education curricula (National Science Teachers Association-NSTA, 1982). A scientifically literate individual is one who appreciates scientific knowledge, differentiates between evidence and opinion, is capable of understanding and using scientific knowledge to solve personal and societal problems, and understands the nature of science (NOS) (Lederman, 1992). Furthermore, it is essential to view all these aspects as interrelated and thus, it would be inappropriate to deal with each one independently (Bell, Lederman, & Abd-El-Khalick, 2000). Bell, Lederman, and Abd-El-Khalick (2000) argue that the inherent assumption guiding the interrelatedness of these aspects is that, these aspects together “provide a profile of the scientific enterprise” (p.564).

Moreover, NSTA (1982) suggests, in addition to the aspects listed above, that a scientifically literate individual needs to understand science and technology, their relationships to society, their uses and limitations, to know the sources of scientific and technological information, and to use this information meaningfully in everyday life. Similarly, recent science education reform projects such as project 2061 (AAAS, 1989) defined a scientifically literate individual as one who is:
Aware that science, math, and technology are independent human enterprises with strengths and limitations; understands key concepts and principles of science, is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (p.4).

Defining a scientifically literate individual necessitates the emphasis on establishing an understanding of NOS. Such an understanding has become one of the most widely accepted and emphasized objectives in science education curricula worldwide. Lederman (1999) argues that when individuals understand NOS, they become more informed and thus, empowered to make educated decisions about science and scientific practices.

*The Nature of Science*

Science educators, researchers and philosophers disagree on a specific definition of NOS. NOS have been used to refer to the epistemology of science: “science as a way of knowing” (Bell, Lederman, & Abd-El-Khalick, 2000; Lederman & Abd-El-Khalick, 1998). Moreover, NOS typically refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge (Lederman & Lederman, 2004; Lederman & Zeidler, 1987). Indeed, according to Bell, Lederman, and Abd-El-Khalick (2000) and Lederman (1992) promoting the development of adequate conceptions of NOS dates back to the turn of the century, as shown in the documents of the Central Association of Science and Mathematics Teachers (1907).

Previously mentioned science education reform documents (e.g. AAAS, 1993; NRC, 1996) and science education research (Abd-El-Khalick, Bell, & Lederman, 1998;
Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, 1999; Smith, Lederman, Bell, McComas, & Clough, 1997) have identified the following aspects of the scientific enterprise: Science is tentative, a product of human creativity, empirically based, subjective, involves human inference, imagination, and creativity, and is socially and culturally embedded; reflecting thus a contemporary view of NOS (Lederman, 1992). One additional aspect is related to the relationship between theories and laws and the function of each, this aspect has not been addressed sufficiently in reform documents but is of equal importance to the previous ones (Lederman, 1999).

Understanding NOS insures and supports successful understanding of science content and helps in developing awareness and appreciation of scientific research and science in general as major components of our contemporary culture (Lederman, 1992). Various researchers have attempted to establish the relationship between teachers’ conceptions of NOS and their classroom practices (Abd-El-Khalick, Bell, & Lederman, 1998; Bartholomew, Osborne, & Ratcliffe, 2004; BouJaoude, 1996; Brickhouse, 1990; Bell, Lederman, & Abd-El-Khalick, 2000; Duschl, 1990; Khishfe & Lederman, 2007; Lederman, 1992, 1999; Lederman & Ziedler, 1987; Water-Adams, 2006). Despite this importance, an inadequate understanding of NOS whether in teachers or students has been reported. Additionally, Bartholomew, Osborne, and Ratcliffe (2004) maintained that most science teachers focus on scientific facts and emphasize the notion that science is an established body of knowledge that does not require validation, rather than highlighting the processes of science.

In fact, considerable work has been accomplished to determine the impact of teachers’ conceptions of NOS that is, their beliefs and understandings about science, on their instructional practices and thus, on their students’ understanding of this construct.
(Abd-El-Khalick, Bell, & Lederman, 1998; Brickhouse, 1990; Lederman, 1999; Waters-Adams, 2006). All this research is guided by two main assumptions: (a) teachers’ classroom practices closely reflect their conceptions and (b) students’ conceptions are directly related to those of their teachers (Bell, Lederman & Abd-El-Khalick, 2000). Brickhouse (1990) found that teachers’ knowledge about NOS, whether it is in line with standard aspects set by science educators or not, mediated an explicit translation of this knowledge into classroom practice. Moreover, their views of NOS directly influenced their beliefs about how their students should learn science. On the contrary, Lederman and Ziedler (1987) found that teachers’ classroom behavior is not a direct implication of teachers’ conceptions and knowledge, the translation of knowledge of NOS to practice, is mediated by teachers’ level of experience and their intentions to teach NOS as well as the perceptions of their students. In fact, a growing area of research maintains that “the relationship between teachers’ conceptions and their classroom practice is far from direct or simple” (Abd-El-Khalick, Bell, & Lederman, 1998, p.419). Whether teachers’ conceptions and understandings of NOS are reflected in their instructional planning and classroom practice remains an important academic research area.

In Lebanon, a summary of the research about NOS by BouJaoude and Abd-El-Khalick (2004) reveals that NOS research is of two types: Descriptive studies and intervention studies. Farah (1994) used the Nature of Scientific Knowledge Scale (NSKS) in a descriptive study whose purpose was to assess science teachers’ conceptions of certain aspects of NOS. Results of this study revealed that teachers did not have adequate understandings of these aspects which are, according to the researcher, a direct result of the failure of university programs to introduce these
aspects to pre-service science teachers. Moreover, while interviewing science teachers and school administrators regarding their views of science, BouJaoude and Abd-El-Khalick (1995) reported that teachers’ thought of science as content without any regard to other important aspects. Similarly, BouJaoude (1999) found that most teachers and students hold traditional views of NOS. In his study, BouJaoude argued that the origin of these views stems from the emphasis on science content in the Lebanese curriculum and the neglect of the epistemology and sociology of science. This results in students having a strong scientific content background but naïve views of the aspects of NOS. On the other hand, Abd-El-Khalick (2001) carried out an intervention study with elementary science teachers. Results of this study revealed that teachers acquired adequate and contemporary conceptions as a result of the study but were not capable of transferring their knowledge into new teaching contexts.

As outlined above, research has shown that translation of teachers’ NOS conceptions into classroom practice is a rather complicated process mediated by various factors. Thus, to facilitate changes in teachers’ classroom practices, educators need first to establish the relationship between these practices and teachers’ beliefs and conceptions and second to investigate the factors that enhance or impede this relationship. In Lebanon, research has focused mainly on teachers and students’ conceptions of NOS with lack of significant emphasis on research regarding the relationship between teachers’ conceptions and their classroom practice and the factors that mediate this relationship. Consequently, the purpose of this study is to examine the possible relationship between conceptions and practices and to determine the factors that mediate this relationship. Specifically, this study is guided by the following research questions:
1. How do teachers’ conceptions influence their practices about the Nature of Science?

2. What are the factors that mediate the relationship between conceptions and practice?

Noting the obvious complexity of the relationship between teachers’ conceptions and their classroom practices, it is useful to explore this relationship closely in order to elicit all the factors that mediate it. Taking into consideration the factors that impede or enhance this relationship might augment teachers’ performance in their classrooms and help them in reflecting their knowledge background in effective instructional strategies. Moreover, establishing a clear understanding of teachers’ beliefs and conceptions about the interrelated aspects of NOS might provide useful knowledge that can be used to enhance curriculum reform efforts in Lebanon that aspire to prepare citizens for the 21st century (National Center for Educational Research and Development [NCERD], 1994)
CHAPTER II

REVIEW OF RELATED LITERATURE

A variety of factors coalesce to influence teachers’ practices and determine the educational approaches they adopt in their classrooms. Among these factors, is the type of education to which teachers were exposed. This experience plays an important role in helping teachers develop specific conceptions—beliefs and knowledge about their specific field of study— which in turn shapes their classroom practices. Developing specific knowledge and beliefs about science education in specific, and the influence this exerts on teachers’ classroom practices are two main areas of research in science education.

Gallagher (as cited in Bartholomew, Osborne, & Ratcliffe, 2004) claims that preservice teachers possess a rather limited knowledge of the processes by which scientific knowledge is generated. This, in turn, sets limits on the capability of these teachers to plan and implement lessons that guide their students and help them to establish an appropriate understanding of science and thus, go beyond the memorization of scientific facts and content. Alongside this, it has been established that having the essential knowledge background alone is not sufficient for teaching. Schwartz and Lederman (2002) assert that teachers need to possess appropriate beliefs about the discipline they are to teach and that is, science. Both dimensions of teacher education shall mediate the translation of knowledge into practice in the classrooms. From this stems the importance of investigating teacher education which comprises two main dimensions: content knowledge and beliefs. Both exert an influence on each other and are influenced by other external factors. Moreover, both dimensions affect teachers’ classroom practices, an assumption that needs to be explored. Thus, for the
purpose of this study, it is necessary to investigate what previous research has reported regarding this influence and the impact of different factors on these two aspects of teacher education and thus, on the practice adopted in classrooms.

Content Knowledge and Practice

Research has been conducted to establish the role of teachers’ content knowledge in determining classroom practice. According to Anderson (1987) and Shulman (1987), content knowledge comprises three main aspects, the curricular content knowledge, subject-matter content knowledge, and pedagogical content knowledge (PCK). The three are considered crucial for successful teaching.

Curricular content knowledge. To start with, the curricular content knowledge consists of the scope and sequence of educational curricula. Developing knowledge of the scope and sequence of a curriculum is essential for teachers to be able to organize content matter in a way that is useful for teaching. The scope of a certain curriculum, according to Ornstein and Hunkins (2004) refers to the “content, topics, learning experiences, and organizing threads comprising the educational plan” (p.241). On the other hand, the sequence of a curriculum constitutes the cumulative and continuous learning or what is called the vertical progression of the different curricular areas or topics. Developing an appropriate view of the scope and sequence of a certain curriculum as well as the learning objectives is essential for appropriate implementation of that curriculum and thus, for achieving the goals and objectives.

Subject–matter content knowledge. A second component of knowledge necessary for successful teaching is related to subject-matter content knowledge. Possessing the appropriate subject-matter content knowledge is crucial for successful teaching. The firm grasp of the content in a certain field allows teachers to be in full
control of their lessons and the questions they pose in their classrooms. Tobin and Garnett (1988) argued that primary teachers who lack the appropriate content knowledge that is necessary for good teaching are unable to prepare their students to understand science and to succeed in higher grades. Even though these teachers may have the essential pedagogical knowledge, the deficiency in their subject content knowledge renders them unable to implement various activities in their science classrooms. Similarly, in a qualitative study, Brickhouse (1990), found that a teacher with a master’s degree in a subject area she teaches demonstrated “more dynamic classroom practices” (p.59) due to her more sophisticated understanding of the content matter and thus, her increased ability to reveal the relationships among the various concepts to her students.

_Pedagogical content knowledge (PCK), instruction, and learning._ Shulman (1987) considers PCK as “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues, are organized, represented, and adapted to the diverse interest and abilities of the learners, and presented for instruction” (p.8). Similarly, Tobin, Tippins, and Gallard (1994) refer to the integration between subject matter and pedagogy as Pedagogical Content Knowledge which includes the knowledge of how to teach specific concepts and thus, goes beyond the knowledge of concepts and topics. Various studies have highlighted the influence of PCK on instruction and instructional strategies employed by teachers. Teachers lacking the appropriate PCK were reported to have difficulty in realizing the major relationships among concepts in their respective fields and thus, were not capable of organizing their knowledge and revealing it to their students through instructional strategies (Mason, 1988). Mason claimed that pre-service teachers who possess an appropriate knowledge
background in their content areas but lacked an appropriate preparation to develop PCK were unable to communicate their subject matter to their students. Mason concluded that it is necessary to show teachers how to apply their knowledge and present it in effective teaching strategies, this, in turn, will help them develop their PCK and will ultimately impact their classroom practices. Another impact PCK has on instruction is evidenced by the way teachers with the essential PCK interact with their students and the way they sequence their sessions (Gallagher & Tobin, 1987). Possessing the appropriate subject-matter content knowledge and PCK influence teachers’ teaching approaches in the classroom and thus, affect the degree of student engagement (Tobin & Garnett, 1988).

Although most of the research has focused on the influence of PCK on instruction, it remains of practical importance to investigate the influence PCK has on student learning because in the end, learning is a major goal all teachers aim at achieving among their students. Research in this area (e.g. Mason, 1998; Gallagher & Tobin, 1987) has arrived at the conclusion that a relationship exists between how teachers approach certain concepts in their instruction and the way students organize these concepts and thus formulate understanding of these concepts. As an example, research focusing on the use of specific instructional methods, accompanied by the adoption of instructional aids such as computer causal models (White, 1998; Wiser & Amin, 2002), has reported increased student achievement and understanding of the different concepts after being exposed to these specific methods. These findings demonstrate the importance of developing pedagogical content knowledge in teachers during their pre-service training in order to enhance student achievement. In fact, developing pedagogical content knowledge in teachers has become a key objective of
most teacher education programs. In summary, the research findings outlined above emphasize the importance of teachers developing curricular content knowledge, subject-matter content knowledge as well as PCK for them to engender learning in their students.

Moreover, research has also reported that beliefs tend to be shaped by teachers’ exposure to new instructional methods and to knowledge about the nature of their fields during their training in pre-service training programs. Richardson (1996) for example, has shown that beliefs are a result of the form of teaching teachers were exposed to and thus, develop in parallel to the development of pedagogical content knowledge. Richardson also asserted that in order to improve teachers’ classroom practices it is necessary to gain full insight into the beliefs adopted by these teachers.

Beliefs and Practice

What are beliefs? Teachers’ beliefs have surfaced as an important and fundamental aspect of teacher education. More specifically, science educators have realized the necessity of examining these beliefs in relation to science teaching and learning. Oliver and Koballa (1992) have identified eight categories of definitions for beliefs through administering questionnaires and conducting interviews. These include: (1) beliefs are equal to knowledge; (2) beliefs are a functional representation of knowledge; (3) beliefs are similar to attitude, motivation, and behavior; (4) beliefs as a relationship between object and attribute that a person holds true, (5) beliefs as “personal convictions that may or may not be based on observation or logical reasoning”; (6) beliefs as a vision oriented by an epistemic system; (7) beliefs as the acceptance or rejection of a proposition and (8) attribute a dictionary definition of belief. Nevertheless, Oliver and Koballa maintained that these eight varying categories
have certain elements in common. These are related to the existence of a relationship between beliefs and knowledge, the assertion that beliefs guide action and the fact that beliefs are developed through communication. On the other hand, Tobin, Tippins, and Gallard (1994) redefined beliefs as “a form of knowledge that is personally viable in the sense that it enables a person to meet his or her goals” (p.55). According to these authors, all beliefs have a social aspect despite the fact that they are personal constructs.

Other researches have developed different definitions for beliefs and asserted that a belief is a construct derived from various fields of study such as psychology, philosophy, sociology, and anthropology. The most common definition agreed upon by various practitioners and researchers in these different fields is: “psychologically held understandings, premises, or propositions about the world that are felt to be true” (Richardson, 2003, p.2). Moreover, other researchers (e.g. Pajares, 1992; Tobin, Tippins, & Gallard, 1994) consider attitudes, confidence, motivation, self-esteem and self-concept to be included under the broad concept of belief. Pajares (1992) also considers that, in an educational context, beliefs comprise the teachers’ conceptions of the nature of knowledge in a given discipline. Constructivists, on the other hand, term beliefs as a type of knowledge that requires less agreement among individuals because it is based on poor informational background (Guba & Lincoln, 1989). Despite the fact that there are different definitions of beliefs, the influence beliefs exert on actions and thus, on practice is a major aspect of beliefs that is generally agreed upon by most researchers. According to Hancock and Gallard (2004), “a belief is an understanding held by an individual that guides that individuals’ intentions for action” (Hancock & Gallard, 2004, p.281). The definition that is adopted for this study is that beliefs are personal constructs and conceptions about the nature of knowledge of a particular
discipline, with a direct implication on practice and action (Richardson, 1996; Hancock & Gallard, 2004; Pajares, 1992).

The relationship between conceptions, beliefs and practice. Emerging research has highlighted the influence of teachers’ beliefs on adopting specific instructional methods in their classrooms. That beliefs impact teachers’ instructional practice, is a common finding among almost all investigations. The impact occurs first by influencing teachers’ views about their students and their learning processes, second, by enhancing their knowledge about the nature of their field and third, by stimulating their ability to accept professional development and thus, to change (Barlow & Cates, 2006). Moreover, Richardson (2003) argues that beliefs are essential to investigate because they impact “how the [teacher] candidates make sense of what they are studying. They are also thought to guide teaching action” (Richardson, 2003, p.4). Furthermore, there is a general consensus that “[teachers’] beliefs are connected to planned and enacted instructional practices in the classroom” (Roehrig & Kruse, 2005, p.413).

The relationship between beliefs and action has been investigated extensively (e. g. Richardson & Placier, 2001; Water-Adams, 2006), however, the question that remains to be answered is whether action drives beliefs, beliefs guide action, or they both interact to result in different practices (Richardson, 2003). Tillema (2000) has investigated this question and concluded that it is suitable to view beliefs as intermingled with actions. “This is not to say that performance or action in teaching can do without beliefs… But one cannot contend that they guide action” (Tillema, 2003, p.587). Other contradictory findings were reported by Water-Adams (2006). The investigator accounted for the fact that beliefs were the “determining factor” that guides
teachers’ decisions about their classroom practices and the instructional strategies they employ.

In sum, an individual’s knowledge and understanding of a certain field of study affects their beliefs about that specific field (Richardson, 1996), in this case science. Thus, in what concerns this investigation, it is necessary to consider the knowledge about the aspects of NOS, acquired from exposure to a specific type of pedagogical content knowledge (in addition to other factors outlined above), its effect on the beliefs teachers hold regarding the nature of science (NOS), and in turn, the influence it applies on teachers’ actions in classrooms.

The Classroom Context for Learning and Teaching Nature of Science

Teaching extends beyond the transmission of information to students through instruction by the adoption of various instructional methods. As outlined earlier, teaching and thus, learning are governed by other factors including teachers’ beliefs related to a specific area of study and comprising their content knowledge in its various types. Similarly, teaching the various aspects of NOS requires an appropriate understanding of these aspects, the PCK necessary to teach these aspects, and the development of the necessary classroom context for teaching NOS in the classroom. According to Lederman and Zeidler (1987) classroom context includes various classroom variables such as teachers’ general instructional approaches, teachers’ content-specific characteristics and the overall atmosphere of the classroom. Investigating these variables would determine if the classroom atmosphere is conducive or not for teaching the various aspects of NOS. Moreover, developing a viable instructional context within which learners can develop their NOS conceptions is essential. A number of researchers (e.g. Schwartz, Lederman, & Crawford, 2004) have
identified this context as a requirement for developing appropriate NOS conceptions. This context includes reflecting upon the developed conceptions as well as maintaining inquiry as one context for teaching NOS. As maintained by Bartholomew et al., (2004), it is essential that teachers develop their own appropriate knowledge of the aspects of NOS and the scientific processes before they can effectively address these in their classrooms.

*Nature of science pedagogical content knowledge (NOS PCK).* Abd-El-Khalick & Lederman (2000a, 2000b) suggested that teachers should possess what they called ‘NOS PCK’, suggesting that for teachers to be able to teach NOS in their classrooms, they not only need to possess the appropriate knowledge of NOS but in addition, they should have the necessary pedagogical content knowledge relative to NOS. This is necessary in light of the fact that even though the importance of NOS has been established in curricular reform documents, research has illustrated that teachers still possess inappropriate understandings of the different aspects of NOS (Lederman & Lederman, 2004). Abd-El-Khalick and Lederman (2000a, 2000b) claim that such pedagogical knowledge can be used to instill NOS aspects in students’ thinking. Moreover, Schwartz and Lederman (2002) highlighted the importance of weaving subject-matter knowledge, NOS knowledge and pedagogical knowledge for teachers to successfully address NOS aspects in their classrooms. All three knowledge areas should interact and coalesce in order to build what Abd-El-Khalick and Lederman (2000a, 2000b) call PCK for NOS. In addition, expressing the necessary intentions towards NOS teaching and learning plays a part in determining whether teachers are going to address NOS in their classrooms or not, as maintained by Schwartz and Lederman (2002). Teachers either view NOS as important and attainable by students and thus,
they include it in their classroom instruction or they do not. Thus, four important factors are necessary for teachers to teach NOS appropriately. These include understanding NOS, PCK of NOS, teachers’ beliefs about NOS, and teachers’ intention to teach NOS. Intention to teach NOS is a new factor proposed by Schwartz and Lederman (2002) and explored in research (e.g. Brickhouse 1990; Gallagher, 1991; Lederman, 1992, 1999; Lederman & Ziedler 1987; Richardson, 1996).

*Teachers’ beliefs and conceptions about NOS: The effect on practice.* Several studies have highlighted the process by which teachers formulate their beliefs regarding NOS. Gallagher (1991) investigated the influence of teachers’ science teaching during secondary school years on their beliefs and understanding of NOS. Gallagher concluded that teachers possess a pre-existing belief about NOS stemming from the type of education they received and from the types of textbooks in which they have studied which typically conveyed science as established facts and truths about natural phenomena. It was reasoned that teachers do not possess an adequate understanding of NOS and thus, their beliefs are not in line with the aspects of NOS established by Lederman (1992).

Similarly, Brickhouse (1990) established the relationship between the conceptions of the nature of scientific theories teachers have acquired during their preparation and the type of instructional approaches they adopt in their classrooms later on. The divergent views of the nature of theories (facts or tools to solve problems) were consistent with the various educational goals the teachers set for their students to accomplish. The goals ranged from mere knowledge of scientific theories to the actual use of these theories in order to solve problems. In addition, teachers participating in this study had various conceptions of how scientific progress occurs. Some of them
thought that science progresses by accumulation, while others conceived that science
progress occurs through the “interpretation of old observations” (p.5).

Abd-El-Khalick and BouJaoude (1997) reasoned that teacher preparation
programs are not facilitating the development of the suitable conceptions related to the
aspects of NOS as outlined by Lederman (1992). In their study, teachers were found to
hold naïve and incoherent ideas related to NOS and thus, the researchers recommended
reforming education preparation programs to enhance the development of the
appropriate knowledge base that includes NOS and NOS-PCK necessary for adequate
teaching practices.

Schwartz and Lederman (2002) emphasized that, depth of understanding of the
aspects of NOS as well as knowledge of the subject-matter content knowledge are of
practical importance in guiding the teachers’ instructional practices in their classrooms
and in helping them realize their intentions. All these dimensions affected teachers’
learning as well as teaching NOS. The researchers found that teachers possessing a rich
scientific background and a developed understanding of NOS were more capable of
addressing NOS in their teaching. On the contrary, a rather limited scientific knowledge
and a constrained view of NOS hindered incorporating NOS in classroom practice.

Thus, teachers’ conceptions are crucial ingredients among all the factors that
determine and more importantly guide action in classrooms, however, it is not, for sure,
the only factor. In their study, Abd-El-Khalick, Bell, and Lederman (1998) highlighted
the fact that all their participants possessed appropriate understanding of the most
important aspects of NOS. Many of them claimed, during interviews, that they refer to
NOS during their classroom instruction and that they actually teach it. Analysis of all
the data obtained during this study revealed the opposite. Despite the fact that all the
participants had the knowledge framework of NOS, explicit reference to NOS was lacking in either their planning or actual instruction in the classrooms.

Likewise, Bell, Lederman, and Abd-El-Khalick (2000) assert that the participants in their study failed to identify the aspects of NOS among the instructional objectives they aim to achieve despite the fact that their conceptions of NOS were appropriate. Concluding that, possessing valid conceptions of NOS does not essentially necessitate the translation of these conceptions into a consistent performance in classroom. A similar conclusion is drawn by Lederman and Ziedler (1987) in another study where they maintain that “A teacher’s classroom behavior does not necessarily vary as a direct result of his/her conceptions [about the NOS.]” (p.73). On the contrary, there are many other factors which should be investigated to enlighten teacher educators about the intricacies existing in actual classrooms. These factors coalesce to determine the adoption of specific instructional strategies that mediate the installation of the appropriate aspects of NOS as set forth by Lederman (1992).

These findings thus highlight the claim that there should be more to implementing NOS instruction in the classroom than just appropriate conceptions. To determine the other factors affecting this implementation, various research studies have been conducted. Some studies (Abd-El-Khalick, Bell, & Lederman, 1998; Duschl & Wright, 1989; Lederman, 1995, 1999; Lederman & Zeidler, 1987) have reported that factors such as viewing NOS as less significant than other instructional outcomes, classroom management, lack of resources, teachers’ experience, lack of planning time, intention, pressure to cover content and perceptions of students all interplay to impede or facilitate the relationship between beliefs about NOS and classroom practice.
In parallel to the findings of the previous studies, Lederman (1999) and Bell, Lederman, and Abd-El-Khalick (1997), claimed that teachers’ classroom practices are not necessarily influenced by their conceptions of science. On the contrary, many factors contribute to the translation of conceptions into classroom practices, some of which include teachers’ level of experience, intentions and perceptions of students. Research results indicate that teachers possessed adequate understanding of NOS in accordance with those identified by Lederman (1992) and reflected in various reforms. Moreover, classroom observations, lesson plans, and interviews revealed a clear difference between teachers’ conceptions and their classroom practices. To probe these results, Schwartz and Lederman (2002) highlighted the importance of strong intentions about teaching NOS, “if one does not feel NOS is important, relevant, or attainable by students, one is not likely to teach NOS” (p. 231). Bell, Lederman and Abd-El-Khalick (1997), argued that for appropriate translation of conceptions into classroom practice, teacher preparation programs should instill among preservice teachers an understanding of the importance of teaching NOS and stressing it in their instructional strategies in classrooms.

The context of teaching NOS. The relationship between the instructional contexts of teaching NOS which is NOS-PCK and the advancement in teachers’ as well as students’ conceptions of NOS has been investigated in various research studies (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007; Hipkins, Barker, & Bolstad, 2005; among others). Some have proposed the use of history of science for teaching the different aspects of NOS (Hipkins et al., 2005). Other researchers, (Schwartz, Lederman, & Crawford, 2004; among others), asserted that using inquiry approaches as a context to teach NOS in
classrooms proved to be successful. Teachers in this study developed a deeper and more meaningful understanding of the aspects of NOS after being exposed to inquiry approaches during which they discussed and reflected upon their conceptions. On the other hand, various research studies (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002) have asserted that using an explicit approach to teaching NOS proved to be more effective than the use of an implicit approach. That is, according to Akindehin (1988), NOS should be explicitly addressed and “planned for instead of being anticipated as a side effect” (as cited in Khishfe & Lederman, 2007). Likewise, Khishfe and Lederman (2007) used an integrated versus a non-integrated approach in their study in order to teach students the aspects of NOS. The integrated approach involves an explicit plan to teaching NOS embedded within the content as opposed to a non-integrated approach which involves an explicit approach without intentionally relating NOS to content (p.940). Results showed that both approaches proved successful in terms of teaching NOS and reported an increased student understanding of NOS.

To conclude, the review of literature presented above shows that although research has been conducted, it does not provide a conclusive and coherent explanation of the relationship between conceptions and classroom teaching. In response, the purpose of this study is to investigate the relationship between teachers’ conceptions about NOS and their classroom practices and to delineate the factors that either impede or mediate that relationship in the case of Lebanon.
CHAPTER III

METHODS

Research Design

This study investigated the relationships between teachers’ conceptions and classroom practice. Since this study involves investigating the views, conceptions of teachers then it was essential to employ a qualitative design in order to capture the meanings that these teachers construct about their experiences. In addition, determining participants’ understanding about the nature of science (NOS) required using an open-ended questionnaire followed by interviews to provide participants with the opportunity to reflect on their views and explain the reasons behind adopting them.

Participants

Participants in the study were seven Grade 10 high school Biology teachers teaching in private secondary schools in Greater Beirut Area and using the Lebanese science curriculum. This Lebanese science curriculum aims at instilling scientific literacy in individuals with an understanding of the nature of science (NCERD, 1997), rendering it appropriate for the purpose of this study. The content in grade 10 Biology national textbook includes knowledge about vascular plants and their mode of nutrition as well as communication mechanisms inside the human body including the nervous and endocrine systems. Some of the concepts discussed in these topics render themselves appropriate for teaching the aspects of NOS since they include experimentation, history of discovery, and various theories. In addition, Grade 10 was chosen because students at this grade level have not yet be tracked into literary and scientific section and are thus still following the same curriculum. Moreover, there are
no official examinations at the end of Grade 10, making it easier to have access to students and teachers.

All the participants have a Bachelors degree (BS) in their respective science field (Biology) in addition to a teaching diploma (TD) in teaching sciences for secondary classes from various universities. Only participants with these two degrees were selected to participate in the study to make sure that they have been exposed to the aspects of NOS in the teacher preparation programs. This selection assured that the participants had adequate pedagogical as well as content knowledge.

**Instruments**

An instrument entitled “Views of Nature of Science Questionnaire- Form C” (VNOS-C) was used to assess teachers’ conceptions of NOS. In addition, classrooms were videotaped and a variety of artifacts, including lesson plans, were collected from teachers. Finally, stimulated recall interviews were conducted with teachers by using the filled out questionnaires as prompts.

*Views of Nature of Science Questionnaire (VNOS-C).* The “Views of Nature of Science Questionnaire” (VNOS-C) (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001) (Appendix I) was used to assess teachers’ conceptions of NOS. VNOS-C is a modified and expanded version of the original VNOS questionnaire and also of form B. Content validity of the items in this questionnaire was established by Abd-El-Khalick et al. (2001). It is an open-ended questionnaire comprised of ten items. This allows the participants to reveal their views in regard to the different aspects of NOS and the rationales that underlie these views. There is no one-to-one correspondence between one item in the questionnaire and one aspect of NOS. Several items might target one
aspect of NOS and one aspect is targeted in more than one item. Due to the open-ended nature of the questionnaire, it is recommended not to set time limits, previous participants spent 45-60 minutes in completing the VNOS-C (Abd-El-Khalick et al., 2001). Each VNOS item is printed on a separate page in order to provide the respondents with ample space to answer freely. Respondents in this study were given as much time as was needed to complete the questionnaire. Moreover, they were informed that there were no correct or wrong answers because the purpose of the questionnaire was to identify their views.

**Videotaping.** The same teachers who filled the questionnaire were videotaped twice in their classrooms. The length of each videotaping was 50 minutes. The fact that teachers filled out the VNOS-C questionnaire might have influenced their practices in their classrooms; a fact that was considered during the analysis. In addition, during the analysis, different classroom variables related to teachers’ practice, the overall classroom atmospheres, as well as teachers’ content specific characteristics were considered and noted. These variables along with their categories and definitions are presented in table 1 and all are adopted from Lederman and Zeidler (1987).

**Individual interviews.** In order to validate teachers’ views of NOS expressed in the questionnaires and elucidate and clarify the views these participants held regarding NOS, semi-structured interviews were used. These interviews were conducted prior to analyzing the responses to the questionnaire in order to avoid analysis of data from other sources. During these interviews, the questionnaire was given to the participants again and they were asked to read, explain, and justify their responses, a process called stimulated recall. Such questions allowed the researcher not only to assess the views and positions held by the participants, but to clarify the reasons behind expressing such
views as well as to delineate the factors that mediate or hinder the translation of these into classroom practice. An interview protocol developed by Abd-El-Khalick et al. (2001) (Appendix II) to clarify and find out the basic assumptions behind the participants’ responses to VNOS-C items was used in this process.

Table 1

*Classroom Variables, their Categories and their Definitions (Lederman & Zeidler, 1987)*

<table>
<thead>
<tr>
<th>Classroom Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rote Memory/ Recall (TG)</td>
<td>Material is (is not) presented at the factual or knowledge level</td>
</tr>
<tr>
<td>Lecturing (TG)</td>
<td>Teacher talk does (does not) monopolize class time with little student involvement</td>
</tr>
<tr>
<td>Frequent Questioning (TG)</td>
<td>Teacher asks (does not ask) frequent questions</td>
</tr>
<tr>
<td>Higher Level Questions (TG)</td>
<td>Higher Level Questions (Bloom’s Taxonomy) are (are not) used frequently.</td>
</tr>
<tr>
<td>Fragmented (TG)</td>
<td>Teacher’s presentation is (is not) “free-flowing” and logically sequential</td>
</tr>
<tr>
<td>Problem Solving (TG)</td>
<td>Open ended questions and/or discrepant events are (are not) used</td>
</tr>
<tr>
<td>Receptive (TG)</td>
<td>Teacher is (is not) receptive to student-initiated questions</td>
</tr>
<tr>
<td>Probing (TG)</td>
<td>Follow-up questions to students responses are (are not) used</td>
</tr>
<tr>
<td>Humor (TG)</td>
<td>Teacher does (does not) interject jokes and/or humorous histrionics during instructional presentations</td>
</tr>
<tr>
<td>Amoral (TC)</td>
<td>Scientific knowledge is (is not) presented as amoral</td>
</tr>
<tr>
<td>Creativity (TC)</td>
<td>Scientific knowledge is (is not) presented as a product of human imagination and creativity</td>
</tr>
<tr>
<td>Developmental (TC)</td>
<td>Scientific knowledge is (is not) presented as being tentative</td>
</tr>
<tr>
<td>Fallibility (TC)</td>
<td>Teacher does (does not) admit uncertainty with respect to content</td>
</tr>
<tr>
<td>Testable (TC)</td>
<td>The importance of empirical validation of subject matter is (is not) stressed</td>
</tr>
<tr>
<td>Unified (TC)</td>
<td>The interrelationship of various science disciplines is (is not) emphasized</td>
</tr>
<tr>
<td>Discipline (C)</td>
<td>Classroom atmosphere is (is not) highly structures and discipline oriented</td>
</tr>
</tbody>
</table>
Table 1 Cont’d

<table>
<thead>
<tr>
<th>Low Anxiety (C)</th>
<th>Classroom atmosphere is (is not) comfortable with little anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapport (C)</td>
<td>Teacher and students do (do not) socialize and interact in a friendly manner</td>
</tr>
</tbody>
</table>

Variable categories: TG: Teachers’ general instructional approach; TC teacher’s content-specific characteristics; C: classroom atmosphere.

Lesson plans. In addition to filling out the VNOS-C and participating in interviewing, each teacher was asked to submit two lesson plans. These lesson plans were used to locate any mention of NOS during planning for the instructional sessions.

Pilot testing

The questionnaire was piloted with one science teacher who was asked to assess the comprehension as well as the content of the questions. It is worth noting that an earlier version of VNOS was used by Khishfe and Abd-El-Khalick (2002) in Lebanon. The teacher who reviewed the questionnaire said that all the questions were comprehensible and suitable for teachers. Additionally, the researcher videotaped one lesson that was taught by a teacher other than those who participated in the study and analyzed it to make sure that it was possible to derive meaning from classroom videotapes.

Procedure

Teachers who participated in the study filled the VNOS-C at the beginning of the study before conducting the classroom videotaping. Responses to the VNOS-C were not analyzed at this point of the investigation to avoid biasing the collection of the rest of the data by labeling the teachers as informed or naïve in relation to the aspects of
NOS. Then classroom videotaping was completed (2 classroom sessions for a total of 100 minutes for each teacher). Concurrently, lesson plans were collected. Following
the videotaping, teachers participated in semi-structured interviews that took between
30 and 40 minutes each. The interviews included a simulated recall activity during
which teachers responded to question about their responses to VNOS-C for validation
purposes. In addition, teachers were asked about the factors that influenced their
decisions to teach or not to teach NOS in their classrooms. The total number of schools
and teachers who participated in this study is shown in the Table 2.

Table 2

*Numbers of Schools and Teachers who Participated in the Study*

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of schools (Private)</td>
<td>6</td>
</tr>
<tr>
<td>Number of teachers responding to the questionnaire</td>
<td>7</td>
</tr>
<tr>
<td>Number of teachers observed (Private schools)</td>
<td>7</td>
</tr>
<tr>
<td>Number of classroom sessions videotaped</td>
<td>14</td>
</tr>
<tr>
<td>Number of lesson plans collected</td>
<td>17</td>
</tr>
</tbody>
</table>

*Limitations*

As outlined before, factors such as high school teaching, PCK and adopted
textbooks used for teaching influence teachers’ beliefs about NOS. The fact that these
factors were not investigated in this study presents itself as a limitation to the scope of
this study. Therefore, this study gives no information about the origin of the beliefs and
the understandings held by the teachers. It is worth noting that these teachers attended
various universities that offer teacher preparation programs. While all of them contend
that they address issues related to NOS in their curricula, there was no way for the researcher to verify these claims, especially how NOS is covered in university teacher preparation classes. Finally, data related to planning and practice were collected through the use of lesson plans and classroom observations, which limited the scope of possible data that could have been used to understand teacher’s views about NOS.

Data Analysis

Data from each participant were analyzed separately in order to generate individual profiles. The analysis involved searching data for evidence of use of the different aspects of NOS. Then comparisons were made between the individual participant profiles to identify similarities and differences across the profiles. Finally, data from the different sources (VNOS-C, videotapes, individual interviews, and lesson plans) of each teacher were analyzed to find out if the views from the different sources were aligned. In order to validate the analysis, a graduate student majoring in science education carried out the same analysis for a randomly selected sample of the data. The researcher and the graduate student followed the following process to validate the analysis:

1. The researcher and the graduate student met and agreed on the process used in the analysis. They also analyzed one data sample together.

2. The researcher and the graduate student analyzed another randomly chosen sample of the data and generated teachers’ profiles and then they met to compare results and resolve any differences. This process was repeated until consensus was reached.
Following this process, then the researcher analyzed the rest of the data by herself.

**Analysis of responses to the VNOS-C and individual interviews.** Participants’ views about NOS were elucidated by the use of the VNOS-C questionnaire as well as through the individual interviews. The interviews were giving priority when explicating participants’ views regarding NOS because they provided the participants the opportunity to elaborate and justify their responses to VNOS-C items. Moreover, these interviews helped to elucidate teachers’ opinions about the factors that facilitate or hinder the translation of their NOS views into classroom practices. One-to-one correspondence between one NOS aspect and one item in VNOS-C is not assumed since the different NOS aspects were targeted in more than one item in the questionnaire. According to Abd-El-Khalick et al. (2001), this approach has two major advantages. First, it is in line with the belief that NOS understanding should not be narrowed into specific answers to specific questions. Second, it allows for a deeper and meaningful understanding of NOS. During analysis, respondents’ answers were not judged literally. Indeed, data from the individual interviews was used to probe the answers and sometimes suggested alternative ways for interpreting these answers. Moreover, the examples that the participants were asked to provide in the questionnaire in support to their conceptions of NOS aspects were carefully examined. These examples helped to contextualize participants’ conceptions of key concepts and shed light on some of their ideas.

Comparisons between the participants’ views and the NOS aspects were generated according to the standard NOS views as set by Lederman (1992) and denoted by Schwartz, Lederman, and Crawford, (2004) and which are described in Table 3. For
each participant, a profile was generated using the responses on the VNOS-C questionnaire as well as the individual interviews. A participant’s view was categorized as either naïve or informed based on the comparisons with the NOS aspects. If the participant’s view was in line with the standard aspects of NOS as set by Lederman (1992), then such a view is considered informed. On the contrary, if the view is not in accordance with the standard definitions of the NOS aspects, such a view is termed naïve. This coding scheme was used in the analysis of both, the responses to the items in the VNOS-C questionnaire as well as to the clarification of these during the interviews. In addition, data from the interviews were used to elicit the factors that either hindered or facilitated the translation of NOS beliefs into actual classroom practice.

Table 3

*NOS Aspects and their Definitions that Served as a Basis for Description (Schwartz, Lederman, & Crawford, 2004)*

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tentativeness</td>
<td>Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.</td>
</tr>
<tr>
<td>Empirical basis</td>
<td>Scientific knowledge is based on and/or derived from observations of the natural world.</td>
</tr>
<tr>
<td>Subjectivity</td>
<td>Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.</td>
</tr>
</tbody>
</table>

29
<table>
<thead>
<tr>
<th>Creativity</th>
<th>Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations and inference</td>
<td>Science is based on both observation and inference. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.</td>
</tr>
<tr>
<td>Sociocultural embeddedness</td>
<td>Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.</td>
</tr>
<tr>
<td>Laws and theories</td>
<td>Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.</td>
</tr>
</tbody>
</table>

*Analysis of classroom observations and lesson plans.* For each participant, two videotapings were made. The videotapes were then transcribed for later analysis. In addition, two lesson plans were collected from each teacher. During the analysis all references to the aspects of the NOS in both data sources, whether implicit or explicit, were documented (Abd-El-Khalick et al., 1998). NOS aspects are explicitly addressed when they are obviously and overtly introduced in classroom activities or in objectives presented in the lesson plans. On the other hand, these aspects are implicitly addressed when they are “inferred from less prominent parts of the data sources” (Abd-El-Khalick et al., 1998, p.422). Moreover, Bell, Lederman and Abd-El-Khalick, (2000) decided to neglect all implicit instances for planning to or teaching the aspects of the nature of
science. They claimed that there is no “empirical support for the notion that an implicit approach is effective for enhancing students’ conceptions of NOS” (p. 569). Whether the implicit instances for teaching the aspects of NOS are effective in enhancing students’ conceptions or not is still a controversial issue in science education. Thus, for the purposes of this study, the implicit instances were taken into consideration, that is, coded and classified.

A coding system was used to analyze the data obtained from the various data sources employed for the purpose of this study. To refer to the participants, a numbering code was used from 1 to 7 preceded by the letter ‘T’ which stands for ‘teacher’. To refer to the information obtained from the VNOS-C questionnaire, interview, lesson plan, or videotapes, the following abbreviations were used: VNOS, Int., LP, and Vid respectively. Moreover, the first letter specifies the informed (I) versus naïve (N) views of NOS.
CHAPTER IV

RESULTS

All data sources were analyzed independently and then together in order to generate a profile for each teacher. The numerous and varied types of data sources (questionnaires, interviews, lesson plans, and observations) allowed for the triangulation of the data and thus, the construction of credible profiles for teachers. The conceptions of the participant science teachers were found lacking in some respects and acceptable in others. The teachers possessed some naïve views, based on Lederman’s standard views (1992), of the different aspects of the nature of science, these neither related to the teachers’ level of experience nor to their teaching practices.

Conceptions of NOS

Participants’ views of NOS were elucidated after the analyses of the two data sources, the VNOS-C questionnaire and the individual interviews. All these views were coded, classified and compared to the standard views set by Lederman (1992) and adopted by Schwartz, Lederman, & Crawford (2004). Evidence about the participants’ views of the nature of scientific investigations was drawn from the analysis of the participants’ responses to questions 1 and 2 in the interview (Appendix II):

- **Do all scientists use a specific method, in terms of a certain stepwise procedure, when they do science? Can you elaborate?**
- **Are you thinking of an experiment in the sense of manipulating variables or are you thinking of more general procedures? Can you elaborate?**

Most teachers (4: 57%) expressed the opinion that scientists use a specific method, a stepwise procedure, during their scientific investigations and defined an
experiment as the manipulation of variables or more general procedures as evidenced in the following excerpts:

*Scientists follow the scientific method and all experiments in science are based on this* (T7, Int.).

[scientists’] use a specific method; there are steps, an ordered discipline. Everything is organized and deals with one thing at a time. (T4, Int.)

[scientists use one method] (problem, proposed explanation, testing the explanation, gathering data and conclusion. (T5, Int.)

The remaining teachers (3:43%) considered that scientists do not follow one method when they are investigating a certain phenomena. Such a view takes into consideration the creative role of the scientist and the subjectivity of his/her investigation as demonstrated in the excerpts below:

*No one method, not the same process of testing or validating results could be other means of inquiry* (T1, Int.).

No, based on what they are doing, they use different ways of categorizing things but they follow certain criteria. (T2, Int.)

[There are] different methods that scientists can use, no standard one. (T6, Int.)

*Tentative nature of science.* “Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge” (Schwartz et al., 2004, p.613). When asked if a developed theory ever changes, all the participating teachers answered by yes. However, when asked about the reasons
leading to the change of a scientific theory in the VNOS-C Questionnaire, teachers provided different explanations and justified their answers as follows:

*Theories change because new scientific knowledge doesn’t always fit into the structure of a theory, so a theory must be modified in order to explain this new observation or accommodate this new knowledge (T1, VNOS)*

*Science may be subject to change when new evidence arises (T2, VNOS).*

*The basis of changing [a certain theory is that] during experimentation, new results and evidences appeared (T3, VNOS).*

*Theories definitely may change, new inventions may help discover new answers and change an old theory, and new discoveries change old views (T4, VNOS).*

*The explanation [theory] is not absolute but the most accepted at the time being, based on evidence. Theories do change, if a new phenomenon might contradict a certain accepted theory or a scientific theory unifies various phenomena and at the same time forms a guide to research more phenomena. (T5, VNOS).*

*There are lots of theories that are trusted, but events might happen and lead to new discoveries thus, new theories or discarding old theories. They [scientists] are certain [about the structure of the atom] as long as no new phenomena put the current model of the atomic structure in question (T5, VNOS).*
The notion of species might change with accumulating evidence. But since no real or rigid evidence exists, it [the structure of the atom] may remain and it will remain debatable. (T6, VNOS)

Technology is advancing, so this can lead to new observations and discoveries that can improve the theory. (T7, VNOS).

Thus, in their justifications, participants attributed the change of old theories or other constructs to the accumulation of new evidence and the collection of new types of data. Hence, some of them believed that change is due to the accumulation of new evidences leading to the discarding of previous theories and the generation of new ones that are more plausible and that fit the new evidence obtained, while others asserted that it is by accretion.

Empirical nature of science. Scientific knowledge is based on and/or derived from observations of the natural world (Schwartz et al., 2004, p.613). When asked if the development of scientific knowledge requires controlled experiments, almost all the participants (except for one) answered by ‘no’. To probe their answers, they were asked during the interviews if astronomy and anatomy, in which no controlled scientific experiments are usually performed, are considered as “sciences”. The participants could be divided into three categories based on their answers. The first category included 43% (3) of the participants who answered that both fields of study are considered science and that science does not necessitate experimentation but is “based on and/or derived from observations of the natural world” as maintained by Schwartz, et al. (2004):

Astronomy and anatomy are considered science and science by definition does not necessarily require controlled experiments (T1, Int.).
Science does not require experiments but we need observations (T4, Int.).

The other two categories either considered that science necessarily requires controlled experiments or believed that scientists actually do experiments in anatomy and astronomy (e.g. observing different colors of stars and trying to estimate their temperature, as asserted by one participant).

[Scientific knowledge requires [controlled] experiments] to prove that a certain idea is true (T2, VNOS).

Yes, we do [controlled] experiments [in astronomy and anatomy], to know how things are functioning (T3, Int.).

The development of scientific knowledge requires [controlled] experiments, because experiments include the trial and error strategy, which helps in proving a specific scientific point (T3, VNOS).

Hence, the majority of the participants (6:85.7%) held naïve views related to the empirical basis of scientific knowledge.

Subjective nature of science. Based on the definition adopted by Schwartz et al. (2004), Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable.
Personal values, agendas, and prior experiences dictate what and how scientists conduct their work” (p. 613).

When asked about this aspect, most participants, (4:57%) seemed to hold informed views related to the subjectivity of science. They considered that “science is influenced and driven by the presently accepted scientific theories and laws” (Schwartz et al., 2004, p. 613) as shown in the excerpts below:

- Preconceived ideas can affect the analysis to a certain extent, but it’s ok if they [scientists] are biased because they are trying to prove what they think is true (T4, VNOS)
- It is important to learn theories because they would be the base of understanding certain things and they would be used in discarding an old theory. Using the knowledge of the old theory and proving how they are wrong today (T4, VNOS)
- No mere observation because the way we infer to find an explanation is based on a theory (T5, Int.)

Moreover, these participants considered that personal subjectivity is unavoidable and that “Personal values, agendas, and prior experiences dictate what and how scientists conduct their work” (Schwartz, et al., 2004).

- Scientists might have the same set of data, and might probably analyze things similarly but each scientist thinks differently. The difference in the way of thinking will lead scientists (even people) to different conclusions. (T3, VNOS).

During the interview, the same teacher probed her answer by saying:
Same set of data but each one [scientist] thinks differently, different ideas, reach different explanations (T3, Int.)

Although all scientists may have access to and use the same set of data, but each scientist has his own mentality and way of thinking and relating evidences to history (T6, VNOS)

The aspect related to the observation versus inference considers that:

Observations are gathered through human senses or extensions of those senses.

Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations. (Schwartz et al., 2004 p. 613).

This aspect considers that scientific knowledge stems from observations of the natural world and interpretations of these observations lead to an appropriate understanding of the phenomenon at hand. Since this aspect also takes into consideration the subjectivity of the scientist that might lead to different interpretations of the same set of data related to the same phenomenon observed, it is considered along with the subjective nature of science.

Data analysis showed that most participants (571.4%) expressed informed views consistent with the view developed by Lederman (1992) as shown below:

[Scientists came up with different conclusions regarding the extinction of dinosaurs] based on their own personal ways of analysis. Same data, different analyses, this is what causes the difference and leads to good science (T4, Int.).

Scientists try to explain what they observe (T4, VNOS).
No, scientists have not seen an atom, [they came up with this elaborate structure] based on experiments conducted or assumptions (T7, Int.).

Not enough evidence was found to support the view of the remaining participants (2:28.5%) who seemed to express no position regarding this aspect.

Creative and imaginative nature of science. Modern conceptions of NOS suggest that human imaginations and logical reasoning play an important role in the creation of scientific knowledge (Lederman, 1992). When asked about this aspect, almost all of the participants (6:85.7%) expressed informed views. Although they expressed such informed views, the participants differed as to the stages during which creativity comes into play in science. Some of them thought that creativity plays a role in the formation of a hypothesis; others claimed that scientists use their imagination as they try to attribute specific explanations to certain observations. Still others considered that creativity comes into play at all the stages of scientific inquiry and the scientific endeavor. The excerpts below demonstrate the views expressed by a number of participants:

Scientists have to use their creativity and imagination at all stages of the scientific inquiry. The planning and design of experiments requires a lot of imagination so does the process of data collection, especially if the tools of data collection are not available. The analysis of these results, however, needs the highest level of creativity (T1, VNOS).

Scientists use their imagination especially at the hypothesis level (T2, Int.)

Creativity and imagination are used in science. ...when hypothesizing, a scientist should use his imagination and think unconventionally to find a
logical explanation to a certain question and he should be creative in finding the means to prove his hypothesis (T4, VNOS).

After getting results, analysis of results also needs some thinking to reach a definite conclusion (T4, VNOS).

There is creativity and imagination in the kind of explanation and in the design of the experiment (T5, Int.).

One participant considered that imagination as such does not play a part in scientific investigations and thus, expressed a naïve view:

Scientists do not use their imagination and creativity in performing experiments, because experiments reflect results (facts) in real life, and you cannot be creative or imagine things in life (T3, VNOS)

Socio-cultural Embeddedness Nature of Science. Modern views of NOS contend that “Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized” (Schwartz et al., 2004, p.613). Among the participants, 4 (57%) expressed naïve views related to this aspect. The following are some of the views expressed by the participants:

Science is universal because the same laws and theories are true in all societies and cultures (T2, VNOS).

Science is universal, but advancement in some fields of science more than others is certainly affected by social belief and values. No, science is not affected by social and cultural values. The fact is not affected but the direction of investigation is affected. A fact is a fact everywhere. The
knowledge becomes universal, but the procedure and development is affected (T5, VNOS)

Science is universal and it is not limited by any cultural or social values, it should be directed towards one thing which is finding answers to unknowns (T6, VNOS)

The rest of the participants (343%) held more informed views related to this aspect. A sample of views they held are as follows:

It [science] should be related to the scientist, the culture will affect so it is cultural and social (T3, Int.).

Yes, science is affected by social and cultural values. The way [scientists] deal with things is affected by their social upraising (T4, Int.).

In general, analysis of participant’s responses to the questionnaire as well as to the interview questions showed that participants were mislead by the word “universal” (question 9 of VNOS-C). They considered that scientific knowledge ultimately becomes “factual” and true and that is why it is considered universal. Participants did not seem to understand the role of society and the culture in which science is situated and more importantly the influence exerted by the community of scientists. The following excerpts illustrate this point:

Science is universal because the same laws and theories are true in all societies and cultures (T2, VNOS)

I think science is universal, if someone is really scientific about facts of science, then social, religion cultural practices cannot change the fact of science (T4, VNOS)
There are international aspects of science, certain concepts known with known backgrounds everywhere (T7, Int.)

Laws and Theories. According to current understandings of NOS, theories are qualitatively different from laws in that theories explain while laws describe (Schwartz et al., 2004). In contradiction to this understanding, all the participants (7:100%) considered that theories are subject to experimentation, whenever proven true and after the accumulation of scientific evidence, they become more significant and they gain a higher status and thus, become laws which are, according to the participants, scientific facts that are proven to be true.

Scientific laws are proved by experimentation while a scientific theory is not at all proved by experimentation (T5, VNOS).

A scientific theory is a scientific idea that will change to be a scientific law after many experiments that will prove it (T3, VNOS).

Some theories become laws if proven (T1, Int.).

To summarize, based on the analysis of all students' responses to VNOS-C and the interviews presented above, participants' views were categorized as either informed (in line with the appropriate conceptions of NOS as set by Lederman, 1992) or naïve or (inconsistent and incompatible with the conceptions set by Lederman, 1992). Analysis of the responses to the open-ended questionnaire and the individual interviews showed that, in general, teachers' views of NOS were fluid and lacked coherence. Though, some of the teachers expressed informed views about a few aspects, almost all of them showed naïve views related to different aspects that are inconsistent and incompatible with the conceptions set by Lederman (1992). Table 4 presents the categorization of
the participants’ views of NOS in response to the items in the VNOS-C and their explications in the individual interviews. It also shows the percentages of these two categories for each aspect of NOS.

Table 4

*Categorization of Participants’ Views of NOS in Response to the VNOS-C and the Interviews and the Relative Percentages of Informed (I) and Naïve (N) views of NOS*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Aspect of the Nature of Science</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tentative</td>
<td>Empirical</td>
</tr>
<tr>
<td>1</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>2</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>I</td>
<td>N</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100% I</td>
<td>85.7% N</td>
</tr>
<tr>
<td></td>
<td>0% N</td>
<td>14.3% I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- I: Informed
- N: Naïve
- U: undetermined (no enough accumulating evidence to support the view)

The table clearly illustrates the inconsistent and naïve views about NOS expressed by the participating teachers. All the participants (7:100%) expressed informed views about the tentative nature of science, while almost all (6:85.7%) of them expressed naïve views about the empirical nature of science, while 6 (85.7%)
expressed informed views about the creative and imaginative aspects of NOS. Moreover, almost half of the participants (45.7%) expressed informed views and naïve views in relation to the subjective and socio-cultural embeddedness natures of science respectively. However, 5 (71.4%) of the participants expressed informed views about observation versus inference all of them expressed naïve views about the relation between laws and theories.

On the other hand, the table also provides information about the overall view of all the aspects of NOS for each participant individually. For participants one, three, four and five, a total of 71.4% and 57.1% of the aspects were informed, rendering the overall view as positive. While for participants two and seven, the overall view is naïve since a total of 57.1% of the aspects’ views are naïve. On the other hand, participant six expressed equal percentages of naïve and informed views of the aspects of NOS with 42.8% while one aspect remained undetermined.

Planning for and Teaching NOS

Each participant presented a minimum of 2 lesson plans for the 2 sessions observed, some of them were asked to provide more for further support and thus, to enrich the data. The coding system consisted of assigning letters (a, b, c…) for each lesson plan preceded by the code T for teacher and LP for lesson plan.

Descriptions of lesson plans. Only one participant presented a lesson plan that included a laboratory investigation. However, this investigation included pre-prepared slide observations, and teacher demonstrations of experiments. Students were not involved in any hands-on or data collecting activities. The demonstrations included the following (T7, LPb):

- Performing the iodine test on starch and the Fehling test on reducing sugars.
• Testing for the presence of starch in a green leaf, a yellow leaf, and a parti-
colored leaf.

• Demonstrating how KOH and Ca (OH)₂ absorb carbon dioxide (T7, LPa).

The rest of the lesson plans consisted of summaries of the content to be
introduced as well as the key objectives to be attained at the end of the chapter or
session. The following is an excerpt from a lesson plan:

Start the lesson by reminding students of the concepts covered during last
period and any related concept to this lesson. Ask: in the previous lessons we
learned how crude sap reaches the leaves. Who can remind us of the pathway it
follows briefly? Ask: for the plant to make its food or organic substances it
needs substances other than water and minerals, what is the substance? Ask:
how does CO₂ reach the leaf? Etc… (T4, LP a)

Objectives: at the end of instruction, the student should be able to:

1. List the different stages of an action potential.

2. Describe the ionic phenomena taking place during each of the stages of
an action potential.

3. State the law of “all or none”.

4. Explain the coding of the nervous message.

5. List the different steps of synaptic transmission. (T1, LP a, b, c)

Analysis of the lesson plans showed that teachers did not mention the aspects of
NOS either explicitly or implicitly. They simply listed sets of experimental results from
which students can arrive to specific pre-determined conclusions through analysis and
interpretation. The following excerpt from an introduction to a lesson illustrates this
point:
The instructor will provide different experimental setups (involving the reaction of the neuron to different intensities of stimulation) and results, and will lead students to come up with the proper conclusions (T1, LP b).

The different experimental setups and results provided in the worksheet prepared by the teacher will be analyzed, and the teacher will guide the students to build their understanding of synaptic transmission (T1, LP c). Communication via blood: Read document and explain it step by step to allow students to come up with the analysis. (Skills: students will develop analytical skills) and then assign for students to prepare the rest of the experiments (T3, LP a)

In conclusion, the lessons included summaries of content chapters and guidelines for analyzing, interpreting, and explaining experimental results presented in tables, graphs, charts or the like and available in the textbook. These activities are typical of what is given in biology official exams in Lebanon and thus, may be the result of this rather than due to a conscious effort by teachers to introduce NOS to their students. It is worth noting that “Analysis” and “Interpretation” as used in the lesson plans represent the official definitions used in scoring exam paper in Lebanese public examinations. Teachers typically train students on responding to questions that use these terms to increase their chances of succeeding in public examinations.

Table 5 presents the implicit versus explicit instances for planning to teach the aspects of NOS identified in the lesson plans. It should be noted that the only aspect addressed is the empirical nature of science, there was no mention of the rest of the aspects.
Table 5

Implicit versus Explicit Teaching of the Aspects of Nature of Science from the Analysis of the Participants’ Lesson Plans

<table>
<thead>
<tr>
<th>Participant</th>
<th>LP</th>
<th>Topic</th>
<th>Aspect of NOS covered</th>
<th>Explicitly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>The nervous message (action potential)</td>
<td>Empirical: Analysis of experimental setups and results + conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Response of a neuron</td>
<td>Analysis of experimental setups and results + conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Synaptic transmission</td>
<td>Analysis of experimental setups and results + conclusions</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>Synaptic transmission</td>
<td>Empirical: Experiments + explanation and conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Discovery of hormones</td>
<td>Experiments + explanation and conclusions</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>Discovery of hormones</td>
<td>Empirical: Experiments + explanation and conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Hormonal communication</td>
<td>Experiments + explanation and conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Structure and function of the thyroid</td>
<td>Experiments + explanation and conclusions</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>Stomatal structure</td>
<td>Empirical: Experiments and explanations then derivation of conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Role of stomata</td>
<td>Experiments and explanations then derivation of conclusions</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>Relationship between plants and fungi</td>
<td>Empirical: Experiments and explanations then derivation of conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Plant supply with raw material</td>
<td>Experiments and explanations then derivation of conclusions</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>Role of stomata</td>
<td>Empirical: Experimental setups, observations, analyses and conclusions</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>The use of photosynthetic products</td>
<td>Experimental setups, observations, analyses and conclusions</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>A</td>
<td>Autotrophy and photosynthesis</td>
<td>Empirical: Conducting experiments in the lab with observations and conclusions. Students analyze tables, documents, and graphs related to the content and interpret results</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Plant supply with raw material</td>
<td>Conducting experiments in the lab with observations and conclusions.</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>The use of photosynthetic products</td>
<td>Conducting experiments with observations and conclusions.</td>
<td>None</td>
</tr>
</tbody>
</table>
Furthermore, slightly more than half of the teachers (45.7%) claimed that they actually teach the aspects of NOS in their classrooms. However, as is evident in the lesson plans, participants introduced students to analysis, interpretation and derivation of conclusions from experimental setups presented in the book during lessons. All these fall under the implicit teaching of the empirical aspect of NOS. In addition to the evidences from the lesson plans, analysis of the lesson videotapes showed no occasions of explicit teaching of the empirical NOS during the discussion of experimental procedures and their results as illustrated in the following excerpts:

*The idea is that we have been provided the experimental procedure and the result for each experiment and we’re supposed to say what each experiment means and what can we deduce from each experiment. (T1, Vid., A).*

*What would be some of the experiments that Pavlov did in order to answer this problem? (T2, Vid., B).*

*When you eat chips and the like, you drink more, [meaning that the more salt enters to your bodies, the more you drink water] (T5, Vid., B).*

*We are going to analyze document b. read it, try to understand it and analyze it (T6, Vid., B).*

Even in class, teachers did not mention the aspects of the nature of science explicitly. All the instances of implicitly addressing the empirical nature of science included the analysis, interpretation and explanation of experimental results presented in tables, graphs or the like. Students were always required to derive conclusions and were always reminded of the criteria to answer specific questions:
If you are going to interpret any document, you have to analyze it first (T5, Vid., A).

That’s a deduction, first they asked us to analyze, and the first question is analyze so how will you do that? We have to use numbers. I would start with the Y axis, means I would start from here, the frequency of AP increases from 1 to 9 as the stimulating temperature increases from 40 to 55 ºC. (T1, Vid., A)

When you finish, take a few minutes to read document b. we are going to analyze document b. Read it, try to understand it and analyze it… First, read the experiment, then observation and finally analysis (T6, Vid., A)

The only exception to the above is participant 7 who assigned a project to be conducted by her students. She gave them criteria for completing the investigation which she explained in class. One of the elements of the criteria was “the collection of relevant data” (T7, Vid., A) which she explained as follows:

You have to make sure that your experiment collects like really a relevant data. This is what it says relevant data, for example if I’m testing for photosynthesis, then my data should be either CO$_2$ consumption or O$_2$ release, isn’t it? And not something else that is irrelevant. Alright and as you are also planning, you should mention that definitely in order to be able to conclude, or having a proper conclusion, we cannot base our experiment let’s say on one plant or one trial of an experiment. So if I’m going to germinate plants, I don’t germinate only one seed and measure its length to see the growth. Is that reliable to base it on one seed?

Definitely no, I usually germinate 2 or let’s say 10 or 20 seeds, especially
if you have small seeds, you can have a large number so that you can really abridge and find reliable results. So these are things that you should keep in mind while you are planning and designing your experiment (T7, Vid., A).

This participant mentioned the germination of more than 10 seeds especially if the seeds were small. However, the teacher was not clear as to the meaning of “small seeds” and how seed size affected germination. Moreover, she did explain clearly what she meant by finding “reliable” results.

Table 6 provides a summary of all the instances during which the aspects of NOS were taught in the classrooms as identified from the videotapes. Since the only aspect addressed is that related to the empirical nature of science which was implicitly brought up through the analysis of experiments and the derivation of conclusions, it is the only aspect mentioned in this table.

Classroom Variables Derived from Videotaping

In order to determine the overall common practices of the participating teachers in their classrooms, specific pre-determined classroom variables were identified and classified based on specific definitions presented in Table 1. The purpose behind elucidating these classroom variables is that they have the potential to shape the classroom atmosphere and the different classroom behaviors which either enhance or impede the translation of teaches’ knowledge into classroom practices; moreover, they differentiate the behaviors of teachers in their respective classrooms (Lederman & Zeidler, 1987). The following excerpts are extracted from the classroom videotapes to clarify the process undertaken in order to determine these classroom variables.
Table 6

*Implicit versus Explicit Teaching of the Aspects of Nature of Science from the Analysis of the Participants’ Classroom Observations*

<table>
<thead>
<tr>
<th>Participant Observation</th>
<th>Topic</th>
<th>Aspect of NOS covered implicitly</th>
<th>Aspect of NOS covered explicitly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A</td>
<td>Nature of the nervous message (action potential)</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Synaptic transmission</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>2 A</td>
<td>Synaptic transmission</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Discovery of hormones</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>3 A</td>
<td>Discovery of hormones</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Structure and function of the thyroid</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>4 A</td>
<td>Stomatal structure</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Role of stomata</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>5 A</td>
<td>Relationship between plants and fungi</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Plant supply with raw material</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>6 A</td>
<td>Stomata structure and function</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>The use of photosynthetic products</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>None</td>
</tr>
<tr>
<td>7 A</td>
<td>Autotrophy and photosynthesis</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td>Empirical (Planning an experimental setup through performing a project)</td>
</tr>
<tr>
<td>B</td>
<td>Plant supply with raw material</td>
<td>Empirical (experiments with analysis and then derivation of a conclusion)</td>
<td></td>
</tr>
</tbody>
</table>
The following excerpt is taken from the classroom videotape of participant 1. It indicates that the teacher stresses the importance of empirical validation of subject matter which is denoted as the ‘testable’ variable.

*I want to know how the CNS [Central nervous system] distinguishes between different lights. How does the CNS “know” the difference between a weak light and a strong light? In order to do this, let’s consider the following experiment. In this experiment, a certain receptor, let’s say the eye, is isolated and an oscilloscope is connected to the sensory neuron, and here we give stimulations, light intensities, light of different intensities/strengths and we obtain the following results (writes results in table) (T1, Vid., A).

Another excerpt, also obtained from the data set of teacher 1, shows that this teacher emphasizes the interrelatedness between the scientific disciplines specifically physics and biology. This emphasis determines the classroom variable ‘unified’.

*If you remember from last year physics, SV and VB. So where you had SV and VB you can change them, so the shape of the AP doesn’t always have to be like this, depending on the settings of the oscilloscope an AP can also look like this (T1, Vid., A).

On the other hand, another passage shows the teacher interjecting with a joke in order to illustrate a scientific concept, this falls under the classroom variable termed “humorous”.

*If a cocaine addict hears a joke, he will stay laughing for let’s say 10 minutes. That’s why sometimes I look at you and I wonder are they using
cocaine? Because sometimes there is a joke and you keep laughing for 10, 15 minutes, kind of repeats itself (T1, Vid., B).

Another instance shows the stress of ‘rote memory/recall’ when the teacher asks the students to recall the definition of a synapse (T2, Vid., A). On the other hand, the teacher presents an experiment on the board and then asks:

*Who can analyze the experiment and give me the significance?*

*Who can relate the significance to the structure of the synapse?*

*What do you expect the experiments done by Pavlov to be and that led to answering the question about how the pancreas would know that there is food in the small intestine?*

*If you were Wertheimer and Lepage, what would you do to check if the problem is nerve-related?* (T2, Vid., A).

This indicates that the teacher uses ‘high level questions’ (design an experiment, derive a conclusion, analyze, and draw out a hypothesis…) and then uses ‘probing’ in order to initiate responses from students. On the contrary, another teacher does ask frequent questions all of which are at the factual/knowledge level and do not enhance higher level thinking. An example of that is presented in the quote below:

*In which direction does the crude sap move in documents A and B?* (T7, Vid., A).

*When the light intensity is zero, [what do we mean by] light intensity is zero?* (T1, Vid., A)

*…the neurotransmitters are responsible for the formation of AP in which neuron? Post-synaptic or pre-synaptic?* (T1, Vid., B)

*…what do we have inside the chyme? What is the chyme?* (T3, Vid., A)
…we all know from last session that the phloem is the organ or is the vessel that is responsible for conduction of the elaborated sap and the xylem is the vessel that is responsible for the conduction of what? What does the xylem conduct? (T6, Vid., B)

Who can define the phloem vessel? What are the phloem vessels? (T6, Vid., B)

A summary of all the variables derived form the videotaping performed in the classrooms are presented in Table 7. If the excerpts provide evidence for the presence of at least one instance of the variable, then it is considered ‘positive’, on the contrary, if the variable is not present then it is considered ‘negative’. Moreover, in case there is lack of enough evidence, the variable is considered ‘undetermined’. It should be noted however, that the presence of the variable does not assure that it enhances the overall classroom atmosphere for teaching the aspects of NOS. This, on the contrary depends on the nature as well as on the definition of the variable presented in Table 1.

The overall atmosphere of the classroom is usually related to teacher’s practices and the adoption of specific instructional techniques (Lederman & Zeidler, 1987). Thus, to determine this relationship, comparisons of the overall classroom atmosphere and the determination of the various classroom variables were performed. All teachers in this study emphasized rote memory/recall, almost all (6:85.7%) used lecturing with less student involvement as a main instructional technique, in addition, almost all (5:71.4%) did not use higher level questioning according to Bloom’s taxonomy and even 3:43% did not ask frequent questions. Problem solving, open ended questions or discrepant events were rarely used by most of the teachers (5:71.4%). Moreover, only
4.57% of the teachers used probing in order to initiate students’ responses and follow-up on their understandings.

Table 7

Summary of the Categorization of each Participant Classroom Variables

<table>
<thead>
<tr>
<th>Classroom Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Instructional Approach:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rote Memory/Recall</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>100%P</td>
</tr>
<tr>
<td>Lecturing</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>85.7%P</td>
</tr>
<tr>
<td>Frequent Questioning</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>57.1%P</td>
</tr>
<tr>
<td>Higher Level Questions</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>71.4%N</td>
</tr>
<tr>
<td>Fragmented</td>
<td>N</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>0%P</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>28.5%P</td>
</tr>
<tr>
<td>Receptive</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>71.4%N</td>
</tr>
<tr>
<td>Probing</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>42.8%P</td>
</tr>
<tr>
<td>Humor</td>
<td>P</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>P</td>
<td>N</td>
<td>28.5%P</td>
</tr>
<tr>
<td><strong>Content-Specific Characteristics:</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amoral</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>0%P</td>
</tr>
<tr>
<td>Creativity</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>100%N</td>
</tr>
<tr>
<td>Developmental</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>85.7%N</td>
</tr>
<tr>
<td>Fallibility</td>
<td>P</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>U</td>
<td>0%P</td>
</tr>
<tr>
<td>Testable</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>100%P</td>
</tr>
<tr>
<td>Unified</td>
<td>P</td>
<td>U</td>
<td>U</td>
<td>P</td>
<td>P</td>
<td>U</td>
<td>P</td>
<td>57.1%P</td>
</tr>
</tbody>
</table>


Table 7 Cont’d

Classroom Atmosphere:

<table>
<thead>
<tr>
<th>Discipline</th>
<th>P</th>
<th>P</th>
<th>N</th>
<th>P</th>
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<th>N</th>
<th>P</th>
<th>71.4%P</th>
</tr>
</thead>
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<tr>
<td></td>
<td>28.5%N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Anxiety</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>71.4%P</td>
</tr>
<tr>
<td></td>
<td>28.5%N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapport</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>42.8%P</td>
</tr>
<tr>
<td></td>
<td>57.1%N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>72% P</th>
<th>61%P</th>
<th>28%P</th>
<th>33%P</th>
<th>56%P</th>
<th>28%P</th>
<th>44%P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28% N</td>
<td>22%N</td>
<td>50%N</td>
<td>50%N</td>
<td>33%N</td>
<td>56%N</td>
<td>44%N</td>
</tr>
<tr>
<td></td>
<td>22%U</td>
<td>22%U</td>
<td>17%U</td>
<td>11%U</td>
<td>16%U</td>
<td>12%U</td>
<td></td>
</tr>
</tbody>
</table>

- Positive (P): if the variable is presented in the classroom
- Negative (N): if the variable is not presented
- Undetermined (U): no enough evidence to support the determination of the variable

At the level of teacher’s content-specific characteristics, factors such as creativity, developmental, fallibility, testable and unified were determined. It should be noted that all of these can provide insights about the teachers’ views regarding the various aspects of NOS. Data analysis show that teachers in this study stress the testable variable (7:100%) which is in high congruence with the empirical nature of science that is frequently and implicitly addressed whether in the lesson plans or in practice. Moreover, none of the teachers emphasized the developmental nature of science which relates to beliefs regarding the tentative nature of science. Similarly, almost all teachers (6:85.7%) neglected the creative aspect of the nature of science which relates to the role of imagination in developing scientific laws and theories governing various phenomena in nature.

In sum, even though the participants possessed some informed views about the aspects of NOS as reflected in their answers to the items of the VNOS-C and to the questions in the interviews, almost all gave no attention to planning or teaching these aspects in their classrooms. This lack of attention is evident also in the classroom variables derived from the classroom observations which signify that all the teachers
did not stress, implicitly nor explicitly, the tentative and creative and imaginative
natures of science. On the contrary, all the participants stressed the empirical/testable
nature of science implicitly, which, according to Bell, Lederman, and Abd-El-Khalick
(2000) has no effect on students’ views

Constraints on Teaching NOS

When asked about the factors that either enhance or impede teaching the aspects
of NOS in the classrooms, the teachers provided various factors some of which are
related to the condensed program required by the Lebanese curriculum which does not
leave room for introducing these aspects. Additionally, these teachers claimed that the
time required to teach the curriculum does not allow them to cover NOS. This stems
from the assertion that some teachers view the aspects of NOS as less significant than
other concepts and hence, chose to devote less or even no time for presenting them in
their classrooms. A number of the participants also asserted that the school facilities
and the experiences of the teachers play a major role in hindering the teaching of these
aspects. For example, a number of the teachers said that they did not have enough
knowledge about NOS and how to teach it even though they have been introduced to
these aspects in their university classes. Additionally, some teachers said that school
laboratories were not fully equipped and thus, were not sufficient for “doing science”.

Another obstacle that teachers identified was the textbooks adopted by the school.
According to these teachers, textbooks that are published by the Center for Educational
Research and Development (CERD) do not pay any attention to NOS. According to
Teacher 1, textbooks
“…dump a theory the way it is, very few books describe the method by which the theory developed” (T1, Int.).

One of the teachers suggested that the cognitive level of the students also prevents teachers from introducing NOS in class especially that grade 10 students are of mixed abilities and many of them are not interested in science. On the other hand, another teacher said that classroom management is a factor that prevented her from teaching NOS. Interestingly, one of the teachers believed that nothing prevented her from introducing NOS in her classroom and that she actually teaches these aspects. However, analysis of videotapes from her class indicated that this teacher does not actually do so.

Even though teachers listed factors that hindered the teaching of the aspects of NOS, 4 of them (57%) claimed that they do present these aspects in their classrooms. A summary of the factors and the claims about teaching or not teaching NOS are presented in Table 8. This table serves to answer the second question that guided the research in this study and which is related to the factors that either facilitate or impede the translation of teachers’ conceptions of NOS into actual classroom practices. As shown in the table, the factors were mostly related to the science curriculum adopted in Lebanon, students’ backgrounds, books, as well as assessment and classroom management. Five out of the seven teachers who participated in the study claimed that the curriculum content textbooks, and the time necessary to finish the curriculum are factors that stopped them from teaching NOS. Moreover, one teacher asserted that the assessment practices shaped her instructional practices and left no space for teaching the aspects of NOS since they are not assessed either in official examinations or in summative school exams. On the other hand, four of the participating teachers claimed
that students’ backgrounds pose a direct influence on the introduction of these concepts in classrooms. One participant claimed that students might become skeptical about science if they were exposed to the aspects of NOS especially that science was tentative; another claimed that students’ level and background were weak and thus they were unable to understand such complex concepts. Finally, two participants claimed that classroom management stopped them from teaching NOS.
<table>
<thead>
<tr>
<th>Participant</th>
<th>Claims about teaching aspects of NOS</th>
<th>Factors</th>
</tr>
</thead>
</table>
| 1           | I tried to teach it but it requires more work | • Program is condensed  
• Books dump the theory as it is, no description of the methodology  
• Students’ backgrounds (consumers and not producers)  
• Hard to instill the theory or concept |
| 2           | No, I don’t teach it. | • Students will become skeptic about any idea that they find weird (no trust) |
| 3           | I show the ideas. We present the ideas and we discuss them but in the end it is how the students believe and think | • Books are so limited  
• Assessment is more important, students don’t know how to answer to specific questions  
• Concepts to be discussed are so limited.  
• Students’ background.  
• Classroom management |
| 4           | Yes, I do teach it to make students act as scientists, be analytical, use their minds and accept new explanations. I mention that science changes. | • No factors hinder the presentation of these aspects |
| 5           | Yes, I do teach it. I stop the lesson and discuss many things. It is not scheduled, it is occasional. A question might provoke it. | • Time, schedule and syllabus do not allow for teaching NOS. We have to finish the curriculum on time.  
• Teachers’ experiences: not all teachers have enough background knowledge to teach aspects of NOS  
• School facilities: no equipment to do experiments |
| 6           | No, I do not teach it. | • Limited curriculum: do not go beyond the concepts in the book.  
• Level of students is weak  
• Classroom management  
• Concepts |
| 7           | Definitely I teach it. Refer and try to observe things happening. Students do lots of experiments and they design their own using any kind of equipment and material to enhance their creativity. | • Requirement of the curriculum: Lebanese curriculum does not require experiments  
• The school system and the equipment. |
Summary

Mediating the translation of teachers’ conceptions into classroom practices is a rather complicated process influenced by various factors as presented in table 8. Table 9 presents a summary of the teachers’ knowledge about the different aspects of NOS, their classroom practices, their planning, as well as the individual profiles of each of the teachers obtained from the analysis of all the data sources in the study. Such an overview of the profiles of the participating teachers answers question one that guided the research in this study and that is related to “how do teachers’ conceptions influence their practices about the Nature of Science?” by referring to the table, it becomes obvious that the conceptions have no direct impact on the practices, as an example, participants 1, 3, 4, and 5 had positive views related to NOS but not sufficient to insure the teaching of NOS their classrooms.

Table 9

Summary of Participants’ Profiles

<table>
<thead>
<tr>
<th>Participant</th>
<th>Views of the aspects of NOS</th>
<th>Lesson plans</th>
<th>Classroom practices</th>
<th>Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Positive</td>
<td>Analysis of experiments</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is positive however, classroom practice does not reflect these aspects.</td>
</tr>
<tr>
<td></td>
<td>66.6% I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33.3% N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Negative</td>
<td>Analysis of experiments</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is negative and teaching these aspects is not addressed in classrooms.</td>
</tr>
<tr>
<td></td>
<td>28.5% I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71.4% N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Positive</td>
<td>Analysis of experiments</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is positive however, classroom practice does not reflect these aspects.</td>
</tr>
<tr>
<td></td>
<td>57% I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>42.8% N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Positive</td>
<td>Analysis of experiments</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is positive however, classroom practice does not reflect these aspects.</td>
</tr>
<tr>
<td></td>
<td>71.4% I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.5% N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Positive</td>
<td>Analysis of experiments</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is positive however, classroom practice does not reflect these aspects.</td>
</tr>
<tr>
<td>---</td>
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<td>-------------------------</td>
<td>--------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Positive</td>
<td>Analysis of experiments</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is positive however, classroom practice does not reflect these aspects.</td>
</tr>
<tr>
<td></td>
<td>Negative</td>
<td>Analysis and conduction of experiments during the lab sessions</td>
<td>Empirical Implicit</td>
<td>The knowledge of the aspects of NOS is positive however, classroom practice does not reflect these aspects.</td>
</tr>
<tr>
<td></td>
<td>57% I</td>
<td>42.8% N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Negative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>33.3% I</td>
<td>66.6% N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Negative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.5% I</td>
<td>71.4% N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Positive views of the aspects of NOS (knowledge): 50% of the views are informed (I).
- Negative views of the aspects of NOS (knowledge): 50% of the views are naïve (N).
CHAPTER V
CONCLUSION, DISCUSSION, and IMPLICATIONS

Current reform efforts in science education are consistently advocating the development of scientific literacy among students. The success of such a goal necessitates the preparation of knowledgeable teachers with appropriate nature of science pedagogical content knowledge (NOS PCK) as suggested by Abd-El-Khalick and Lederman (2000a, 2000b) which not only comprises standard views and attitudes towards the aspects of NOS but in addition, instills in teachers the ability to introduce these to their students by using various pedagogical approaches. Based on the results of the study the following assertions can be made:

Assertion 1: Teachers participating in this study possessed incoherent and inconsistent views of the various aspects of NOS. Almost all teachers expressed naïve views related to the empirical, creative and imaginative, and sociocultural embeddedness natures of science. In addition, they all thought that theories and laws are hierarchically related in the sense that, as theories are proven true they become laws which are, according to the participants, scientific facts. On the contrary, all the teachers believed that science and scientific knowledge change with the emergence of new evidence. Moreover, almost all expressed the view that science is subjective, that is, it is influenced by current theories and by the scientist’s own background, and that inferences are interpretations of observations which are made through human senses.

Assertion 2: Whether naïve or informed, the NOS aspects were neither planned for nor taught in the classrooms, except for implicit instances for teaching the empirical nature of science. When asked about the reasons that stopped them from teaching NOS, the participating teachers listed a number of factors which included the
curriculum, the adopted textbooks, students’ backgrounds, lack of time, classroom management problems, as well as the assessment criteria and practices.

Assertion 3: Analyzing the videotapes showed that the teachers participating in this study emphasized rote memory/recall, almost all used lecturing with minimal student involvement as the main instructional technique, and rarely used problem solving, open ended questions or discrepant events. Analyzing the videotapes also showed that teachers stressed the testable nature of scientific knowledge, that is, the empirical nature of science but neglected to emphasize the tentativeness of scientific knowledge and the creative nature of science which relates to the role of imagination in developing scientific laws and theories. It seems that the classroom factors identified above established a classroom environment that was not conducive to the introduction of the aspects of NOS.

Teachers’ Conceptions of NOS

As previously stated, teachers’ conceptions were found lacking and incoherent in many respects. Previous research in Lebanon (Abd-El-Khalick, 2001; BouJaoude, 1999, 2000; BouJaoude & Abd-El-Khalick, 1995; Farah, 1994) has reported similar findings related to these naïve and inconsistent views about some of the aspects of NOS. These naïve and inconsistent views possibly originate from the type of education these teachers were exposed to whether in their high-school or college education. As proposed by Irez (2006), the educational history of a science teacher is an important contributing factor to his or her beliefs about NOS. Even though science teacher preparation programs might cover aspects on NOS, these programs are not long enough or sufficiently focused on teaching NOS to reverse the beliefs that teachers have developed in their long experience with science in school and at the college level
during which the emphasis is typically on science as content and in assessment systems that measure the acquisition of this content to the neglect of the other aspects of the scientific endeavor such as NOS.

As previously asserted, the results reveal that teachers’ understandings of NOS were inconsistent and fragmented, that is, teachers understanding of one aspect did not necessarily mean an understating of other related aspects. As an example, a number of the teachers who viewed science as tentative still believed that theories became laws that represented sure factual knowledge, a finding that resonates with research results reported by Schwartz, Lederman, and Crawford (2004). These results suggest that teacher education programs do not emphasize NOS aspects sufficiently or that teachers themselves do not take this matter seriously, an issue that has not been adequately researched in Lebanon. Educational institutions are bound to modify the structure as well as the content of teacher preparation programs as recommended by BouJaoude (2000). BouJaoude also stresses the fact that teachers are not well prepared during their pre-service training to become decision-makers and reflective problem solvers. Such insufficient preparation results in the replication of the modes of teaching teachers themselves were exposed to, leading to teachers who prepare students who possess large stores of knowledge about science but that are not capable of reflecting their knowledge in everyday life while attempting to solve personal and societal problems.

Conceptions and Classroom Practice

The results of this study clearly show that conceptions have no direct impact on classroom practice and that an aggregate of various factors coalesce to determine this practice and shape the overall atmosphere of the classroom and of the instructional practices adopted by a specific teacher in a specific context. Previous research has paid
significant attention to teachers’ understanding of NOS (Abd-El-Khalick & Lederman, 2000a; Bell, Lederman, & Abd-El-Khalick, 2000; Lederman, 1995; Lederman & Zielder, 1987; Schwarz & Lederman, 2002), the results of this study suggest that this is only one factor among other critical ones that need to be considered in order to understand why high school students do not possess adequate understanding of NOS. Whilst classroom practice is not necessarily a direct consequence of possessing appropriate NOS conceptions, teachers participating in this study neither planned for nor addressed aspects of NOS, at least for those aspects for which they held informed views, in their classrooms. This suggests that various factors, other than views and conceptions, coalesce to determine the translation of knowledge into actual practice. Among the factors determining classroom practice, as implied by the results of this study, and as suggested by the participating teachers, are problems with classroom management, teachers’ intentions to apply NOS, the Lebanese curriculum and its textbooks, as well as the summative public assessment practices adopted as promotion criteria. Additionally, teachers might possess adequate NOS understanding, but do not have the necessary tools to teach these conceptions such as activities and appropriate resources.

Teachers participating in this study paid minimal attention to any of the NOS aspects in their teaching. Even when the empirical nature of science was implicitly addressed, these teachers did not intend to address it. This aspect was part of their lessons. Teachers emphasized supporting evidence since they needed it to help students derive conclusions and perform the necessary analysis of various scientific documents presented in the textbooks; skills that students need to answer questions on public national examinations. Since NOS aspects are not part of public examinations and
require a lot of work, as asserted by one of the study participants during the interview, teachers do not plan to address those aspects in their science classrooms. Furthermore, another participant in this research claimed that introducing students to these aspects might cause them to become skeptical about science and scientific knowledge in general and thus, was not ready to emphasize it. The above arguments seem to stem from teachers’ views about the necessity and value of NOS understanding; which might influence their intentions to teach NOS.

According to Abd-El-Khalick and BouJaoude (1997), knowledge is indispensable for teaching in the classroom but is not considered to be sufficient. Schwartz, Lederman, Khishfe, Lederman, Mathews, and Liu (2002) maintained that teacher’s intentions are necessary for effective translation of conceptions into classroom practices. According to them, teachers with informed views of NOS were not efficient in translating these views into effective classroom practices unless they intentionally planned to teach these aspects. Thus, developing appropriate conceptions of NOS is not sufficient for the translation of conceptions into classroom practices. As recommended by Abd-El-Khalick, Bell, and Lederman (1998) “the crucial translation of preservice teachers’ conceptions of NOS into classroom practice needs to be reinforced by the culture of teacher preparation” (p.432). In this, teachers should be aware of the importance of teaching NOS and they should develop a rationale for presenting these aspects in their classrooms.

Implications for Teaching

The findings of this study suggest that effective teaching of the aspects of NOS requires change at the school and the educational system level. First, there is a need to prepare in service as well as pre-service teachers who are adequately prepared to teach
NOS aspects. As mentioned above these teachers need to understand NOS, have the skills to teach NOS, and have clear intention to implement what they know in their classrooms. This change however, will not happen unless the curriculum, textbooks, and assessment practices change too in such a way to value teaching NOS. As suggested by Lederman (2006), the goals of teaching NOS should be considered a cognitive rather than an affective outcome, a consideration that necessitates teaching NOS aspects explicitly rather that assuming that students will acquire these conceptions implicitly during teaching.

Implications for Research

Gaining insights about the origin of teachers’ NOS conceptions might provide insight to the neglect of the aspects of NOS in teaching. In addition, investigating the effect of teachers’ practices, beliefs and conceptions on students views about science in general and scientific knowledge more specifically, is essential for understanding ways by which these beliefs and practices could be changed to benefit students. Similarly, investigating implicit versus explicit teaching of different aspects of NOS is important to understand how NOS can be taught in ways that make it meaningful for students. Finally, the classroom is a complex entity and it should be treated as such, the conditions necessary for good teaching are varied and complex. Thus, isolating one or more factors to study might not be productive. There is a need to design research studies that mirror classroom complexity. This could be done by conducting long term research studies that employ multiple research methods and that address a variety of issues concurrently. This approach might help shed light on the multiple complex factors that influence teaching and learning an important concept like NOS.
Appendix I

Views of Nature of Science – Form C
VNOS-C

Name: ________________________________
School where you teach: __________________

The following items are part of the questionnaire developed by Abd-El-Khalick, Lederman, Bell, and Schwartz (2001).
You are provided with ample space to write your responses, you are encouraged to write as much as you can and make sure you address ALL the sub-sections of each item and provide the necessary EXAMPLES where asked to.
Please note that there are no RIGHT or WRONG answers to any item. The intention is to elicit your views on some issues related to NOS.

Thank you in advance for your time and cooperation.

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 the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what the atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar 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 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.
Appendix II

Interview Protocol

Name: ______________________
School: _____________________

Interview protocol developed by Abd-El-Khalick et. al (2001)

1. Do all scientists use a specific method, in terms of a certain stepwise procedure, when they do science? Can you elaborate?

2. Are you thinking of an experiment in the sense of manipulating variables or are you thinking of more general procedures? Can you elaborate?

3. “Let’s consider a science like astronomy (or anatomy). Can we (or do we) do manipulative experiments in astronomy (or anatomy)?”
   - If the answer is positive, the interviewees are asked to explicate their answers and to provide examples.
   - If the answer is negative, the interviewees are then asked, “But we still consider astronomy (or anatomy) a science. What are your ideas about that?”

4. When scientists perform ‘manipulative’ experiments they hold certain variables and constant and vary others. Do scientists usually have an idea about the outcome of their experiments?”
   - If agreement is established then they were asked, “Some claim that such expectations would bias the results of an experiment. What do you think?”

5. The history of science is full of examples of scientific theories that have been discarded or greatly changed. The life spans of scientific theories, 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 these theories? Why do we invest time and energy to grasp these theories?

6. Which comes first when scientists conduct scientific investigations theory or observation?

7. 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?

8. Have we ever ‘seen’ an atom?
   - If the answer is negative, a new question is then posed: “So, where do scientists come up with this elaborate structure of the atom?”
   - If the answer is positive then the interviewees are asked to elaborate. On their answers.
9. 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 specie, knowing that the aforementioned species are ‘different’ species and have different names?

10. Creativity and imagination also have the connotation of creating something from the mind. Do you think creativity and imagination play a part in science in that sense as well?

11. In your classroom, do you instill the aspects of NOS among your students?
   • If the answer is yes, the participants are asked to elaborate on their answers.
   • If the answer is no, the participants are asked about the possible reasons that hinder them from instilling these aspects in their students’ minds.
References


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