Impact of Combined Explicit Reflective Nature of Science and Inquiry-based Instruction on Middle and High School Students' Conceptions of the Nature of Science

التأثير المزدوج لطبيعة العلوم الصريحة والإنعكاسية والتعليم الإستقصائي
على فهم طلاب المدارس المتوسطة والثانوية لطبيعة العلوم

by

LARA NABIL ABDALLAH

A thesis submitted in fulfilment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY IN EDUCATION
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September 2018

Impact of Combined Explicit Reflective Nature of Science and Inquiry-based Instruction on Middle and High School Lebanese Students' Conceptions of the Nature of Science

دراسة تأثير برنامج طبيعة العلوم العكسي والصريح القائم على الاستقصاء على فهم طلاب المدارس المتوسطة والثانوية لطبيعة العلوم في لبنان

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ABSTRACT

The purpose of this study is to examine the impact of a combined explicit reflective NOS and inquiry-based instruction on middle and high school students' conceptions of nature of science. The existing literature has not succeeded to examine the impact of the combined explicit reflective and inquiry-based instruction on students' conception of NOS which encounters for curriculum structure and instructional strategies at the same time. Guided by Duschl and Grandy 2013 Explicit NOS Instruction Model, Vygotsky's Social Cognitive Theory, and Lederman's Conceptualization of NOS Model, the sequential explanatory mixed method approach examined the success of the intervention to address the research questions.

The sequential explanatory mixed method research approach was utilized to collect 'pragmatic' data to answer the thesis study questions, (1) What conceptions of the nature of science do Lebanese middle and high school students have?, (2) How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?, and (3) How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?

The sample was representative of the whole population and consisted of 116 middle and high school students. Data was collected using the Explicit Reflective Inquiry Based Instruction Nature of Science Questionnaire (ERIBINOSQ), reflective journal prompts, field notes from class observations and interviews with students. The quantitative data was analyzed using SPSS, while the qualitative data was analyzed using thematic coding and peer debriefing.

The combined explicit reflective and inquiry-based instruction have caused a major improvement in students' views of the NOS aspects. This intervention was successful at all levels since it has a curriculum implication and an instructional approach. The intentional explicit discussions of NOS themes using inquiry-based instructional approach caused a change. Three themes emerged as a conclusion: (a) Cultural and Social Development in relation with Implicit Teaching Approach, (b) Combined Curriculum and Instructional Implications, and (c) Communicating Science to Construct Literacy.

These results suggest that the intervention had a positive influence in enhancing students' NOS conceptions, but more research is needed to study the relationship between the traditional perceptions of NOS and students attainment in standardized tests.

الملخص

الغرض من هذه الدراسة هو دراسة تأثير التعبير العكسي والصريح القائم على الاستفسار على مفاهيم طلاب المدارس المتوسطة والثانوية لطبيعة العلوم. لم تنجح الأدبيات الحالية في دراسة تأثير التدريس العكسي والصريح القائم على الاستقصاء حول مفهوم الطلاب لطبيعة العلوم المبني على دراسة المناهج والاستراتيجيات التعليمية في نفس الوقت. مسترشدًا بنموذج دوسن وجراندي 2013 التعليمي الصريح ، ونظرية المعرفة الاجتماعية في فيجوتسكي ، وتصور ليدرمان لنموذج لطبيعة العلوم، استرشد منهج بحث توضيحي متعدد الأساليب لنجاح التدخل للإجابة على أسئلة البحث.

استُخدم منهج بحث توضيحي متعدد الأساليب لجمع البيانات "العملية" للإجابة على أسئلة دراسة الرسالة ، (1) ما هي مفاهيم طبيعة العلوم التي يعرفها طلاب الصفوف المتوسطة والثانوية في لبنان؟ (2) ما هو تؤثر التعبير العكسي والصريح القائم على الاستفسار على مفاهيم طلاب الصفوف المتوسطة والثانوية لطبيعة العلوم ؟ ، و (3) كيف تؤثر متغيرات التركيبة السكانية للجنس والمستوى المدرسي على تصورات طلاب الصفوف المتوسطة والثانوية لطبيعة العلوم في سياق تأثير التعبير العكسي والصريح القائم على الاستفسار ؟

كانت العينة مؤلفة من 116 من طلاب الصفوف المتوسطة والثانوية في مدرسة خاصة في لبنان. تم جمع البيانات باستخدام استبيان "طبيعة التعليم الاستقصائي العاكسة القائمة على طبيعة العلوم "، والملاحظات العاكسة اليومية ، والملاحظات الميدانية من الزيارات الصفية والمقابلات مع الطلاب. تم تحليل البيانات الكمية باستخدام الحزمة الإحصائية للعلوم الاجتماعية ، في حين تم تحليل البيانات النوعية باستخدام الترميز الموضوعي واستخلاص المعلومات من الأقران.

لقد أدى التعليم الانعكاسي الواضح الصريح القائم على الاستفسار إلى حدوث تحسن كبير في مفهوم الطلاب حول جوانب طبيعة العلوم . كان هذا التدخل ناجحًا على جميع المستويات نظرًا لأنه يتضمن منهجًا دراسيًا ونهجًا تعليميًا. تسببت المناقشات الصريحة المتعمدة للمواضيع باستخدام النهج التعليمي القائم على الاستفسار في حدوث التغيير. برزت ثلاثة مواضيع كخلاصة: (أ) التنمية الثقافية والاجتماعية فيما يتعلق بنهج التعليم الضمني ، (ب) المنهج المشترك وانعكاسات التدريس ،(ج) و مناقشة بالمواضيع العلمية لبناء المعرفة العلمية.

تشير هذه النتائج إلى نجاح التدخل بشكل إيجابي في تعزيز مفاهيم طبيعة العلوم للطلاب ، ولكن هناك حاجة إلى مزيد من الأبحاث لدراسة العلاقة بين التصورات التقليدية لطبيعة العلوم وتحصيل الطلاب في الاختبارات المعيارية.

DEDICATION

I dedicate this work to my father, Nabil Ali Abdallah. Throughout my entire life in general and through this study journey in particular, he had strong believe in my potential. He had spoken very highly about me which made me feel that I can overcome any obstacle that I face. The inspiration of a lifelong love of learning came from the endless faith and patience in my abilities. Thank you for understanding how important it was for me to complete my PhD.

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I am grateful to Professor Sufian Forawi who enlightened in me the passion about nature of science (NOS). His enthusiasm about scientific literacy and NOS inspired me to pursue this topic of my thesis. His patience and encouragement guided me through this study. His dedication a lot of time to provide valuable constructive feedback to complete this work was a true asset in the completion of this thesis.

Besides, I'd like to thank my closest best friend for his limitless patience, emotional support, and his strong belief in my capabilities that carried me through the stressful and hard times. I also would like to express my gratitude towards my mother and my father for their continuous encouragement.

Third, I would like to sincerely ask my two daughters, Alissar and Layal to forgive me for being away from them for long hours to complete my studies and write my thesis. They were my source of energy and ideas. Thank you for allowing me to achieve my dream while balancing my role as a mother.

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CHAPTER 1: INTRODUCTION

1.0 Introduction

In the twenty-first century, the rapid changes are raising a lot of issues for organizations, communities, and government. Genetic engineering, organ transplants, environmental issues, and climate change are the major concerns globally. Both formal and informal systems of education are proactive to respond to improve the global interest in science. This interest inevitably demands a lot of metacognitive awareness and understanding of the procedural aspects in the science subject. Science is becoming embedded in every facet of the real world in an increasingly futuristic implementation with technology in the globalized world. Furthermore, global competitiveness of a community is dependent on the specialized scientists and equity of education to develop the knowledge and skills for the demand. The shortage of scientists is a very disappointing reality that prevents the development of workforce worldwide. On one hand, Freeman (2005) states that the number of scientists in the United States is decreasing rapidly. On another hand, The World Bank (2008) reports that in most Arab countries only 20% of university students are enrolled in science programs. Hence, the number of enrolled students in science majors is low globally especially in Arab World. Few Arab students have had exposure to develop interest to pursue science related degrees. Abd-El-Khalick & Said (2009) state that very few students in the Arab countries have developed favorable interests and attitudes towards science. For instance, in Qatar only 19% of students have chosen science and engineering programs as a major at universities (The World Bank, 2008). In comparison to Lebanon where 55% of students are registering in science and engineering programs in universities (CERD, 2011). Arabic countries have been aware of this problem and unfortunately only some countries are trying to act upon this dilemma by placing a lot of emphasize on the development of their education while other countries are ignoring this issue. Lebanon and United Arab Emirates (UAE) are the most active countries in the Arab world in searching for various means to develop the scientific literacy skills of their citizens and their youth generation.

For instance, the Government of Abu Dhabi (2008) places education and training at the core of enhancing human capital development through improving productivity and competitiveness of the workforce. While the government is keen on the development of its citizens, the leaders are searching for best solutions to obtain sustainable development. New curricula and teaching approaches are needed to better prepare students for an ever changing future (Tairab, 2016). Working on improving the skills of the current workforce is rewarding but a better future for the nation requires skillful and competent youth. UAE Vision 2021 (2009) emphasizes that productivity and competitiveness are driven by investment in science, technology, research and development. This link between sciences and the improvement of civic quality was agreed upon by many countries. Bottoms and Uhn (2001) state that companies are looking for employees who possess strong scientific and mathematical background, considering that Arab countries boast merely 371 qualified scientific workers per a million residents, a figure which is significantly lower than the global rate of 979 per million (United Nations Development Programme [UNDP], 2003) does not support the research and this fact confirms the lack of qualified scientific workers in the Arab countries. Consequently, those countries are not able to handle environmental issues and future challenges. The society is unable to come up with innovative ideas to improve its current situation. The work place needs innovative critical thinkers able to resolve issues instead of workers waiting for a set of tasks to execute. Conclusively, this issue is becoming a universal issue rooted in the lack of emphasis on an adequate development of interest in science and scientific majors. Many science educators report the inadequate nature of science (NOS) understanding despite of the curriculum reforms (Lederman, 1992; Lederman, 2006; McComas et al., 1998, Vazquez-Alonso et al., 2016, Yacoubian and Khishfe, 2018). Specifically in Lebanon, where this research was conducted, Sarieddine and BouJaoude (2014), state that a holistic targeted planning process is required to develop an appropriate NOS concepts. NOS concepts are easy to state but they are hard to achieve. The development of NOS concepts is a complex process controlled by various primary and secondary variables that either have a direct or an indirect impact on enhancing students understanding of NOS. Scholars (Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018) are actively testing various ways to develop an adequate students' understanding of NOS concepts.

Globally, many countries are keen on reform efforts to equip the coming generation with competencies and skills to resolve problems that we have yet to hear about. Such a goal can only be achieved if the scientific literacy skills are well developed among students. Concurrently, considerable work has to be done to develop scientifically literate individuals within the workforce. Increasing the scientific literacy skills of the nation is the key of any reformation (Preczewski et al., 2009; Fouad et al., 2015; Smith & Scharmon, 2008). Nature of science is regarded as the fundamental target for thousands of research studies (Abd-El-Khalick et al., 2012; Ramnarian & Chanesta, 2016; Kampourakis, 2016; Karisan & Zeidler, 2017) as well as any science curriculum reformation (Hurd, 1997; Wilcox and Lake, 2018; McComas and Nouri, 2016). Nature of science has been defined as the inherent processes to develop scientific knowledge (Akerson & Donnelly, 2010; Wolfensberger and Canella, 2015), the core value of science (Kruse & Borzo, 2010), and the guiding book of how science works (Hanuscin and Lee, 2009). Educators are calling for science reformation to develop appropriate understanding of NOS aspects (Fouad et al., 2015; Smith & Scharmon, 2008; Tala & Vesterinen, 2015; Wilcox & Lake, 2018; Cofré et al., 2018) and to enable citizens to be scientifically literate (Çil & Çepni, 2016; Leung, Wong & Yung, 2015; National Research Council, 2013; Sandoval & Morrison, 2003). The development of students' scientific literacy and nature of science (NOS) views are major positive impacts of science educational reforms. For that reason, in many countries such as Turkey, United Kingdom, United States of America and Lebanon, NOS is becoming an integral element of curriculum mapping design (e.g. USA: NGSS Achieve, 2013; UK: QCA, 2007; Turkish Science Curriculum, 2006; Lebanon: Lebanese Association for Education Studies, 2007). In the Arab World, the level of scientific literacy is declining even though science is an integral component of life in modern society. Scholars (Miller, 2006; Gerber, Cavallo & Marek, 2001) concluded that adults acquire shallow scientific literacy levels and the depth of their scientific literacy is directly proportional to the sustainability of scientific enterprise. Therefore, citizens have to be scientifically literate (Sandoval, 2005; National Research Council, 2013). They have to be able to think logically, use evidence to hypothesize, and draw valid conclusions. The possession of a thorough understanding of scientific concepts makes an individual scientifically literate and able to make informed decisions about societal and personal issues (NRC, 2013; NSTA, 2003) that makes informed life decisions, forms judgments, and decides about the quality of the scientific claims (Serdar Köksal & Tunç Şahin, 2014; Forawi, 2010). To sum it up, the future is growing totally dependent on how wisely citizens use science and scientific knowledge to sustain the economy using wise decisions.

In the science education literature, there exists a general agreement around the necessity of improving students' views of nature of science (NOS). For the past century, the research studies documented this as a primary goal (Abd-El-Khalick et al., 1998) and this has been investigated in numerous amount of studies for the past 60 years (Lederman, 1992; Park et al., 2014; Abd-El-Khalick, 2013; Allchin, 2014; Bloom, Binns & Koehler, 2015;

BouJaoude, 2002; Clough, 2011; Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018). Historically, as per Layton (1981), the British Association for the Advancement of Science recommended to include in science teaching the methods and history of science rather than solely experiments results. In 2007, the European Commission (EC, 2007) insisted on the need of a pedagogical renewal that aims to focus on the processes and the methods of science rather than the content knowledge only. Back to 1968, Laudan identified the need to create a framework for science and its mechanism (Rocard et al., 2007). In a different context, in Portuguese, science education admits the need to develop scientific literacy and adequate views of NOS which results in assuring informed and active citizens (Torres & Vasconcelos, 2015). Throughout the last fifty years of the twentieth century, the world witnessed rapid development in technology and science. Thus, science educators started calling for shifting the focus of science curriculum to how scientific knowledge is obtained, validated and developed. In response, the science curriculum has accommodated to aspects focused on the nature of scientific content and the process of science (NGSS: Appendix F, 2013; NGSS: Appendix H, 2013; NGSS: Appendix I, 2013).

The strength of the coming future depends on the adequate growth of the scientific community and the scientific literacy skills of all citizens. Et & Memis (2017) state that science literacy is important for societies and individuals. Those aspects allow individuals to become able of resolving innovatively daily life problems. Whereby, the whole society becomes rich of mind powers with strong metacognitive and cognitive abilities. In parallel, new innovative learning areas and skills are needed to operate life in line with the continuously emerging issues. The starting point of this road map begins at a young developmental age, were young people develop the perceptions about science and scientists from their teachers' reflections in the class environment (Et & Memis, 2017).

A scientifically literate person has the ability to synthesize knowledge from different fields, to apply concepts in practical ways, and to deal with science-social as well as personal civic problems. These characteristics are vital in daily life. They allow citizens to decide about the quality of scientific claims and to make informed decisions on social-scientific issues. The two fundamental components of scientific literacy are learning about aspects of NOS and learning science content knowledge (Damastes & Wandersee, 1992; Uno & Bybee, 1994). The achievement of life-long individual learners is rooted by properly educating students about NOS. The proper understanding of NOS is based on a clear segregation between the states of the world (data) and ideas (hypothesis, theories). The implied relationship among those factors allows for the construction of scientific knowledge. In specific, students tend to improve their general understanding of science in relation with real life situations when their NOS aspects are well comprehended. An adequate understanding of NOS allows students to reject unrealistic ideas and to use scientific knowledge for life (Sedar Koksal & Tunc Sahin, 2014). Many scholars insist that understanding NOS enhances students' learning activities (Sandoval & Marrison, 2003; Lederman, 1992; Lederman et al., 2003) and the way they understand scientific concepts (Leach, 2006; Hacieminoglu, 2016). Thorough understanding of NOS motivates students to participate in decision-making processes and to connect applied technology and science as active learners. Thus, NOS is a vital component of scientific reasoning and a center of attention of science educations (Hwang, 2015; Ramnarain & Chanetsa, 2016; Leung et al., 2015). Acquisition of NOS understanding empowers students to be scientifically educated, to understand the role of science in their own societies and cultures, and to increase their ability to acquire science content material (Bloom, Binns & Koehler, 2015). Yacoubian and Khishfe (2018) concluded that students become able to use argumentations to collect evidence and support their conclusions only when they possess informed views of scientific knowledge. The accessibility of K-12 students to the aspects of the nature of science allow them to become scientifically literate (Lederman, 1999; Lederman, 2007b; Wilcox and Lake, 2018).

1.1 Background

Establishing scientific literacy of which the nature of science is a key aspect, is vital for allowing an individual to become a well-rounded decision maker. Scientific literacy aims to provide students with scientific knowledge foundations (Forawi, 2011; Forawi, 2010; Forawi & Liang 2011) and to prepare students to take decisions as informed citizens regarding scientific and social issues (Torres et al., 2015; Smith et al., 2012; Serdar Koksal &Tunc Sahin, 2014; Forawi, 2011). In this respect, NOS is considered a fundamental element of scientific literacy and at the same time it is attained as an outcome of a thorough understanding of science content and its processes (Abd-El-Khalick, 2013; Allchin, 2014; Bloom, Binns & Koehler, 2015; BouJaoude, 2002; Clough, 2011; Guerra et al., 2013; Hwang, 2015; Lederman, 1999; Lederman et al., 2002; Leung, Wong & Yung, 2015; Ramnarain & Chanesta, 2016; Wolfensberger & Canella, 2015). Such interconnections between scientific literacy and nature of science attract reformers of science learning. NOS is a pre-requisite to develop scientific literacy and a crucial foundation for science learning (McComas et al., 1998).

Even though NOS and scientific literacy are directly proportional to each other (Fouad, Masters & Akerson, 2015; Krell et al., 2015; Lederman, 1999; Park et al., 2014; Tala & Vesterinen, 2015), research in science education discloses that students and scholars possess inadequate views of NOS (Torres et al., 2015; Lederman et al., 2002; Vázquez-Alonso et al., 2016). Students learn the "what" of science, but they do not learn the "how" of science. Subsequently, the inadequate understanding of NOS is tightly connected to the way science is taught. Adedoyin & Bello (2017) insist on the essential need for an adequate NOS knowledge for a student to excel in the field of science. Students are taught science yet they are not scientifically literate. Science literacy is declining due to the lack of strong emphasize towards developing it (Miller, 2006; Statistics: US department of education, 2007).

Despite the multiple factors to consider in the problem of inadequate students views about NOS aspects, there are not great strides towards developing science literacy worldwide. Students are studying facts about natural phenomena rather than discovering natural phenomena through experimental learning. The science learning process is focused on achieving the learning targets set by the curriculum goals rather than enhancing the scientific literacy skills of students. Science is a potent tool for finding solutions to the ever-changing problems as a field of study with no borders. Its values and principles extend beyond the classroom. It is a variable aspect of human lives and is seen as a way of understanding nature and its components. Adedoyin & Bello (2017) envision science as a set of conscious activities that explains nature and its elements. Unfortunately, science educators are unable to present the endless values, prospects and processes of science. For the purpose of this thesis, the definition of science is derived from the following definition from Bickmore and Grandy (2007, p.1):

> "Science is the modern art of creating stories that explain observations of the natural world and that could be useful for predicting, and possibly even controlling, nature."

This definition implies that scientific explanations are constantly changing and new discoveries are made that change the way the natural phenomena function. Scientists provide crafted stories to explain observations. Students need to inhabit practices to allow them to think and to act as if they are scientists. In particular, students learn best through social interactions which shape their cognition and hone their skills.

Science is a unique discipline seeking to explain natural phenomena through rigorous observations. The observations of the natural world provide rich data enhancing science. Oakes and Lipton (2003) believe that students are little scientists eager to explore and to investigate in a self-directed manner. Science concepts are thought about as a sphere with well-tested theories located at the core of that sphere. At its edges, all the speculations and assumptions waiting to be tested are situated. Quinn (2010) states that scientists are continuously expanding theories, seeking new explanations, and drawing ongoing connections. Students become skillful when they are indulged in learning activities focused on solving real world problems. They design a plan, analyze information, and apply the abstract knowledge to deal effectively with real world mysteries. Their understanding of scientific facts is solidified when it is tightly connected to real life. Woolfolk et al. (2010) state that meaningful experiences allow students to understand and learn. Various practices such as investigating new ideas, analyzing challenging problems, synthesizing information, and articulating knowledge allow students to discover the basic aspects of the nature of science. Conclusively, students construct their own understanding of the real world based on how their experiences relate to the daily life issues (Wilcox & Lake, 2018; Olusegun, 2015).

When science topics are presented holistically, students become more scientifically literate. Our ever-changing world demands scientifically literate people who are able to impact their personal and social aspects (Stefanova, Minevska & Evtimova, 2010). PISA (2006) key findings revealed that the majority of students have mastered the science curriculum content knowledge while very few of them are able to apply the skills in real life situations. Additionally, PISA (2009) results support that students have adequate scientific knowledge but are unable to apply this knowledge in similar situations. In Dubai, in particular, the government is setting high expectations for private schools. In January 2014, HH Sheikh Mohammad Bin Rashid released the national agenda which has set the expectations of students' performance through standardized tests. The seven indicators of the national agenda focus mainly on quality of teaching, leadership qualifications and student achievements in international benchmark tests (UAE Vision 2021, 2009). Two indictors specify the UAE rankings in PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study). In 2021, it is hoped that the UAE shall be among the 20 highest performing countries in PISA and among the 15 highest performing countries in TIMSS. The *Knowledge and Human Development Authority* (KHDA) are working with private schools in Dubai to discuss their action plans and to provide them with individual targets that they should meet in the coming standardized tests. Gningue et al.(2013) state that poor performance in international assessment raise a concern to improve student achievement in mathematics and science. Sonyel & Perkanzeki (2014) insist on the growing demand for new forms of knowledge, skills and responsibilities to respond to the rapid change of economy, industry and society. There are many factors that have a direct or indirect impact on developing the scientific literacy of citizens. Achievement gaps in science (Bowers, 2007; Gopalsingh, 2010; Murphy, 2009; National Center for Education Statistics, 2012; Wagner, 2008), inquiry based learning and instruction (Marshall & Horton, 2011; National Research Council, 1996; Piaget, 1928/2009), program assessments (Ali, Yang, Button, & McCoy, 2011; Burton & Frazier, 2012; Lee & Ready, 2009), and science skills (Asunda, 2011; Feller, 2011; National Center for Education Statistics, 2012; Schiavelli, 2011) are major factors that allow the proper establishment of scientifically literate individuals.

From a different angle, students' achievement in science examinations is not reflective of their scientific literacy. Commonly, their attainment in tests is high but their scientific literacy is relatively low (OECD, 2016). The delivery of the current science curriculum is adding to the problem of low scientific literacy among the new generation. Science must be delivered in a more meaningful way with real world context. In a science class, students rely immensely on the teacher for information where a teacher is considered a dispenser of knowledge (Clough, 2011; Hacieminoglu, 2016; Hwang, 2015; Jones & Talbott, 2015; Zarnowski & Turkel, 2013). Science becomes interesting when natural daily experiences are embedded in science topics. Reducing science to a set of facts is a dangerous educational trend. Tairab (2016) states that science teaching and learning processes need to focus on enhancing the intellectual and manipulative skills of students. Science learning is currently focused on the content rather than the process. In 1993, the American Association for the Advancement of Science (AAAS) called for the United States to stress the development of science literacy among American students by releasing the following statement:

> "As the world becomes increasingly scientific and technological, our future grows more dependent on how wisely humans use science and technology. And that, in turn, depends on the effectiveness of the education we receive. With the exploding impact of science and technology on every aspect of our lives, especially on personal and political decisions that sustain our economy and democracy, we cannot afford an illiterate society."

It is not a matter of improving a practice anymore, it is becoming a wide nation dilemma that is forcing numerous countries worldwide to react. Countries are expected to look meticulously at their science curricula to increase scientific literacy in educational practices. It is not a matter of becoming a better country or have an outstanding curriculum, it is a matter of enhancing a whole generation to become scientific thinkers and decrease scientific illiteracy. While there is this big emphasis on the science education reform, there is a huge shift in the pedagogical approach used in schools to deliver the content knowledge (Dillon, 2009; Rocard et al., 2007). Many scholars (Abd-El-Khalick, 2013; Bloom et al., 2015; Çil & Çepni, 2016; Griethuijsen et al., 2015; Khishfe & BouJaoude, 2016; Lederman, Antink & Batros, 2014; Vázquez-Alonso et al., 2016; Wolfensberger & Canella, 2015) state that the current approaches to deliver science education in schools neither allow students to become scientifically literate (Clough, 2011; Hacieminoglu, 2016; Hwang, 2015; Jones & Talbott, 2015; Lederman, Antink & Bartos, 2014; Lederman, 2007b; Zarnowski & Turkel, 2013), nor enable them to understand contemporary views of NOS (AAAS, 1993; Hodson, 2014a; Khishfe & BouJaoude, 2016; Sarieddine & BouJaoude, 2014). Students are dictated the concepts and are rarely engaged in inquiry-based learning opportunities to construct their scientific knowledge by themselves.

NOS is the root of science focusing on science as a way of knowing. Huang, Wu, She, Lin (2014) state that NOS is the epistemology of science, the values and beliefs inherent to scientific knowledge and characteristics of scientific knowledge. NOS is referred to as scientific knowledge or nature of science. The use of nature of science and nature of scientific knowledge as NOS can be confusing (Hodson, 2014b). Lederman, Antink & Bartos (2014) state that NOS stands for nature of scientific knowledge.

Many scholars have defined “Nature of Science (NOS)” (Lederman, 2007a; Abd-El-Khalick, 2013; Forawi, 2014). The majority of definitions share common elements, but each definition focuses on one single aspect of NOS. Studies in the previous three decades focused on the significance of understanding nature of science (Abd-El-Khalick et al., 1998; Akerson, Abd-El-Kalick & Lederman, 2000; Akerson & Hanuscin, 2007; Akerson, Hanson & Cullen, 2007; Duschl & Grandy, 2013; Duschl & Wright, 1989; Lederman, 1999; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Lederman et al., 2003;

Lederman & Lederman, 2014; McDonald, 1996; Schwartz et al., 2002; Schwartz, Lederman & Crawford, 2004; Shanahan & Nieswandt, 2011; Smith & Scharmann, 2008). Concepts of NOS are ever dynamic and scientists and science educators agree to disagree on the meaning of the nature of science and its fundamental concepts. Although NOS has many facets, at a certain level of generalization, there is a shared perception among all science educators about nature of science. Bearing in mind the variety of definitions the consensus agrees on the basics. Research supports that NOS has multi-universal accepted definitions (Erduran & Dagher, 2014). NOS aspects are defined based on Abd-El-Khalick et al. (1998) definition:

> "virtually no disagreement among historians, philosophers and science educators. . .are that scientific knowledge is tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (theory-laden); partly the product of human inference; imagination and creativity (involves the invention of explanation); and, socially and culturally embedded." (p. 418)

For the purpose of this study, NOS is a discipline that deals with the epistemology of science, science as a way of knowing, or the beliefs that underpin the development of scientific knowledge Lederman (1992). The descriptions of NOS aspects by international organizations (NSTA, 2003; NRC, 2013; NGSS: Achieve, 2013; AAAS, 1993) provide confusing guidelines for science education and specialists. NRC (1996) states that some scientific ideas are open to change while others are core, fixed and unlikely to change. NOS understanding has to be intentionally targeted in teaching since it is a cognitive instructional outcome (Karaman, 2016). Implementing inquiry processes allows students to design explorations but it is not enough to provide insightful ideas about NOS. NOS views do not necessary develop by an inquiry based science class (Ayvaci, 2007; Abd-El-Khalick, 2013). The understanding of the nature of science is an individual understanding that is individually varied. Considering the history of the development of understanding, the science topics from childhood to adolescence illustrate clearly the tentative nature of scientific knowledge. Although scientific knowledge develops and evolves but students believe that current scientific laws are final. In addition, scientists believe that scientific knowledge increases and progresses based on new scientific discoveries or deep analysis of existing information. Individuals have to be flexible with a growth mindset. Thus, tentativeness is a crucial component that allows individuals to recognize the nature of science.

An analysis of recent trends in the research field of NOS has highlighted two main areas of interest. The first is concerned with instructional approaches that aim to improve participants' views of NOS-explicit and implicit NOS instructional approaches (Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018; Cil & Cepni, 2016; Karison & Zeilder, 2017). The other concern is related to the curriculum structure and the presence of NOS aspects as part of the science discipline (Tairab & Al-Naqbi, 2017; Cogger & Miley, 2013; Tan and Leong, 2014; McComas & Nouri, 2016; Wilcox & Lake, 2018). Implicit instructional approaches to teaching NOS rely on the view that an understanding of NOS results from engaging students in inquiry-based learning activities without deliberately focused NOS instruction (explicit). Many scholars utilize an implicit instructional approach indicated that participants views of NOS did not substantially develop (Moss, Abrams & Robb, 2001; Sandoval & Morrison, 2003; Schwartz et al., 2001). Besides, an explicit NOS instructional approach intentionally focuses on various aspects of NOS during science learning process. This approach is based on the belief that NOS instruction has to be planned for and considered a central component of science learning. The findings reported in reviews of literature (Akerson et al., 2000; Hanuscin et al., 2006; Kim et al., 2005; Khishfe & Abd-El-Khalick, 2002) indicate that explicit approaches to

NOS instruction is effective in promoting an informed understanding of NOS. Recently, Wilcox and Lake (2018) conducted a study and stressed on the need to explicitly incorporate NOS aspects into a variety of activities to develop an adequate understanding of NOS. The explicit discussions revolving around NOS aspects support students' natural creative potential to acquire a holistic perception of the various aspects of the nature of science.

Students are expected to have sufficient understanding about all the eight understandings of NOS aspects (NGSS: Appendix H, 2013), and mainly the four aspects of NOS (Ledermann, 2006): the tentative aspect, the empirical aspect, the creative aspect, and the inferential aspect. Understanding NOS is based on a clear differentiation between ideas (theories, hypothesis) and states of the world (data), this generates an understanding of scientific knowledge as a construction of data and ideas (Koerber, Osterhaus & Sodian, 2015). McComas (2008) insists that NOS is an inherent guidelines used by scientists to develop knowledge and aspects of scientific knowledge.

The perceptions that students possess about NOS come as a result of the process of science. Examining their perceptions answer questions about how to design and deliver the planning, to enhance the implementation, and to promote science learning. This study seeks to provide guidance about the primary factors of the curriculum implications and instruction approach implications that contribute to students understanding of NOS aspects. It aimed to examine whether students' perceptions about NOS witness a change due to the combined explicit reflective and inquiry based-instruction approach which entails planning for both curriculum elements and the instructional approach. If there is a relationship between NOS understanding and combined explicit reflective and inquiry based-instruction approach, then findings from this study could lend a support to studies conducted by educators (Cheung, Slavin, Kim & Lake, 2017; Khishfe, Alshaya, BouJaoude, Mansour &

Alrudiyan, 2017; Sarieddine & BouJaoude, 2014; Vázquez-Alonso et al., 2016). If the result is to the contrary, this study is expected to raise the concern of neglecting the approach factor when considering the factors that affect students' conceptions of NOS.

1.2 Context of the Study

The context of this study is set in the Republic of Lebanon. In Lebanon, many studies were conducted to determine the elements that affect students' acquisition of different aspects of NOS (Griethuijsen, Eijick, Haste, Brok, Skinner, Mansour, Gencer & BouJaoude, 2015; Sarieddine & BouJaoude, 2014). Many factors such as curriculum standards, teaching strategies resources, and student motivation have been identified as indicators that affect students' conceptions of NOS. Despite the disagreement among researchers (Abd-El-Khalick et al., 1998; Duschl & Grandy, 2013; Lederman, 2007b; Leung et al., 2015) about the components of NOS that have to be part of science education, all science educators and scholars (BouJaoude et al., 2011; BouJaoude et al., 2009; Chinn, 2017; Fouad et al., 2015; Khishfe, Alshaya, BouJaoude, Mansour & Alrudiyan, 2017; Tala & Vesterinen, 2015; Schwartz, Lederman & Crawford, 2004; Bartholomew et al., 2004; Bell, Lederman & Abd-El-Khalick, 2000; NGSS Achieve, 2013) agree on the necessity of developing students' informed conceptions of NOS. Yet, students' conceptions of NOS, which result in deep understanding of scientific literacy, remain under the direct influence of implicit or explicit teaching of NOS aspects in science classes (Akerson, Morrison & McDuffie, 2006; Celik & Bayakceken, 2006; Çil, 2014; Hacieminoglu, 2016; Koerber, Osterhaus & Sodian, 2015; Michel & Neuman, 2014; Peters, 2012; Schussler, Bautista, Link-Pérez, Solomon & Steinly, 2013; Seckin Kapucu, Cakmakci & Aydogdu, 2015).

The research studies conducted in Lebanon, concluded that students hold inadequate conceptions of NOS that tend to have traditional views of NOS (BouJaoude et al., 2011;

BouJaoude, 2003; BouJaoude, Abd-El-Khalick & El-Hage, 2009). The lack of adequate understanding of NOS originates from the emphasis of the Lebanese curriculum on science content (BouJaoude, 2003), and the absence of any explicit reference to NOS in science classes (Bell, Lederman & Abd-El-Khalick, 2000). Sarieddine and BouJaoude (2014) insist on the need to conduct further studies in Lebanon to investigate the appropriateness of instructional approaches to teach the aspects of NOS. As reported by many Lebanese scholars (Sarieddine & BouJaoude, 2014; Griethuijsen et al., 2015; Khishfe & BouJaoude, 2016), finding a way to provide students with appropriate NOS conceptions is a countrywide Lebanese target to enhance students' scientific literacy. Tala and Vesterinen (2015) recommend to conduct extensive research to study NOS in a variety of contexts in science and to have research and science education walk balanced to establish the nationwide target of scientifically literate citizens.

On one hand, being an epistemology of science and a way of developing scientific knowledge, NOS is required to become an integral part of the science curriculum. Nature of science is the foremost foundation of science activities (Wolfensberger & Canella, 2015; Ramnarain & Chanetsa, 2016; Fouad et al., 2015; Lederman, 2006) and a crucial factor in developing the scientific literacy (Vázquez – Alonzo et al., 2016). On the other hand, many efforts nowadays arise to teach NOS aspects explicitly using generic NOS activities (Michel & Neuman, 2014; Abd-El-Khalick, 2013; Brase, 2014; Jenkins, 2013) and to use a specific approach to teach NOS (Çil, 2014; Hacieminoglu, 2016; Koerber, Osterhaus & Sodian, 2015; Schussler, Bautista, Link-Pérez, Solomon & Steinly, 2013; Seckin Kapucu, Cakmakci & Aydogdu, 2015). Conclusively, a blend of both a curriculum aspect and an approach aspect, strengthen students' conceptions about NOS and further develop their scientific literacy.

Mainly, there has been two broad approaches for teaching NOS: implicit approach and explicit approach. Inquiry-based instruction focuses on exploring science concepts, principles and laws while explicit-reflective teaching approach allows students to be engaged in a discourse about NOS aspects. Thereby, the explicit-reflective teaching approach is the most promising way to teaching NOS (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2006; Dagher et al., 2004; Lederman, 2006; Smith & Scharmann, 2008; Wolfensberger & Canella, 2015). Wilcox and Lake (2018) stress on the need to explicitly incorporate NOS aspects into a variety of activities throughout the process of science learning. The explicit-reflective teaching approach is associated with many pedagogies such as modelling approach, experiential learning approach, and direct teaching approach. However, the inquiry-oriented pedagogy is most commonly used to develop NOS concepts among students (Khishfe 2008; Akerson, Hanson & Cullen, 2007). Scientists work in utilizing inquiry, hence teaching science has to follow the same approach. Students learn both scientific processes and scientific concepts once learning activities are designed in an inquiry-based set-up (Abd-El-Khalick, 2013; Barrow, 2006; Bybee, 2006). Inquiry-based instruction engage students in practical experimentations to construct scientific knowledge (Cofré Santibáñez Jiménez Spotorno Carmona Navarrete & Vergara, 2018). The adapted approach to deliver science content knowledge is a major factor that affects the development of scientific literacy skills (Ibanez-Orcajo & Martinez-Aznar, 2007; Cil and Cepni, 2016).

Implicit teaching approach is a type of experiential learning were learning takes place through personal and societal experience. To begin with, the implicit teaching approach lacks specific attention to NOS. Implicit NOS teaching includes a sequence of instructional activities compatible with a particular field of science (Bell et al., 2000). Even though engaging students in an inquiry based learning develops their understanding of NOS conceptions, the inquiry based learning approach does not necessarily lead to rich discussions about NOS. Moreover, explicit teaching consists of intentionally planned objectives, instructional strategies and assessments focusing on aspects of NOS. Explicit NOS teaching happens through guided reflections and specific questioning discussions. The teacher clearly states the concept, the purpose, and connect the activities to ideas related to NOS. Learning opportunities and model performance are designed to link the science content knowledge to specific aspects of NOS. Conclusively, scholars advocate of explicit guided attention and reflection on NOS are McComas (2004), Khishfe and Abd-El-Khalick (2002), Schwartz Lederman & Crawford (2004), and Wilcox and Lake (2018). Explicit and guided attention on NOS aspects allow students to achieve deeper understanding of NOS (McComas, 2004; Schwartz et al., 2002) and to have a richer science education discipline (McComas et al., 1998). Wilcox and Lake (2018) insist on the need of asking students to think about NOS ideas explicitly and to reflect on how their experiences relate to the daily life issues. Therefore, considering this study for its value in evaluating the impact of a combined explicit reflective NOS and inquiry-based instruction on students' conceptions of NOS, science educators can look at the relationship between the approach and intentional planning for NOS outcomes that result in students' perceptions of NOS from a different spectrum.

1.3 Statement of the Problem

Students are scientifically literate when they possess adequate understanding of NOS aspects in addition to having well established knowledge of scientific inquiry. Scientific literacy does not only entail having knowledge of the content and methods of science, but it means the acquisition of knowledge about the nature of science. The acquisition of scientific literacy necessitates the emphasis on understanding the nature of science (Sarrieddine & BouJaoude, 2014; Lederman, 2006; Wolfensberger & Canella, 2015;

Karisan & Zeidler, 2017; Kampourakis, 2016). Science with its structure, philosophy and epistemology includes products, processes and ethics (Abimbola, 2013). Through that structure, students have to get a good grasp of concepts to become scientifically literate. Most of which were focused on teachers' perceptions rather than students' perceptions of NOS. The extensive review of literature shows that very little attention is paid to students' understanding of NOS aspects. This is severely noticed in the approaches used to deliver science content knowledge in schools in Lebanon (BouJaoude et al., 2011; BouJaoude, 2003; BouJaoude, Abd-El-Khalick & El-Hage, 2009). As reported by many Lebanese scholars (Sarieddine & BouJaoude, 2014; Griethuijsen et al., 2015; Khishfe & BouJaoude, 2016), finding a way to provide students with appropriate NOS conceptions is the country's target to enhance students' scientific literacy, but studies conducted reported that students have inadequate NOS understanding. Yet, there were no interventions tested in the Lebanese context to improve students' views about nature of science. Mostly, the studies focused on understanding students' perceptions rather than what has to be done to improve the current situation. Tala and Vesterinen (2015) recommend to conduct extensive research to study NOS in different contexts of science and to have research and science education integrated to establish the nationwide target of scientifically literate citizens. The very recent studies are still stressing on the need to give the majority of attention to study students' views about the nature of science (Adedoyin & Bello, 2017; Wilcox & Lake, 2018). Few studies have investigated the impact of either implicit or explicit approaches, whereas, this study aims to focus on the value of intentionally planning to integrate nature of science aspects with science content, on the need to deliver this planning using inquiry-based instruction, and on allowing students to reflect during science learning. Based on this and in response to findings of these previous studies, this research is proposed to investigate the combined impact of using the implicit teaching approach to deliver science content and intentionally discussing and reflecting about the aspects of NOS in relation to the science topics.

1.4 Purpose and Questions of the Research Study

The overall purpose of the study was to examine the impact of a combined explicit reflective NOS and inquiry-based instruction on middle and high school students' conceptions of nature of science. This was addressed by filling the existing gap within the Lebanese literature that fails to examine the impact of explicit reflective inquiry-based instruction on students' conception of NOS.

The study has threefold purpose to: (1) investigate middle and high school students' conceptions of the nature of science (NOS), (2) examine the impact of combined explicit reflective NOS and inquiry-based instruction on middle and high school students' understanding of the nature of science, and (3) investigate middle and high school students' conceptions of the nature of science regarding demographic variables.

Based on the threefold aims of this research study, the following questions were answered:

1-What conceptions of the nature of science do Lebanese middle and high school students have?

2- How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?

3- How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?

This study incorporated a classroom intervention that has been designed to include a combined explicit reflective and inquiry based instructions to provide opportunities for middle and high school students to develop NOS perceptions. Explicit approach was implemented throughout the classroom intervention. Thus, the study approach and methodology aimed at providing the evidence needed to prove that a theoretical representation of the internal structure of the NOS data lead to a reliable, interpretable and theoretically-grounded measure of middle and high school students' conceptions of NOS.

1.5 Significance of the Study

In Lebanon, many studies were conducted to investigate NOS understanding. Most of which were focused on teachers' perceptions rather than students' perceptions of NOS. Farah (1994), BouJaoude (2000) and later Sarieddine & BouJaoude (2014) conducted studies to investigate students' and teachers' views of NOS understanding and concluded that teachers' and students fail to acquire the basic aspects of NOS. Sarieddine & BouJaoude (2014) consider students' perceptions of NOS as an important issue that has to be investigated very well. The strength of the teachers' perceptions starts from the beginning of their personal journey when they were students. Fixing the issue of inadequate NOS has to start with young learners who shall become the contributing members of future generations. NOS is considered a vital component of scientific reasoning and a center of attention of science educations (Hwang, 2015; Ramnarain & Chanetsa, 2016; Leung et al., 2015). Acquisition of NOS understanding empowers students to be scientifically educated, to understand the role of science in their own societies and cultures, and to increase their ability to acquire science content material (Bloom, Binns & Koehler, 2015). Yacoubian and Khishfe (2018) insist that informed views of scientific knowledge allow students to use argumentation to support claims by evaluating evidence. Weaving subject-matter knowledge together with NOS knowledge builds a strong population with scientific literacy skills that is sustainable. Scientifically literate students have the scientific knowledge foundations (Forawi, 2010; Forawi, 2011; Forawi & Liang, 2011) that prepares them to make decisions as informed citizens regarding scientific and social issues (Torres et al., 2015; Smith et al., 2013; Serdar Köksal & Tunç Şahin, 2014; Forawi, 2011). Studies that were conducted in Lebanon were either descriptive studies or intervention studies (Sarieddine & BouJaoude, 2014), but none of which provided solid foundation for a holistic change to achieve an adequate understanding of NOS among K-12 students. Unfortunately, those studies focused on one of two inseparable factors which are curriculum and approach. They either investigated curriculum structure or instructional approach (Bou Jaoudi et al., 2011; Wilcox and Lake, 2018). Specifically in Lebanon, where this research was conducted, Sarieddine and BouJaoude (2014), state that the development of an appropriate NOS concepts is a complex process that requires targeted planning and thinking. This assures that the claim of addressing NOS issue has to be tackled in the planning process as well as the implementation process.

There are many contributions that this study is expected to rethink the field of NOS. To begin with, the developed instrument for this study consists of many different domains which focus on perceptions about NOS aspects, science learning activities, and science learning approach. In accordance, the triangulation between these three corners provide a clear insight about how students value each component. The use of a suitable instrumentation provides data through statistical tests that allows for the investigation of NOS views (Dogan & Abd-El-Khalick, 2008; Lombrozo Thanukos & Weisberg, 2008; Neumann Neumann & Nehm, 2011). An equal importance is given to each of the three factors which are core in the developed instrument. The collective data from the qualitative method and the quantitative method provided plentiful information to investigate the complexity of NOS phenomena. Researchers support (Cil, 2014; Cil & Cepni, 2016; Hacieminolgu, 2016; Huang et al., 2014; Hwang, 2015; Kahraman & Karatas, 2015; Koeber et al., 2015; Krell et al., 2015; Torres et al., 2015) using a mixed method approach to generate a comprehensive blend of quantitative and qualitative data to investigate NOS conceptions. Therefore, the multiple research methodologies used for the topic of this study aimed to add to current international studies and to offer enhancement to science education in K-12 classrooms.

Second of all, this study considers students' perceptions in relation to the science learning environment rather than focusing solely on the actual aspects of NOS. Science learning requires a well-structured curriculum that connects NOS to the standards in every level, a suitable instructional strategy to allow students to establish knowledge of scientific inquiry, and various learning opportunities to enable students to reflect about their learning experiences. Students can establish an authentic access to NOS once it is interwoven with science concepts (Bloom et al., 2015; Çil & Çepni, 2016; Griethuijsen et al., 2015; Khishfe & BouJaoude, 2016; Lederman, Antink & Batros, 2014; Vázquez-Alonso et al., 2016; Wolfensberger & Canella, 2015).The understanding of NOS is an outcome of science education. Aside from that, the instructional approach has been always looked at as the key to develop students' conceptions of NOS aspects. The effectiveness of various teaching approaches on students' understanding of NOS was widely investigated (Çil, 2014; Hacieminoglu, 2016; Koerber, Osterhaus & Sodian, 2015; Schussler et al., 2013; Seckin Kapucu, Cakmakci & Aydogdu, 2015). Hence, students' perceptions of their learning environment was investigated in this study seeking to reveal the factors that contribute to a better NOS perceptions.

Lastly, this study focuses on the three components that complement each other in the learning process. It examines the combined effect of implicit and explicit approach on students' understanding which means that both planning and implementation shall be designed to work in harmony. This study focuses on two components which complement each other rather than focusing on one and neglecting the other. So far, curriculum adaptations worldwide did not produce fruitful results when tackling this issue. Many science educators report the inadequate NOS understanding despite curriculum reforms (Lederman, 1992; Lederman, 2006; McComas et al., 1998). If the results of this research study show the relationships between students understanding and explicitly planning to integrate NOS aspects, its findings shall provide guidance for education reformation teams. This study would furnish positive or negative evidence about the value of intentionally planning to integrate nature of science aspects with science content on the need to deliver this planning using inquiry-based instruction in conjunction with allowing students to reflect while science learning is happening.

1.6 Overview of the Research Study

This thesis consists of five chapters: introduction, literature review, methodology, results and analysis, and discussions and conclusion.

The current chapter highlights the main aspects related to the statement of the problem, description of the research problem, significance of the study, and purpose of the study.

Chapter two consists of the conceptual framework, theoretical framework, bodies of literature, and the situated literature. The conceptual framework consists of Duschl and Grandy NOS perceptions model and the Next Generation Science Standards (NGSS) structure in relation to Duschl and Grandy explicit NOS instruction model. The three theories that underpin this study are Lederman's Conceptualization of NOS Model, Vygotsky's Social Cognitive Theory, and Theory of Change. The review of the extensive literature produced emerging themes such as approaches to teach NOS, NGSS structure, and scientific ways of knowing. Finally, the situated literature focuses on the most recent main studies that investigated students' perceptions about NOS.

The third chapter is the methodology utilized to answer the research questions. In this chapter the research approach, site, sampling, and instrumentation is presented in detail. In addition, the details related to the pilot study results, data collection, and data analysis are discussed to provide a clear picture about the study. Additionally, there is a section that focuses on the planning of a combined explicit reflective and inquiry-based instruction to set up the scene for the way the intervention happened.

Chapter four consists of the analysis and results. It focuses on the analysis of the quantitative data obtained from the ERIBINOSQ instrument that shall be used as a pretest and a posttest. Various tests were used to analyze the data using Statistical Package for Social Science (SPSS) version 25 such as Paired t-test, Cronbach's Alpha, and Descriptive statistics. The analysis of the pretest results were analyzed to answer the first research question. The analysis of the results of the pretest and posttest results of the explicit reflective and inquiry-based instruction group was done to answer the second question. The analysis of the posttest of the explicit reflective and inquiry-based instruction group was done to answer the third question. In addition the qualitative data were analyzed from four various sources. Firstly, there is a presentation of the analysis of the open ended questions of the ERIBINOSQ instrument. Secondly, the analysis of the reflective journal prompts is done using code descriptions and exemplars about the natures of science as well as the approaches used to learn science from student's perceptions. Next, the analysis of the field notes from class observations is presented. Finally, the analysis of the interviews with students and teachers is summarized and coded.

Chapter five presents the discussion and the conclusion. The discussion section presents the research findings in relevance to the reviewed literature. The first question was answered using the results of the data analysis from the ERIBINOSQ pretest. The analysis of the pretest results of all participants allowed the researcher to determine the NOS conceptions of the Lebanese middle and high school students. The second question was answered using the results of the ERIBINOSQ pretest and posttest results, reflective journal prompts, field notes from class observations, and students' interviews of the experimental group. The third question was answered using the results of the data collected from the ERIBINOSQ posttest of the experimental group. The second section draws in the final conclusions of the study which constituted of three themes. The third section presents the recommendations and the suggested areas for future research. The last section shows the limitations of this research study.

CHAPTER 2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Overview

This chapter provides an overview of the literature that is related to the nature of science, scientific ways of knowing, curriculum structure, instructional approaches used to teach NOS, and the factors that have an impact on students' perceptions of NOS. The aim of this study is to examine the impact of a combined explicit reflective NOS and inquiry-based instruction on middle and high school students' conceptions of the nature of science (NOS). Several studies have been conducted to assess various components that contribute to an advanced level of students' understanding of NOS aspects (Celik & Bayakceken, 2006; Cil, 2014; Hacieminoglu, 2016; Peters, 2012; Michel & Neuman, 2014; Schussler, Bautista, Link-Pérez, Solomon & Steinly, 2013; Seckin Kapucu, Cakmakci & Aydogdu, 2015). The themes emerged from the review of the recent literature. It is organized in a way that presents the conceptual framework, theoretical framework, bodies of literature, and the situated literature.

The conceptual framework is the analytical tool that captures several variations and contexts. It was derived from models related to aspects of nature of science and the design of US science curriculum. The study was thrust by two models: Duschl and Grandy's versions of NOS perceptions model and the NGSS structure in relation to Duschl and Grandy 2013 explicit NOS instruction model. These two models are interrelated. Duschl and Grandy's versions of NOS are reflected in NGSS structure. Science educators and scholars agreed on explicitly teaching NOS aspects (Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018; Karisan & Zeidler, 2017; Hodson, 2014b; Koerber, Osterhaus & Sodian 2015) regardless of the set of the components of NOS aspects. In the light of the existence of many models, Duschl and Grandy's model is the most suitable for this study due to its embeddedness in the NGSS curriculum structure (Vazquez-Alonso et al., 2016; NGSS: Achieve 2013; NGSS: Appendix I, 2013) which is the science curriculum used in the private school where this study was conducted. Based on this model, the eight understandings of NOS stated in NGSS (NGSS: Appendix H, 2013) are: (a) different methods are used to carry out scientific investigations, (b) empirical evidence is a base for scientific knowledge, (c) new evidence affect the review of scientific knowledge, (d) national phenomena are explained using scientific models, laws, theories, (e) science is a way of knowing, (f)science is a human endeavor, (g)science addresses inquiries about the natural and material world, and (h) scientific knowledge is consistent in natural systems.

The theoretical framework provides a point of focus for finding a relationship between two theories and one model. Lederman's Conceptualization of NOS Model, Vygotsky's Social Cognitive Theory, and Theory of Change are the three frameworks that ground the rationale of this research study. Since this study was investigating the impact of a combined explicit reflective and inquiry-based instruction on middle and high school students, the students were collaborating and communicating in the science class as a basis of learning concepts of NOS. Accordingly, Vygotsky's social cognitive theory is one of the building blocks that this study relies heavily on (Olusegun, 2015; Oliver, 2000; Mvududu & Thiel-Burgess, 2012; Amineh & Asl, 2015). Currently, this study was investigating the impact of an intervention to show whether it caused a change or not. Clear definitions of the intervention elements, the pre-conditions, and the indicators were required. For this purpose, the theory of change is the second theory that underpins this study (Weiss, 1995; Stein and Valters, 2012). Furthermore, Lederman's Conceptualization of NOS model is the third block of the theoretical framework. The NOS aspects of Lederman's Conceptualization Model allows the construction of students' epistemic knowledge (Liang et al., 2006). The domains of Lederman are suitable for the age group of the population of this study.

This is followed by a detailed description of the bodies of relevant literature. The extensive review of various types of literature related to the underlying structure of nature of science construct modeled in this study was considered. In the first place, a broad section is dedicated to discussing the scientific ways of knowing whereas science, nature of science, and scientific literacy are its three building blocks (Ramnarian & Chanesta, 2016; Tala and Vesterinen, 2015; Bello & Adedoyin, 2017). Secondly, the NGSS structure is explained in detail to provide a clear idea about the science curriculum. In the third point, the views about NOS aspects are presented with two subtitles: teachers' views about NOS aspects and Students' views of NOS aspects. The views of parties involved in the teaching and learning process are essential for understanding the causes of the current status about NOS aspects (Sarieddine & BouJaoude, 2014; Hacieminoglu, 2016; Leach, 2006; Cil and Cepni, 2016; Vazquez-Alonso et al., 2016). Fourth, the approaches to teaching NOS are presented. In the absence of an absolute agreement on one single approach to teaching NOS aspects (Cil, 2014; Hacieminoglu, 2016; Schussler, Bautista, Link-Pérez, Solomon & Steinly, 2013). On top of all mentioned approaches, implicit teaching approach was widely studied (Forawi, 2010; Justice et al., 2002; Spronken-Smith, 2012; Ortiz, 2015). Then, the explicit teaching approach was advocated (McComas, 2004; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004). As an extension to the explicit teaching approach, the explicit-reflective teaching approach (Lederman&Lederman, 2014; Bloom et al., 2015) and the explicit reflective inquiry-oriented NOS instruction approaches (Abd-El-Khalick, 2013; Bou Jaoudi et al., 2011) were investigated. Finally, the gender inequities in science education is presented to identify the factors that contribute to various gaps in science learning due to gender differences. In the middle and high school classrooms, the gender gap becomes noticeable and significant (Jones et al., 2000; Walper et al. 2013; Baran 2016) especially in science education (Goetz, 2007; Baran, 2016; Osborne et al., 2003; Sainz, 2011). The existence of the gender gap is a result of various factors (Dennisen et al., 2007; Goetz, 2007; Krapp, 2002; Bhanot and Jovanovic, 2009; Kumari and Saraladevi 2014).

The last part of this chapter is the situated literature. It focuses on specific key studies pertaining to the purpose of this study for example, the studies conducted by Forawi (2014), Vazquez-Alonso et al. (2016), Cil and Cepni (2016), Bello and Adedoyin (2017), Karison and Zeidler (2017, Seckin Kapucu et al. (2015), Haung et al. (2014), and Cil (2014).

2.2 Conceptual Framework

Duschl and Grandy NOS perceptions model and NGSS structure in relation to Duschl and Grandy explicit NOS instruction model shall culminate the study by connecting the NGSS science curriculum to the NOS models.

2.2.1 Duschl and Grandy's versions of NOS perceptions model

When it comes to instructional approach, scholars are in disagreement on how to provide students with informed conceptions of NOS. NOS aspects have to be a main target for science learning (Abd-El-Khalick, 2013; Bloom et al., 2015; Çil & Çepni, 2016; Griethuijsen et al., 2015; Khishfe & BouJaoude, 2016; Lederman, Antink & Batros, 2014; Vázquez-Alonso et al., 2016; Wolfensberger & Canella, 2015), yet there are various approaches that can be used to develop students' understanding about the aspects of the nature of science (Erduran & Dagher, 2014; Hodson, 2014a; Hodson, 2014b; Koerber, Osterhaus & Sodian, 2015; Lederman, 2007b; Lederman et al., 2014; Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018; Karisan & Zeidler, 2017). Thus, all science scholars are in agreement to teach explicitly NOS aspects, regardless of the different set of components of NOS aspects (Wilcox and Lake, 2018; Wolfensberger and Canella, 2015).

Duschl and Grandy created a model in 2013 called the “explicit NOS instruction model”. This model stresses the importance of explicitly including NOS aspects as a point of reference for teaching content. The domains of NOS are in agreement with Norman Lederman Conceptualization of NOS Model. Thus, in every scientific concept, the teacher is expected to emphasize (a) certainty domain, (b) inventive domain, (c) empirical domain, (d) theory-laden domain, and (e) the social and cultural domain (Duschl and Grandy, 2013).

Certainty domain allows students to understand how the scientific knowledge is constructed. Observations enable students to see how the evidence is the collected bit to make a conclusive statement about a phenomenon. The collected new evidence provides support for various theoretical perspectives and at the same time challenge prior scientific claims. Hence, theories are endured if inferred explanations are coherent with prior knowledge, otherwise, there shall be argumentation and confusion on whose scientific claims are true. The collection of evidence-based facts from observations are fundamental to the development of theories. Theories become reliable when they are supported by a body of evidence, have been subject to critique, and have survived after a lot of argumentation and scrutiny. One of the seven pillars of science is evidence (Gauch, 2009). Conclusively, findings in science are always subject to change. New evidence provides new dimension about a specific topic. The new evidence creates room to critique scientific knowledge. The back and forth arguments about scientific claims allow scientific knowledge to be reliable. Uncertainty is a key feature of science allowing new discoveries and critical argumentations to be welcomed. Concurrently, students develop their critical thinking skills by discussing controversial issues about evolving nature of knowledge. They start accepting evidence against their prior beliefs only when they view knowledge as changeable in nature. Hence, students understand the tentative nature of science and the notion that scientists reconsider their ideas when provided with new evidence. As a result, scientific practices are tentative in nature and science is durable, yet subject to change.

Inventive domain highlights on how each scientist has their own mindset. This perceptual apparatus manages the creative element of the scientist's work (Lederman 2007a). The explanations presented by a scientist go beyond the data available to involve creative insights. The creativity and imagination invite a scientist to take a new path and to try different scenarios in an attempt to build a new body of evidence. Even though critiquing and debating are common features among scientists, scientific knowledge is composed through the reflective practices and the human exchange of ideas. Each scientist conducts various experimentations and tries different paths based on personal inspirations. While data is tangible, assumptions are not unless they are justifiable. The imagination enlightens the human's brain to analyze data and to transform predictions into the tangible results.

Socially and culturally embedded domain focuses on the impact of societies on the scientific discoveries. Science takes place in the laboratories, schools, and in the culture of the world's scientific communities. However, these contexts are not restricted to only laboratories, communities, and social and cultural fabric of countries in which scientists work (Lederman, 2007a). Scientists are rooted in their own cultures and are individually varied in terms of levels of economic, technological, and social development stages. Those differences have various consequences on the construction of knowledge. The construction of scientific knowledge is related to the sensory experiences of human beings, the prior knowledge of scientists, and the cultural dispositions and values. Thereby, scientists' practices are culturally and socially predisposed.

Theory-laden domain explains the blend of subjectivity and objectivity to explain natural phenomena. The evidence is collected from experimentation to support scientific claims. The collected evidence is subject to various competing justifications based on the perceptions of the scientists (Lederman, 2007a). The different mind-sets of scientists provide the source of subjectivity in science and the basis for argumentation required to construct science knowledge. Empirical evidence is used to support theories about either observable or unobservable entities. Those theories form a coherent set of subjective concepts used to explain natural phenomena, to guide research questions, and to hypothesize setting (Lederman, 2007b). Consequently, theoretical perspectives set forth the basis for science to operate and thus support the construction of knowledge process. This makes science complex yet organized in its structure.

Certainty domain allows students to understand the seriousness of conducting experiments and to collect accurate data. Critique is at the heart of science knowledge construction. The continuous process of testing and pursuing ideas results in new evidence leading to back and forth considerations. The collection of evidence-based information is a fundamental catalyst to develop theories about real-world phenomena. Even though scientists transform these facts into a coherent justification their creativity inspires them to think in the way they do. Once the scientists conduct tests and establish new evidence, they compare the new conclusions to other conclusions drawn from their predecessors. If the data contradicts the interpretations of other scientists then this creates an unbalanced situation where further investigations are required. The new evidence collected challenges different theoretical perspectives as well as prior scientific claims (Lederman, 2007b). Such a back and forth path justifies the tentative nature of science and the uncertainty of scientific knowledge construction.

Empirical Domain shows the value of experimentations in the formation of scientific knowledge. Although not all scientific knowledge can be built directly using the five senses. Scientists conduct various types of experimentations to investigate various issues in an attempt to explain natural phenomena. The habit of actively searching for descriptive interpretations and explanations is the empirical attitude of a scientist (Lederman, 2007b). Observations completed using only the five senses are easy to conduct. Scientists rely on the obtained data to explain difficult concepts. Although observation data is used, it is not the only source of information used to explain the phenomena. This explains the nature of scientific knowledge construction which is neither solely constructed through observation nor through implicitly theory-laden.

Additionally, Duschl and Grandy (2013) present two versions of their model to demonstrate the differences with Norman Lederman model. The basis as described by Duschl and Grandy (2013, p.3) is presented in Version 1:

> "…is the position that NOS should be benchmarked using domain-general, consensus-based aspects of NOS and taught through explicit references to a set of heuristic principles (Lederman et al., 2002) that philosophers and historians of science use to characterize science as a way of knowing (p. 3)."

They elaborated further in Version 1 that the explicit teaching of NOS requires teachers to explicitly connect the science content knowledge to the features of the nature of science (p.4). However, the foundation for Version 2 (as supported by Duschl, Grandy, and others):

> "…is the position that science, as well as science education, should be conceptualized in terms of cognitive, epistemic, and social practices and the material and technological contexts that characterize doing science. In this version, science education position is that NOS learning occurs when students' engagements are situated in these practices in age-appropriate contexts (pp. 3-4)."

The second version focuses on providing a model to engage students in learning science to develop scientific knowledge. Duschl and Grandy's Version 1 and Version 2 were reflected in Next Generation Science Standards (NGSS, Achieve, 2013) Richard Duschl acted as the NGSS writing team leader and emphasized on the urgency for all students to understand the conceptions of nature of science and to connect its elements to science topics. The eight understandings of NOS were customized for every phase using a student friendly language as documented in NGSS (Appendix H, 2013): K-2 phase, 3-5 phase, middle school phase and high school phase.

The first version of the explicit NOS instruction model is in agreement with Lederman Conceptualization Model. The second version emphasized on the need for the contextualization of science education in cognitive, social, and epidemic practices. The conceptualizing of material, a set of learning opportunities is required to engage students in age appropriate practices to allow the NOS learning to happen. Duschl & Grandy (2013) present two versions of explicit NOS instruction model demonstrated in the table below:

Table (1): Duschl and Grandy 2013 explicit NOS instruction model

Author	Date	Explicit NOS instruction model
Duschl & Grandy (in agreement with Lederman model)	2013	1. General domains and concurrence-based aspects of NOS explicitly are the point of reference for teaching NOS. 2. Teachers explicitly link the features of science program to the consensus statements.
Duschl & Grandy	2013	1. Science and science education have to be conceptualized in cognitive, social, and epistemic practices. In addition to conceptualizing it in the material and technological context of doing science. 2. The position of science: Engaging students in age-appropriate practices to allow NOS learning to occur.

The principles of the model stress on the learning of the science and the approach used to enhance scientific literacy skills for students. Adapting this model allow science learning to happen spontaneously as a result of experimentations and observations. The model shift science educator's attention away from looking at science as a mere collection of topics and ideas. The mastery of knowledge happens while sharpening the skill set of students.

2.2.2 NGSS Structure in Relation to Duschl and Grandy 2013 Explicit NOS Instruction Model

In schools that follow the American curriculum, it should be noted that science does not have national standards, instead, US National Research Council (NRC, 2013) created a policy that guides the development of Next Generation Science Standards (NGSS) (NGSS; Achieve 2013; NGSS; Appendix I 2013; NGSS; Appendix F 2013). NGSS provided a clear roadmap for the development of students' scientific knowledge, scientific skills, and personal and social abilities.

The NGSS writing team leader, Richard Duschl, reflected the views of Duschl and Grandy's versions of NOS perceptions in NGSS (NGSS; Achieve 2013). NOS is not a separate dimension in the NGSS standards framework. It is emphasized in all of the performance expectations for every standard. Additionally, a separate appendix (NGSS Appendix H, 2013) is dedicated to specify the development of NOS conceptions in each phase. This appendix states clearly the eight understandings of NOS and the research base evidence that supports the customization of each aspect for every phase. Clear explanation is provided for every aspect to specify clearly the depth of NOS understanding required at each level. For example, the aspect "Scientific knowledge is consistent in natural systems" has a different set of expectations in the K-2 phase, 3-5 phase, the middle school phase and the high school phase. For k-2 phase, students have to understand that the natural events are happening nowadays in the same way that they happened in the past. That is to say, the plants have the same characteristics everywhere and at all times. For 3-5 phase, students start to look at patterns in nature to understand that the laws of nature are universal. In the middle school, science learning focuses on measurements and observations to conclude the consistent patterns of the events in the natural system. At high school, science knowledge is based on justifying natural laws as consistent throughout different phases of time. Therefore, the eight understandings of NOS are embedded in NGSS context with age-appropriate grade level outcomes and are based on Duschl and Grandy's versions of NOS perceptions (2013) as demonstrated in the table 2.

Table (2): Eight Understandings of NOS in NGSS based on Duschl and Grandy's versions of NOS perceptions

Eight understandings of NOS in NGSS	1- Different methods are used to carry out scientific investigations
	2- Empirical evidence is a base for scientific knowledge
	3- New evidence affect the review of scientific knowledge
	4- National phenomena are explained using scientific models, laws, theories
	5- Science is a way of knowing
	6- Scientific knowledge is consistent in natural systems
	7- Science is a human endeavour
	8- Science addresses inquiries about the natural and material world

NGSS framework structure shows how the scientific content and NOS aspects complement science curriculum. Vázquez-Alonso et al. (2016) appraise NGSS structure due to the existence of cross-cutting concepts and features associated with scientific and engineering practices. NGSS responded to the global calls to help students acquire an adequate understanding of the nature of science and scientific knowledge (NGSS: Appendix H, 2013). Students need to acquire sophisticated knowledge of NOS aspects to have a proficient understanding of science content and its processes (Krell, Koska, Penning & Krüger, 2015; Clough, 2011; Çil & Çepni, 2016; Khishfe & BouJaoude, 2016; Vázquez-Alonso et al., 2016). The only way to achieve this is by having a well-structured curriculum which places a huge emphasis on connecting NOS aspects to science content knowledge.

NGSS framework for K-12 science education announces in its statement the importance of the NOS. It was designed to allow students to learn the intrinsic values of science.

The integration of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas places nature of science at the heart of the teaching and learning process. Such emphasis on observations, hypothesis, inference, and theories enable students to understand what is meant by NOS. They shall be acquiring scientific literacy skills through being indulged in experimentations and observations. The process of collecting evidence allow students to become systematic and logical. NGSS is designed to explain the natural world in accordance with the formation of evidence-based scientific explanations.

In particular, the scientific and engineering practices engage students in learning opportunities to understand how the natural world functions. Hodson (2014a) states that the content of science curriculum has to incorporate features of science such as methods and history, to be able to teach NOS explicitly. Teachers can be inspired by the ideas presented in the scientific and engineering practices to design authentic experiments for their students.

Going back to the structure of NGSS document, it offers four progressive foci K-2, 3-5, middle school, and high school. Each Performance Expectation (PE) is divided into three foundation areas: (a) science and engineering practices, (b) disciplinary core ideas (DCI's), and (c) crosscutting concepts. A specific content is designed for each one of the four progressive learning schools. The eight understandings of the NOS in NGSS represents the NOS Matrix in the NGSS (NGSS: Appendix H, 2013). The first four understandings are associated with the scientific and engineering practices whereas the last four are associated with the crosscutting concepts (NGSS: Appendix H, 2013). Such integration allows students to use evidence to provide explanations, to observe how the entire universe operates, and to develop models based on their proposed theories. As a result, they develop to become scientifically literate.

The group of designers of NGSS were mainly scientists with a broad interest in education rather than science teachers (McComas & Nouri, 2016). Thereby, there was a wide inclusion of crosscutting themes. While some scholars consider NGSS an asset to strengthen NOS elements, McComas & Nouri (2016) consider NGSS a big disappointment for several reasons. First, NOS aspects are spread throughout the document without dedicating one clear specific section for NOS. Secondly, it may be perceived that the embeddedness of NOS in the practices and crosscutting themes minimized their importance. Thirdly, NGSS authors kept NOS as a separate document, Appendix H. Adding to all of what is stated, McComas & Nouri (2016) recommend a "wholesale revision of NGSS" (p.559).

Supporting McComas and Nouri (2016) claims, a recent study was conducted by Wilcox and Lake (2018) about teaching elementary students the aspects of the nature of science. They pointed out that NGSS is an insufficient document for students to develop a deep understanding of NOS. Despite the fact that NGSS has science and engineering practices, yet it does not provide clear guidelines for teachers to train their students to act like scientists. Wilcox and Lake (2018) state that referring to NGSS Framework only is not enough to develop an adequate understanding of NOS aspects. Neither NGSS curriculum Framework nor the NGSS appendices provide a clear idea about scientists thinking habits and the construction of scientific knowledge (Wilcox and Lake, 2018).

2.3 Theoretical Framework

Lederman's Conceptualization of NOS Model, Vygotsky's Social Cognitive Theory, and Theory of Change are the three corners that ground the theoretical framework of this research study as presented below.

2.3.1 Lederman's Conceptualization of NOS Model

Lederman's conceptualization of NOS model is the theoretical model underpinning this research study (Lederman, 2007a; Lederman et al., 2002; Lederman & Lederman, 2014). This model is supported by several associations (AAAS, 1993; The National Association of Science Teachers: NSTA, 2003; NRC, 1996; NRC, 2000; NRC, 2005; NRC, 2013) and is integrated with the new science framework documents within the Next Generation Science Standards (NGSS) (NGSS Achieve, 2013).

Lederman's model of NOS aspects has seven main aspects. First, observations and empirical evidence are used to make scientific claims; however, science does not rely solely on them. Theories are subject to change based on new evidence, current knowledge, and future investigations. Second, observations provide evidence that is tangible using the five senses, while inferences state facts that are not obtained using the senses. Third, laws and theories are different, whereby theories are inferred from explanations but laws are supported by many sources of strongly reliable evidence. Fourth, creativity and imagination result in the generation of scientific knowledge. Fifth, science is subject to the different interpretations of scientists yet it maintains its objectivity. Sixth, science influences and is influenced by the cultural and social factors. Seventh, there are various methods that a scientist can use to carry on scientific investigations.

The first aspect is the empirical nature of scientific knowledge. Scientists conduct a vast amount of experiments to observe natural phenomena. The data collected from the observations is the starting point for scientific investigations. Observations and experimental evidence are used to propose a scientific claim. Although empirical evidence is vital, science does not rely solely on it. Consequently, experimental evidence and observations support rather than prove scientific claims.

The second aspect is the perspectives of current science –inferences and observations– which are relied on heavily. Scientists write hypothesis to direct their investigations and experimentations. The perception of the scientists and research guide both observations and inferences to generate a hypothesis. Additionally, hypotheses in science may lead to either theories or laws. While observations are descriptive statements about natural phenomena, inferences are statements indirectly concluded about them. Although multiple perceptions contribute to valid multiple interpretations of observations, all interpretations are logical and true.

The third aspect is the nature of scientific theories and scientific laws. To start with, a theory is an inferred explanation for a natural phenomenon or/and a mechanism for a relationship among natural phenomena. A scientific theory is based on a set of assumptions. On one hand, it generates research problems and on another hand, it guides future investigations. For instance, a law describes consistent relationships among observable phenomena in nature. Certainly, theories and laws are different kinds of scientific knowledge. Clearly, they are distinctly and functionally different types of knowledge.

The fourth aspect is the creative and imaginative nature of scientific knowledge. Scientific knowledge is created by scientists who use creativity and imagination throughout all stages of scientific investigations: (a) planning and investigating, (b) experimenting, (c) making observations, (d) analysis of data, (e) interpretation of results, (f) reporting the results, and (g) drawing conclusions. The investigations completed by any scientist is influenced by their beliefs, expectations, innovation, and previous knowledge. Additionally, the production of scientific knowledge is affected by the mindset of the scientist. Creativity inspires the scientist to experiment various scientific processes and to draw a conclusion.

The fifth aspect is tentativeness. Scientific knowledge is neither absolute nor certain. Scientific knowledge changes due to either new evidence or new ways of looking at existing evidence. The development of investigations, inquiries, and interpretations of data is filtered through the lens of current theories. Scientific knowledge is affected by new observations or/and the reinterpretations of existing observations. To be more precise, all other aspects of NOS provide a rationale for the tentativeness of science.

The sixth aspect is the social and cultural embeddedness of scientific knowledge. Science is a human endeavor. It is influenced by the traditions, values, and principles of the society in which it is practiced. The beliefs of the culture determine how science is interpreted, conducted, and what makes it accepted. This subjectivity is unavoidable, yet, it enables science to progress and remains consistent. Peer review limits subjectivity and presents differences in data interpretations. Hence, science is a combination of subjective and objective components and is interrelated science with culture. Society both influences and is influenced by science. Therefore, both social and cultural values impact scientific knowledge.

The seventh aspect is the scientific method. Scientists use distinct procedures to lead to functional solutions. Scientists observe, compare, measure, test, and hypothesize to formulate theories. Though they all use those procedures, they may follow different paths. There is no universal scientific method. In other words, scientific methods are various and diversified. Table 3 presents Lederman Model of NOS aspects.

Table (3): Lederman Model of NOS Aspects (Lederman et al., 2002)

Empirical Nature of Scientific Knowledge	• Scientific claims are based on observations • Scientific knowledge does not rely solely on empirical evidence • empirical evidence supports but does not prove scientific claims
Theoretical Entities, Observation, and Inference in Science	• Observations are descriptive statements about natural phenomena • Inference are statements indirectly concluded about natural phenomena
Scientific Laws and Theories	• scientific theroies are based on a set of assumptions • scientific theories generate research problems and guide future investigations • Scientific laws are phrases describing relationships among observable phenomena
Imaginative and Creative Nature of Scientific Knowledge	• Generating scientific knowledge invloves imagination and creativity • Scientists work is influenced by beliefs, previous knowledge, experience and expectations • Production of scientific knowledge is subject to the mind set of the scientist
Cultural and Social Embeddedness of Scientific Knowledge	• Social and cultural elements impact scientific knowledge
Scientific Method	• Various scientific methods can be used by scientists as stepwise procedures to lead to functional solutions • Scientists observe, compare, measure, test, and hypothesize to formulate theories
Tentative Nature of Scientific Knowledge	• Scientific knowledge is neither absolute nor certain • Scientific knowledge is reliable and durable

The NOS aspects of Lederman's conceptualization model allow the construction of students' epistemic knowledge. The epistemic knowledge of students is the intrinsic value of construction of science (NRC, 2013). At this developmental stage, middle and high school science students are engaged in lively discussions to distinguish between observations and inferences, scientific laws and theories, and the characteristics of scientific knowledge. Certainly, students' ability to conduct investigations, to analyze critically and to follow systematic approaches is shaped up by means of exploring NOS aspects in science classes. Thus, the domains of Lederman's theoretical framework are suitable for the age group of the population of this research study represented by middle and high school students.

2.3. 2 Vygotsky's Social Cognitive Theory

Given that science is a human endeavor, one needs to take into consideration the social context that is best described by Vygotsky's Social Cognitive Development Theory. The overarching aim of the study is to shed the light on the cognitive development of students' conceptions of NOS in an inquiry-based instruction setup which makes room for social interaction. Society contributes widely to the individual development. Vygotsky (1978) argues that social interaction precedes the development of human competencies. Cultural beliefs as well as students' attitudes have an impact on the way learning takes place. Culture is one of the tools of intellectual adaption which allows students to use their cognitive abilities to adapt to the culture in which they live. Researchers have been drawing directly on Vygotskian Social Cognitive Theory in their science learning studies (Hodson, 2008; Leach, Hind & Ryder, 2003; Musante, 2005; Wells et al., 1990).

Human knowledge is constructed as a process. People encounter practical experience as they undergo various setups within social communities. Knowledge is built rather than passively absorbed. Humans create new knowledge based on observations occurring in the course of time. The social, economic and political arena where knowledge is available allows individuals to gain social cognitive knowledge. Similarly, the interaction within groups allows individuals to create meaning.

Social transformations have had a major influence on education. Students' negotiations with learners represent different learning opportunities for students. Students combine and compare their personal beliefs, attitudes, and knowledge to enhance learning. Cooperative, collaborative, and reflective learning allows the interchange of ideas and the production of knowledge. Designing learning opportunities focused on grouping students together creates argumentations. Thus, the construction of knowledge happens as a result of social interactions. The social construction of knowledge happens when students collaborate with other community members (Richardson, 2003), hence, knowledge goes with the world views that individuals hold (Kemp, 2005). Students acquire new knowledge by fitting new information together with prior knowledge. The beliefs and attitudes of the learner, as well as the social experiences, suggest how humans construct knowledge and meaning.

People construct their own understanding of the real world (Phillips, 1995; Driscoll, 2000; Oliver, 2000) based on personal experiences and reflections on those experiences (Olusegun, 2015). In the discourse of teaching, the teacher assesses the students' pre-existing knowledge to build on what they already know (Oliver, 2000; Mvududu & Thiel-Burgess, 2012); hence, the learning process doesn't become a passive transmission of information from the teacher to the students. Vygotsky states that a child's mind is inherently social in nature (Amineh & Asl, 2015).

Social interaction allows the development of thoughts in the light of what individuals experience in their everyday life. Thoughts develop from society to the individuals (Amineh & Asl, 2015; Vygotsky, 1986; Bailey & Pransky, 2005). Culture and social interaction have a deep impact on learning and knowledge (Mvududu & Thiel-Burgess, 2012; Amineh & Asl, 2015). Thus, according to Vygotsky, cognitive development is a function of cultural, historical, and social interaction.

Social constructivism is the joint perception of collaborative social interaction and context in social constructivism (Applefield, Huber and Moallem, 2000). It represents the modern perceptive of constructivism combined with the social interaction and the cultural role for the cognitive growth of leaners. In the construction of knowledge, learners interact with their surroundings and other people before their knowledge is internalized. Woolfolk et al. (2010) presented the four major social constructivist views based on Vygotsky: (a) Social Constructivist View of Learning, (b) Social Constructivist View of teaching, (c) Social Constructivist View of the learner, And (d) Social Constructivist View of the teacher.

Social constructivist view of learning is the construction of knowledge a collaborative process among a group of people. Woolfolk et al. (2010) states that meaningful experiences allow students to understand and learn. The interactions with each other and with the environment they live in allow individuals to make meanings. The learner starts to take daily decisions based on the experiences that he had in the past. The interactions that happens within the school and in daily life situations results in knowledge construction. The collective experiences provide a harmonic learning process. In specific, Vygotsky (1978) believes that learning is a continuous process were as the learner's intellectual level improves to reach the closest point to the learner's potential. The human mental activity is a particular case of social experience (Amineh & Asl, 2015).

Social constructivist view of teaching considers the teaching approach as a major factor that allows collaboration among learners. It stresses on the need for collaboration among learners and on the society's practical experiences. The teaching approach has to include practical learning opportunities to involve learners in practical experiences. It has to be structured to allow students to collaborate, communicate and discuss. Those opportunities create a platform among students to share personal ideas, to discuss real-world challenges, and to develop a sense of belonging. Hence, students interacts to build their own learning blocks.

Social constructivist view of the learner stresses on allowing learners to create their own version of the truth based on their own background, experiences, and culture. Learners cannot create their own perceptions if they are dictated by the teachers all the time. They need to try to do things by themselves. Conducting experiments in a self-directed manner develops various skills and competencies. Besides, the background shapes up the truth that the learner attains in the learning process. Young children develop their thinking abilities through interaction with other human beings, living things, and the physical world.

Social constructivist in the view of the teacher, emphasizes teachers to act as a facilitator rather than an instructor providing knowledge. Teachers have to design student-centered learning opportunities. Prior to the lesson, the teacher authors a plan for the lesson, whereas students work together during the lesson to master the learning outcomes. In particular, the teacher needs to display a completely structured set of guidelines to draw the roadway for learners to draw their own conclusions. Students have to do all the investigations to justify the hypothesis while the teacher monitors their progress. The teacher could interfere to provide support and to redirect the thoughts of the students. As a facilitator of learning, the teacher uses continuous interactive dialogues until the learning targets are achieved. Thus, the learning environment challenges learners to be effective thinkers.

The social development theory introduces two major principles of cognitive development. First, cognitive development is limited to a certain range within the age group of the individual. Each individual has a potential to develop their skills and competencies. This potential varies from one individual to the other. However, individuals within the same age group are expected to share common abilities according to their physical and mental developmental age. Second, cognitive development is subject to the social interaction which results in establishing its full development. Individuals are tightly connected to the social world and the cultural values of the surroundings where they live. Their ideas are constructed based on the standards set by their societies. The interactions between learners and other members of the community shapes up the construction of knowledge.

Social interaction, cultural influences, and the real world experiences are the main providers of an individual's knowledge acquisition. The focus of this study aims to investigate the impact of a combined explicit reflective NOS and inquiry-based instruction, which relies heavily on the theoretical perceptions of Vygotsky's social cognitive theory that envisions collaboration and communication as the basis of learning. Vygotsky argues that a child's development has to be considered in conjunction with the external social world constituting the child's life (De Valenzuela, 2002). A child is a social being who seeks a sense of belonging and participating of society. Students learn best through social interactions which shape their cognition and hone their skills. In this context, students become indulged in a combined explicit reflective NOS and inquiry-based instruction context in science lessons. The designed learning opportunities allow students to come up with their own explanations for natural phenomena. Oakes and Lipton (2003) believe that students are little scientists eager to explore and to investigate in a self-directed manner.

2.3.3 Theory of Change

The Theory of Change (ToC) is a specific way to guide the work of community-based initiatives that aim to detect the factors that have an impact on certain performances. In 1995, the Theory of Change was developed by Carol Hirschon Weiss. His concept of grounding a theory of change aims to specify "how and why the program works" (Weiss 1995, p.65). ToC focuses on mapping out "what" an intervention does and "how" it results in desired achievements. It requires a layout for the expected sequence of outcomes as a result of an intervention, a plan for the evaluation strategy to determine whether the expected outcomes are achieved or not, and a set of assumptions to clarify the steps of the intervention in relation to the performed activities and the desired outcomes.

The Theory of Change processes are fourfold: (a) an outcomes framework, (b) a set of assumptions, (c) a set of interventions, and (d) a set of indicators.

To begin with, the researcher has to define all the necessary pre-conditions required to bring out a given long-term outcome. Those definitions clarify the framework of the early and intermediate outcomes that shall take place prior to the attainment of the long-term outcomes. Those conditions stand for the mandatory requirements needed for testing the usefulness of the intervention. For instance, this study aims to investigate the impact of a combined explicit reflective and inquiry-based instruction on middle and high school students' conceptions of nature of science. The outcomes framework is: (a) explicitly integrating NOS aspects with science content, (b) using the inquiry-based instructions to deliver science content, and (c) using reflective journals to allow students to express themselves. The intervention constitutes of all of those three components happening simultaneously to evaluate the combined effect on students' perceptions of NOS aspects.

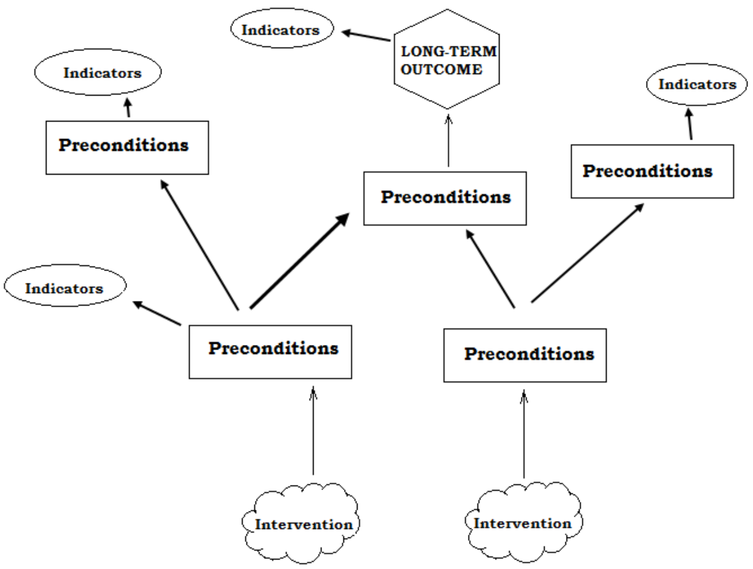
Secondly, the outcomes of each stage are defined and considered as preconditions for the stage that follows. The set of assumptions paves the way for the development of the outcomes by providing various justifications. As a priority, it connects the various outcomes that might be obtained in the course of action. In the second place, it sets forth the group of end results as the sufficient and necessary pre-conditions for the target attainment. In the third place, it gives grounds for the end results throughout the course of the study. In the fourth place, it articulates the obstacles in the environment that might prevent the achievement of the long-term goal.

Next, the researcher is required to articulate assumptions about the change process. Those assumptions outline the environmental factors, connections among long-term and early outcomes, and justifications to support the links between outcomes and intervention plan. This link allows the creation of the concept map that clarifies the pathway of the researcher throughout the phase of data collections.

Lastly, in regards to the target population, amount of change required to guarantee success, and the timeline over which a change is expected to happen have to be defined. In particular, time and change are directly proportional. Change needs time. The amount of time dedicated to witness a certain change has to take into consideration many elements such as:

(a) the mentality of the people who are required to change, (b) the social and cultural factors, (c) the resources available to support the change, and (d) the readiness for the target population to embrace the change. Thus, the time indicator clarifies the degree of the favorable outcomes to be articulated. On the other hand, humans are resilient to change. Some people tend to be more receptive to new practices and new ideas while others feel uncomfortable to try to learn something new when they are proficient in what they used to do. Consequently, some people tend to accept to change more than others. Thus, the target population should be specific to clarify with whom this intervention may provide successful outcomes. Figure 1 demonstrates the elements in a pathway of a change.

Figure (1): Elements in a pathway of a change by Weiss (1995)



Weiss (1995) considers ToC as “a theory of why and of how an initiative works.” Stein and Valters (2012) state that research, based on the guidelines of the Theory of Change, allows the lived experiences of practitioners, research studies, and empirical investigations to generate a hypothesis. Consequently, a designed intervention based on the theory of change principles is easy to sustain due to the clearly defined ideas behind its desired outcomes and needed resources.

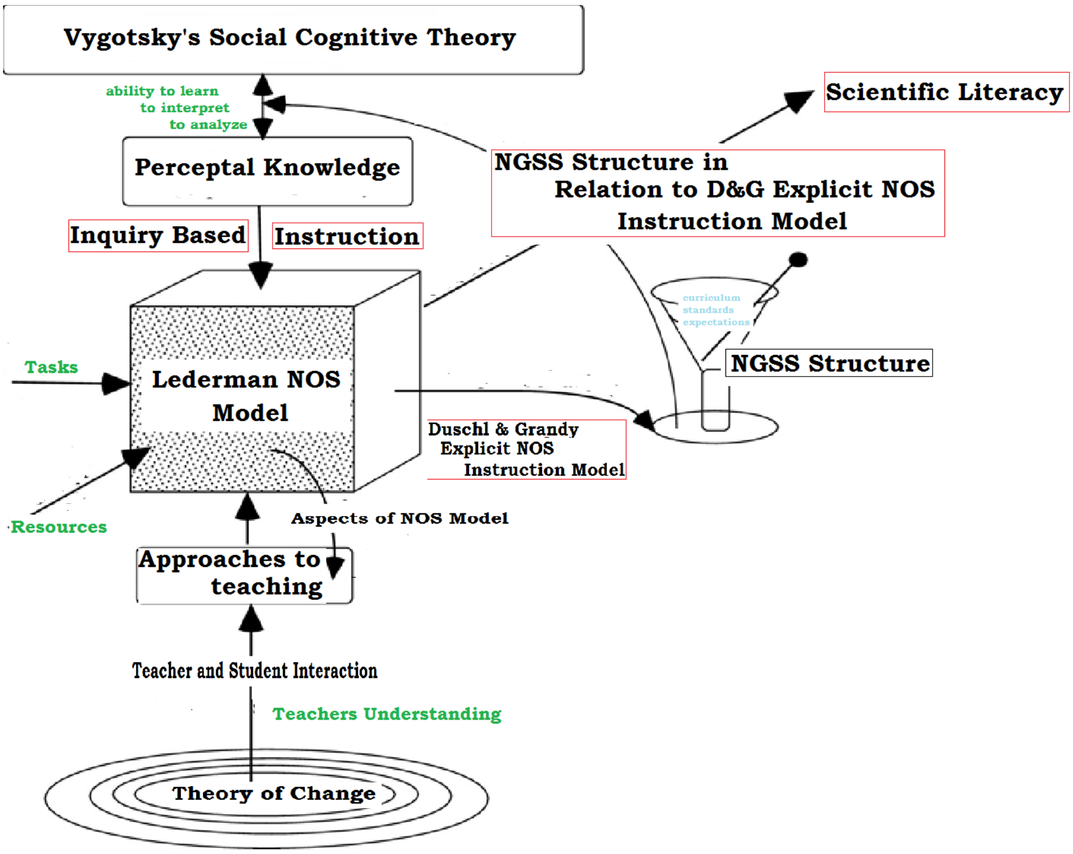
The Theory of Change provides an example of how combined factors result in a single desired outcome. It clarifies the relationship among articulated assumptions, designed intervention, and required outcomes. As a matter of fact, this research study adopts ToC approach to specify the outcomes framework, a set of assumptions, a set of interventions, and a set of indicators. The combined explicit reflective NOS and inquiry-based instruction intervention shall be aligned with the Theory of Change to identify all the pre-conditions that must be in place to have informed NOS conceptions and scientific literacy among middle and high school students. In conclusion, all the phases of this study are to be designed based on TOC model to measure accurately the amount of change in students' conceptions of NOS over a specific time period for a specific target population which might result in successful outcomes.

The models and theories presented in the conceptual and theoretical frameworks are inter-related. Primarily, the relationship between them is neither linear nor concentric. Both of them, the Theory of Change and Vygotsky's Social Cognitive Theory, support Lederman NOS model in creating an authentic foundation for the designed intervention. The Theory of Change provides a complete series of details to define the intervention program. Teacher understanding, teacher-student interaction, and the approaches to teaching NOS aspects combine together to form the intervention program. All the indicators, pre-conditions, and intervention elements were defined as per the criteria set by the guidelines of theToC.

From a different angle, Vygotsky's Social Cognitive Theory supports the use of inquiry-based instruction to allow for the interaction among learners, hence develop an adequate understanding of the content knowledge. Its ethos was reflected in the resources, tasks, and learning opportunities designed by science teachers to deliver NGSS curriculum.

Specifically, here the conceptual and theoretical frameworks intersect at more than one point. NGSS structure emphasizes the urgency of using an approach that allows for experimentations and reflections to develop the perceptual knowledge. Moreover, NGSS structure in relation to Duschl and Grandy Explicit NOS Instruction Model stresses on explicitly linking NOS aspects while doing science. Hence, it relates to Lederman NOS Model in conjunction with Vygotsky's Social Cognitive Theory to develop NOS perceptions. In a broader context, the development of NOS perceptions results in the strong formation of scientific literacy skills. As shown in Figure 2, the relationship between the theories and models that underpin this study is multidimensional. They are tightly connected. Lederman NOS model outlines in its structure the eight understandings of NOS in NGSS. Those understandings are the base of NGSS structure. Besides, Duschl and Grandy Explicit NOS Instruction Model connect the aspects of NOS as the approach to deliver. To sum it up, there is neither a central loop nor an external loop to demonstrate the relationship among the theoretical and conceptual framework. Figure 2 below demonstrates the multidimensional relationship between the theoretical framework and the conceptual framework.

Figure (2): Theoretical and Conceptual frameworks



2.4 BODIES OF RELEVANT LITERATURE

Based on the extensive review of literature, five major themes emerged as a body of the literature section. First, a broad section is dedicated to discussing the scientific ways of knowing whereas science, nature of science, and scientific literacy are its three building blocks (Ramnarian & Chanesta, 2016; Tala and Vesterinen, 2015; Bello & Adedoyin, 2017). In the second consideration, the NGSS structure is explained in details to provide a clear idea about the science curriculum. In the third place, the views about NOS aspects are presented with two subtitles: teachers' views about NOS aspects and students' views of NOS aspects. The views of parties involved in the teaching and learning process are essential for understanding the causes of the current status about NOS aspects (Sarieddine & BouJaoude, 2014; Hacieminoglu, 2016; Leach, 2006; Cil and Cepni, 2016; Vazquez-Alonso et al., 2016). Fourth, the approaches to teaching NOS are presented in the absence of an absolute agreement on one single approach to teach NOS aspects (Cil, 2014; Hacieminoglu, 2016; Schussler et al., 2013). On top of all mentioned approaches, implicit teaching approach was widely studied (Forawi, 2010; Justice et al., 2002; Spronken-Smith, 2012; Ortiz, 2015). Then, the explicit teaching approach was advocated for (McComas, 2004; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004), and as an extension to the explicit teaching approach, the explicit-reflective teaching approach (Lederman & Lederman, 2014; Bloom et al., 2015) and the explicit reflective inquiry-oriented NOS instruction approach (Abd-El-Khalick, 2013; Bou Jaoudi et al., 2011) were investigated. Finally, the issue of the existence of the gender gap is discussed, according to the literature, there are many factors that contribute to the existence of a gender gap (Dennisen et al., 2007; Goetz, 2007; Krapp, 2002; Bhanot and Jovanovic, 2009; Kumari and Saraladevi 2014).

2.4.1. Scientific Ways of Knowing

Science is a field of study to uncover all the natural phenomena and its components. Science is a body of knowledge (Abimbola, 2013; Bello & Adedoyin, 2017) that encounters all the conscious activities that aim to discover and understand nature. Bello and Adedoyin (2017, p. 1) define science as:

> "Science has since the dawn of civilization been a potent tool for finding solutions to the never-ending human problems, or at least, help man to manage his challenges well (p.1)."

Science is a way of knowing as a combination of observation and reasoning by logic. Its building blocks are the empirical observation, the replication by other scientists, and the logical explanations. Science, being a way of knowing, is dependent on unbiased and verifiable information to make valid decisions about our natural world. Science is a combined set of historical accumulation of knowledge and practices (NGSS: Appendix H, 2013). A human being needs science to find solutions for daily issues, to manage the real world challenges, and to resolve dilemmas.

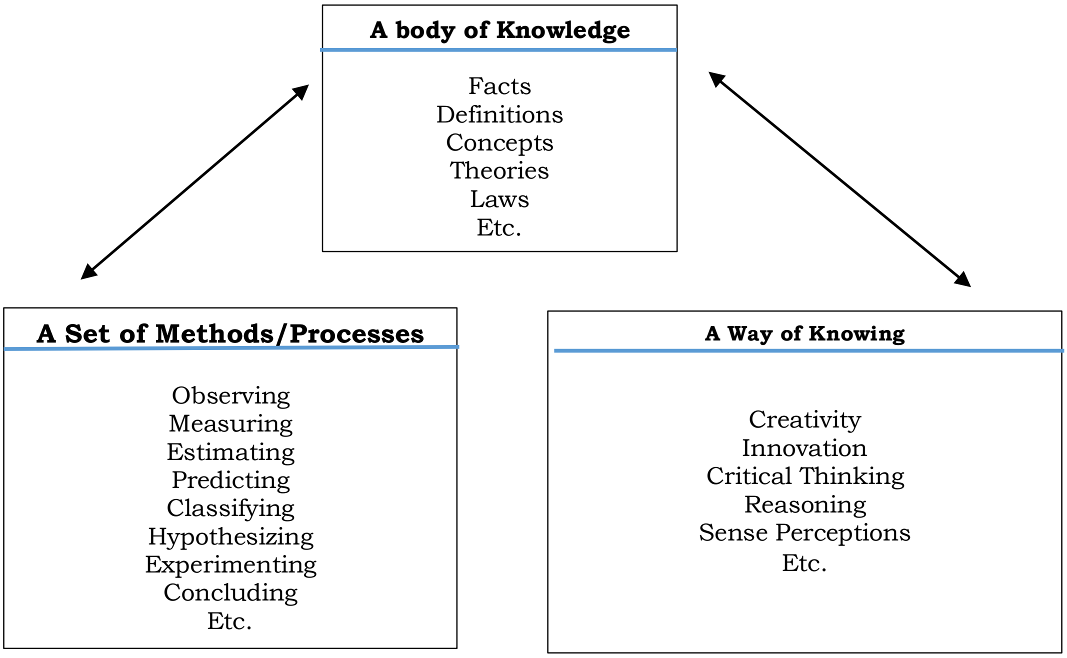
Science is an absolute human venture (Leung et al. 2015), despite the wide usage of the word "science", everyone interprets a different meaning. Science is a body of knowledge based on collected data from a set of methods. Fouad, Masters & Akerson (2015) value science as a way to transform collected data into assumptions, connections, and interpretations. Etymologically, as stated by Kanu (2015) "science is derived from the Latin word SCIENTIA which means knowledge". It is a systematically comprehensive discipline that constitutes of three interrelated components a body of knowledge, a set of methods/ processes, and a way of knowing. Nowadays, science is becoming embedded in every facet of the real world in an increasingly futuristic implementation with technology in the globalized world.

First, as a body of knowledge, science aims to explain things, to state facts, and to define specific terminologies. Essentially, the laws and theories are trusted as they were tested and judged by the factual outcomes from empirical evidence. The scientific explanations operate within the constraints of available evidence from experimentations. In this sense, science exhibits a large degree of objectivity in handling the data to explain the phenomena of the physical world. Inevitably, science is a theoretical explanatory discipline which objectively provides concepts, facts, theories, and laws. Science is a potent tool for finding solutions to the ever-changing problems as a field of study with no borders.

Secondly, science seeks to explore the occurrences in the real world. In this context, science is a set of processes to collect data. Various methods are used to carry investigations and collect empirical data. Observing, measuring, estimating, classifying, hypothesizing, and predicting are the main components of the scientific processes. Further explained, the observation of natural phenomena provides empirical data about the topic. Measurements give accurate information about the objects being tests. Estimations provide a rough calculation of a value to judge its value. In science, a prediction is a rigorous conjecture stating if something might happen under specific conditions. Classifications provide a system of sorting for things that share the same characteristics. Moreover, hypothesizing is the suggestion of a certain explanation for a specific phenomenon. It is used to put forward a guess or the foundation for a new theory. It is considered a temporary solution in the absence of a complete set of empirical evidence to create a theory. In addition, experimentation is used to test existing theories, to support or disapprove new hypotheses, and to show how a particular process works. New ideas are tried out through performing experiments. Conclusively, concluding is the art of explaining the results using key facts. It provides a brief explanation of whatever has been discovered.

Finally, science is a way of knowing. The process of developing a new theory is a logical procedure based on four major components: (a) scientific knowledge is based upon evidence, (b) creativity plays an important role in science, (c) scientific knowledge can change over time, and (d) background knowledge influences how scientists view data. Whether the process of deduction or induction is used, there have to be patterns of reasoning to derive universal conclusions. Data is collected anecdotally to lead a close examination of the required phenomena to formulate a hypothesis. The critical assessment of the facts provides high credibility for the generalizations stated in science. Thus, the data collection results in several conclusions which aim at constructing theories and laws. Figure 3 demonstrates the three components of science.

Figure (3): Science threefold



There are two classifications created by science educators. The first classification considers science as a purely academic discipline based on a discrete scientific method. This classification presents science as a mere set of topics. It presents science as just a disciplinary subject taught at school without any relevance to real-world. It is a set of facts that were established after being tested. The second classification considers science as tentative and open in nature in which subjectivity is accepted. Considering both classifications, it is evident that all the characteristics of science are encapsulated in the nature of science. Although science is viewed differently by scientists at a certain level of generality there is a common perception about science. For the purpose of this thesis, the definition of science is derived from the following definition from Bickmore and Grandy (2007, p.1):

> "Science is the modern art of creating stories that explain observations of the natural world and that could be useful for predicting, and possibly even controlling, nature."

2.4.1.a Nature of Science

NOS goals have been the century-long targets in many science curricula. These targets have not been successfully achieved at any level of education (Karisan & Zeidler, 2017; Ramnarian & Chanetsa, 2016; Vazquez-Alonzo et al., 2016; Kampourakis, 2016) . While some treat NOS as a single dimension construct (Bell & Linn, 2000; Wenning, 2006), others consider it a multidimensional construct (Chen, 2006a; Lederman et al., 2002). Nature of science, just like science, has undergone changes in compliment to the gradual development of science (Abd-El-Khalick and Lederman 2000). Despite the explicit statements about the meaning of NOS, many definitions are contrary to one other. Many scholars have defined "Nature of Science (NOS)" (Lederman, 2007a; Abd-El-Khalick, 2013; Forawi, 2014), and all definitions share common elements but each definition identify with one single aspect of NOS. Studies in the previous three decades focused on the significance of the understanding nature of science (Abd-El-Khalick et al., 1998; Akerson, Abd-El-Kalick & Lederman, 2000; Akerson & Hanuscin, 2007; Akerson, Hanson & Cullen, 2007; Duschl & Grandy, 2013; Duschl & Wright, 1989; Lederman, 1999; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Lederman et al., 2003; Lederman & Lederman, 2014; McDonald, 1996; Schwartz et al., 2002; Schwartz, Lederman & Crawford, 2004; Shanahan & Nieswandt, 2011; Smith & Scharmann, 2008). Concepts of NOS are ever dynamic. Scientists and educators agree to disagree on the meaning of the nature of science and its fundamental concepts. Even though NOS has many facets, at a certain level of generalization, there is a shared perception among all science educators about it. Bearing in mind the variety of definitions, all of them agree on the basic aspects of NOS. Nature of science is commonly referred to as the epistemology of science (Ramnarian & Chanetsa, 2016; Fouad et al., 2015; Wolfensberger & Canella, 2015;

Lederman, 2006) and the beliefs inherent to the development of scientific knowledge (Muslu & Akgul, 2006; Vazquez-Alonzo et al., 2016).

Historically, for over 60 years, a dominant topic in almost all research studies is the conceptions of nature of science in science education (Abd-El-Khalick, 2004; Abd-El-Khalick, 2012; Duschl & Grandy, 2013; Lederman et al., 2003; Ramnarian & Chanetsa, 2016). There are two classifications created by science educators. In 1998, McComas et al., described NOS as the intersection zone of issues addressed by the history, sociology, philosophy, and psychology of science (p.5). Simultaneously, Abd-El-Khalick et al. (1998) consider NOS as the value system embedded in scientific knowledge. Furthermore, definitions were authored using the examined aspects of NOS. Nature of science has been defined as the inherent processes to develop scientific knowledge (Akerson & Donnelly, 2010), the core value of science (Kruse & Borzo, 2010), and the guiding book of how science works (Hanuscin and Lee, 2009).

Nature of science is the epistemology of science focusing on science as a way of knowing. Huang, Wu, She, Lin (2014) state that NOS is the epistemology of science whereas the values and beliefs inherent to scientific knowledge and characteristics of scientific knowledge. The model is referred to nature of scientific knowledge or nature of science. The use of nature of science and nature of scientific knowledge as NOS is confusing (Hodson, 2014b). Lederman, Antink & Bartos (2014) state that NOS stands for nature of scientific knowledge. It is clear, NOS has multi-universal accepted definitions (Erduran & Dagher, 2014); however for the purpose of this study, NOS is defined based on Abd-El-Khalick et al. (1998) definition:

> "…virtually no disagreement among historians, philosophers and science educators. . .are that scientific knowledge is tentative (subject to change); empirically based (based on and/or derived from observations of the natural world); subjective (theory-laden); partly the product of human

inference; imagination and creativity (involves the invention of explanation); and, socially and culturally embedded (p. 418)."

Between Norman Lederman and Richard Duschl, there is a strong debate about the difficulties in addressing the abstract nature of science views with K-12 students. Both scholars agreed on the following attributes of NOS to be the basis for the scientific community as stated by Lederman et al. (2002, p.515): "(1) scientific knowledge relies heavily, but not entirely, on observations, experimental evidence, rational arguments, and skepticism, (2) observations are theory-laden, (3) science is tentative/fallible, (4) there is no one-way to do science and hence no universal, recipe-like, step by step scientific method can be found, (5) laws and theories serve different roles in science and hence theories do not become laws even with additional evidence, (6) scientific progress is characterized by competition among rival theories, (7) different scientists can interpret the same experimental data in more than one way, (8) development of scientific theories at times is based on inconsistent foundations, (9) scientists require accurate record keeping, peer review, and replicability, (10) scientists are creative and often resort to imagination and speculation, and (11) scientists' ideas are affected by their social and historical culture (p.515)".

While no singular consensus definition for NOS exists (Abd-El-Khalick et al., 2008; Coburn, 2004; Irez, 2009), researchers (Lederman, 2007a; Lederman and Lederman, 2014) do agree to specify the NOS aspects that include: (1) nature of scientific knowledge, (2) inferences, (3) scientific theory, (4) scientific theories and laws, (5) creativity in science, (6) subjectivity, and (7) social and cultural influence.

Conceptions of NOS are multifaceted, ever dynamic, and complicated. Those conceptions witness continuously various transformations throughout the development of science. Therefore, the approach used to develop the conceptions of NOS has to be active, adjustable and systematic. NOS is a fundamental goal of science education (Kampourakis, 2016), hence has to be taught in a challenging content (Karisan & Zeidler, 2017). The essence of NOS is to make people understand scientific endeavors with little acquisition of scientific knowledge. Besides, the individual's conceptions of NOS has been reflected in their beliefs about scientific knowledge whether it is tentative, empirically based, affected by human creativity, or socially and culturally embedded (Lederman & Zeilder, 1987). Hence, for the purpose of this study, NOS is a discipline that deals with the epistemology of science, science as a way of knowing, or the beliefs that underpin the development of scientific knowledge Lederman (1992).

2.4.1.b Scientific Literacy

Scientific literacy is a golden goal of science education. A common feature of all communities is promoting students' understanding of science (Forawi, 2010). Scientifically literate individuals are able to analyze information, to generate hypothesize, and to discover solutions for problems that have yet to be resolved globally as a worldwide primary goal (Roberts, 2007; Lederman, Antink & Bartos, 2014; Leung, Wong & Yung, 2015). Scientific literacy does not only entail having knowledge of the content and methods of science, but it means the acquisition of knowledge about the nature of science. Hodson (2014a) insists that scientific literacy has three aspects (a) learning of science, (b) learning to do science, and (c) learning about science. The sum of the knowledge of scientific inquiry and the nature of science equates to the scientific literacy (Bell et al., 2012; Wolfensberger & Canella, 2015). On one hand, the nature of science outlines the epistemological fundamentals of the activities of science, and on the other hand, scientific inquiry describes the developmental process of the scientific knowledge. Ramnarian & Chanesta (2016) consider the understanding of NOS and the scientific literacy as two inseparable components. The acquisition of scientific literacy necessitates the emphasis on understanding the nature of science (Sarrieddine & BouJaoude, 2014; Lederman, 2006).

Science education aims to promote scientific literacy (Wolfensberger & Canella, 2015; Laugksch, 2000; Tala & Vesterinen, 2015). The possession of a thorough understanding of scientific concepts makes an individual scientifically literate and able to make informed decisions about societal and personal issues (NRC, 2013; NSTA, 2003) that makes informed life decisions, forms judgments, and decides about the quality of the scientific claims (Serdar Köksal & Tunç Şahin, 2014; Forawi, 2010). Therefore, a scientifically literate person is expected to make informed decisions about scientifically-based issues, to weigh the claims and evidence, and to compare the characteristics to the nature of science aspects (Lederman, Antink & Bartos, 2014; Wolfensberger & Canella, 2015; Lederman, 2007a). Forawi (2010, pp.9) states:

> "Scientific literacy generally aims to provide students with a broad foundation of scientific knowledge, skills, and understanding to be able to live in an increasingly scientific and technological world (p.9)."

Scientific literacy is the ability to apply scientific knowledge in different situations, to evaluate knowledge in different contexts, to evaluate spoken and written texts, and to use the language of science for interpretation. It aims to provide students with scientific knowledge foundations (Forawi, 2010; Forawi, 2011; Forawi & Liang, 2011) and to prepare them to make decisions as informed citizens regarding scientific and social issues (Torres et al., 2015; Smith et al., 2013; Serdar Köksal & Tunç Şahin, 2014; Forawi, 2011)

The accessibility of K-12 students to the seven aspects of NOS (a) tentativeness, (b) empirically based, (c) subjectivity, (d) imagination and creativity, (e) social and cultural, (f) observation and inferences, (g) laws and theories allow them to become scientifically literate (Lederman, 1999; Lederman, 2007b). Designing scientific experimentations allow the development of scientific literacy skills. Skills are acquired through observing the natural phenomena not through studying the facts related to those phenomena. The accessibility of students to learning opportunities designed based on the seven aspects of NOS develop the desired scientific literacy skills in a natural way.

Krajcik and Sutherland (2010) suggest five principles to support students in developing scientific literacy. The five strategies are: (a) connect new concepts to prior knowledge and experiences, (b) anchor learning in meaningful questions derived from the daily life experiences of students, (c) connect multiple representations, (d) design learning opportunities to use science ideas, and (e) motivate students to be engaged with the discourses of science.

The first principle is linking new knowledge to prior knowledge through engaging students in inquiry-based activities. Prior knowledge forms the basis for all subsequent learning. When the concepts are explained in a disconnected manner, students assume that they are abstract and challenging. Consequently, concepts become disconnected from everyday life experiences. Middle and high school students fail to understand science content knowledge unless the science instructions become explicitly linked to students' pre-acquired knowledge (Krajcik and Sutherland, 2010). Prior knowledge can either be in the form of real-world experiences or in the form of previous learning. Proper understanding is constructed if the designed learning opportunities are designed to connect ideas.

The second principle is articulating meaningful questions derived from the daily life experiences of students. The instruction used in the science classroom is expected to support students' exploration of natural phenomena. Questions focused on connecting concepts to their lives motivate students to invest time and effort to understand difficult material. Even though questioning strategies could encourage students, the complex sentence structures with complex scientific terminologies are challenging. Students experience science every day without the knowledge that it is science. For instance, the concept of chemical reactions sounds obsolete unless students know that it is related to tearing when peeling an onion and various colors of fireworks. Students listen attentively to the teacher when real life examples are brought into science lessons.

Questions serve the purpose of redirecting students' concentration to important details pertinent to the explained concept. Designing instructional strategies using various questioning techniques illustrate for students how scientists develop their inquiry thoughts. Thus, they start to analyze critically and to differentiate between what is known and the unknown. In conclusion, questioning plays a major role in science-content learning, supports the development of literacy skills for science learning, and engages students in scientific-inquiry practices as scientists.

The third principle to develop scientific literacy is to be able to use functional elements such as maps, graphs, models, diagrams, and simulations. The combined effect of texts and graphics allow the development of scientifically meaningful argumentations. In particular, middle school students understand better when models and mind maps are used. The enormous amount of information related to one phenomenon is better comprehended when modeled to show the back and forth relationship between the elements. Currently, the age of ubiquitous technologies provides many visual, auditory, and tactile interactions. Students develop a better understanding when they see animated videos that demonstrate a certain phenomenon such as kinetic energy theory. Even though visual representation is vital to developing scientific literacy, the ability to read texts and representations remains the most important among all.

The fourth principle is making sense of ideas. The learning opportunities in the science class have to provide students with guidelines to apply science concepts to new contexts.

The materials and instructions need to open students' eyes to make sense of the classroom and everyday experiences using science. Students have to critique, articulate, and extend their understanding of science by resolving confusing situations and creating solutions for newly emerging problems. The tasks and questions sequence stimulate students' brains to think about the application of scientific ideas to phenomena not experienced in science class. Once the reasoning and interpretation abilities are developed, students become able to generalize further to new situations.

The fifth principle to develop literacy in science is engaging students in the discourses of science. Students need to become familiar with the language of science and its practices. They need to speak and write about science, to read a science text and comprehend its meaning, and to practice supporting their ideas with data and evidence. They become engaged in inquiry setup once they compose written explanations, organize data to defend, and make arguments to support a conclusion. Moreover, the precision of the words used to explain phenomena provides meaningful justifications. The selection of words is important in the discourse of science. The language used, the conclusion drawn, and the ideas put together provides a different form of engagement in science. To explain a phenomena, a scientist uses evidence to support assumptions, illustrates reasons from available evidence, and employs the language of science to draw a conclusion. Whether oral or written communications are used, science inquiry depends on the validity of data as an evidence for justification and explanation. Students have to be taught to pay attention to the evidence to support claims, to the way an evidence is used, and to the appropriateness of the evidence. They have to know whether or not the evidence is accurate to support a claim.

Scientific literacy can only be built on understanding scientific principles and concepts, engaging in literacy practices such as investigation and designing instructional strategies based on the integration of literacy practices and inquiry science education (Krajcik and Sutherland, 2010).

Although all practices stated above can't guarantee that students pursue careers in scientific fields, it allows students to become capable of reading science-related materials throughout their lives. It is imperative that science reformers support students in writing, reading, and communicating in science as a priority. Hence, those students become the cable of taking proper decisions as members of the society. In short, being scientifically literate is using science content and practices in the real world.

2.4.2 NGSS Structure

The process for the NGSS development focused on the significance of having the scientific and educational research communities to specify the core ideas and articulate them across grades. The National Research Council (NRC, 2011) started with constructing a Framework for K-12 Science Education to ensure validity and accuracy. Eighteen experts in science, engineering, cognitive science, teaching and learning, curriculum, assessment and education policy formed a team to author the Framework. This Framework consists of interrelationships among practices, cross-disciplinary concepts, and disciplinary core ideas. The NRC released a draft for public feedback during the summer of 2010 and the final report was released in July 2011. Achieve, an independent, nonpartisan, nonprofit education reform organization and one of the partners in NGSS, facilitated the next step. It is a state-led process where state policy leaders, higher education, K-12 teachers, science and business community among others developed science standards in the Framework. Furthermore, all stakeholders had multiple opportunities for public feedback, review, and discussion.

NRC released the framework for the NGSS in 2011 (NRC, 2011). NGSS curriculum was established based on the premise that learning is continuous and progressive. It is designed to help young learners to build and to revise their innate, acquired knowledge, and abilities starting with their curiosity and initial conception on how the world works. Bybee (2011) stated that practitioners began to ask about the reasons that justify the shift from scientific inquiry to science practices. Supporting Bybee claim, Osborne (2014) stated that scientific inquiry outlined in NGSS structure is one form of scientific practice. McComas & Nouri (2016) stated that although NGSS has three prominences, yet, there is no prominence for NOS.

NGSS concentrates on a limited number of core ideas in science and engineering within and across the disciplines. It also focuses on learning science and engineering with the integration of content knowledge and practices needed to engage in scientific inquiry and engineering design. Strengthening the engineering aspects of NGSS clarify for students the relevance of science, technology, engineering and mathematics (STEM) to everyday life. Cogger & Miley (2013) specify that the curriculum design which promotes enjoyment, challenge and hands-on learning for students allow them to apply the math and science knowledge in engineering learning. The interconnections of the four STEM fields are indicated in the three dimensions of the foundation box, namely, Scientific & Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. These dimensions are based on the Framework published by the National Research Council (NRC, 2012).

The NGSS outlines the main practices to guide the scientific inquiry process which gives teachers a clear picture of what scientific literacy is about. Tan and Leong (2014) insist that the design of the science curriculum has to raise a generation that is scientifically literate. According to them, a scientifically literate learner is one who has good literacy skills, sound decision-making skills, knowledgeable of how the world works and has mental and physical strength.

NGSS design connects performance expectations to engineering, scientific engineering practices and nature of science. Even though NOS does not exist independently as a prominence but the connections to science topics are either listed in the crosscutting connections section or the practices section of the foundation box. McComas & Nouri (2016) recommend a wholesale revision for NGSS framework to include NOS aspects explicitly rather than embed them within sections.

For each domain, the NGSS structure consists of the title, performance expectations, the Foundation Boxes and the Connection Boxes.

The title for a set of performance expectations is not necessarily discrete and they are interchangeably used at other grade levels. Below the title, a collection of performance expectations are listed describing what students should be able to do at the end of the instruction. The performance expectations are combined practices, core ideas, and crosscutting concepts which are used to describe how students can show what they have learned. A clarification statement under each performance expectation is indicated to provide examples or additional clarification to the given performance expectation. The assessment boundary is also found after the clarification statement and it provides guidance about the scope of the performance expectation at a particular grade level. The asterisk (*) affixed in some performance standards indicates engineering connection where the given performance expectation integrates traditional science content with engineering through a practice or core idea.

The next box is called the Foundation box and is composed of three dimensions: Scientific & Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. These three were taken from the Framework for K-12 Science Education that was used to form the performance expectations in NGSS. The first dimension, namely, Scientific & Engineering Practices lists the activities that scientists and engineers engage in to either understand the world or to solve a particular problem. The second dimension called Disciplinary Core Ideas is a list of concepts in science and engineering that have broad importance within and across disciplines as well as relevance in people's lives. Lastly, the Crosscutting Concepts are ideas that are not specific to any one discipline but interdisciplinary. The Connections to Nature and Science are also listed in either the practices or the cross-cutting connections section of the foundation box.

The last box in NGSS is the Connection Box. This includes the practices elsewhere in NGSS or in the CCSS that have connections to the performance expectations on the particular page. Codes for performance expectations are also noted. Every performance expectation has a unique code and items in the foundation box and connection box reference this code. In the connections to the Common Core State Standards, italics indicate a potential connection rather than a required prerequisite connection.

2.4.3 Views of NOS aspects

The teaching and learning process is absolutely dependent on teachers and students. Together they create an authentic learning environment. Teachers write the planning for the lessons and they execute those plans with students. Students are trained by their teachers who set the expectations for the learning targets. Students are receptors of knowledge and creators of self-directed learning. For that reason, to evaluate the status of NOS understanding a meticulous evaluation of the literature related to the student's and teacher's views of NOS has to be made. Thus, this section includes two parts. The first part focuses on teachers' views of NOS. The second part focuses on students' views of NOS.

2.4.3a Teacher's Views of NOS

Early research studies (Anderson, 1950; Barufaldi et al., 1977; Riley, 1979) concluded that teachers acquire an inadequate understanding of NOS. As McComas et al. (1998) boldly state that teachers have the central role of providing an in-depth discussion about science and all its aspects yet they do not acquire appropriate conceptions of science and its nature. Supporting his claim, Lederman et al. (2002) emphasize the role of teachers in explaining how science operates. Khishfe (2012) considers the dynamics of the learning environment created by the science teacher as the main factor to develop strong argumentation skills and adequate science learning. In this respect, the lack of an adequate NOS understanding prevents teachers from using inquiry questioning techniques (Castle & Ferreira, 2015). All the stated factors are dependent on the teacher's ability to create authentic synergies and to reflect their thorough understanding of NOS aspects. Conclusively, there are many gaps in strengthening scientific literacy skills as a result of deficient teachers' understanding of NOS aspects.

Science programs do not have clear representation of NOS (AAAS, 1989; AAAS, 1990; AAAS, 1993; NRC, 2013). Even the most recent NGSS curriculum framework lacks the explicit explanation of NOS as an independent prominence (McComas & Nouri, 2016; Wilcox and Lake, 2018). This creates a heavy burden on teachers. Specifically, they have to identify NOS aspects related to science content knowledge and at the same time, they have to design learning opportunities. Sarieddine and BouJaoude (2014) believe that all teachers need to possess appropriate knowledge of the aspects of NOS prior to teaching NOS. Teacher's understanding of NOS is reflected in their explicit or implicit teaching of NOS in the classroom. Lederman (2007a) insists on the necessity of teachers to have a solid understanding of NOS to be able to teach the model. Teachers need to be proficient in their understanding of NOS aspects to better explain it to students. For instance, if the teacher considers science a pure presentation of scientific facts without knowing how those facts evolved, then the teacher relies on this message to the students in the class. Consequently, students consider science merely a set of facts. Teachers have to know how scientific knowledge is constructed (scientific method, observations, empirical evidence, tentativeness), what factors affect the construction of scientific knowledge (cultural and social influence, creativity), and why scientific knowledge is in continuous evolution (certainty, theory-laden). Teachers have to start looking at NOS aspects as a primary component of science learning. They have to use those aspects as the base for designing plans for science lessons. NOS is not an optional component in science learning, on the contrary, it is the fundamental catalyst to acquire proficient scientific literacy.

There are five major indicators of a meaningful science teaching that focus on how teachers translate their scientific knowledge into a meaningful science learning experiences (Hunter & Sampson, 2015). The teacher has to start with creating a need for learning. This can either be achieved by making the content relevant to students or by challenging them. Secondly, teachers must model thinking in front of students. As a result, students start imitating their teachers. Thus, they develop logical thinking skills based on a cognitive model by the teacher. Thirdly, teachers have to design activities to optimize students to analyze, predict, critique, and conclude. Thus, students are able to explore the content at the heart of experimentation. The fourth indicator urges teachers to indulge students in the practices of science. In this perspective, the NGSS framework includes scientific practices to provide students with various opportunities to conduct various investigations. Teachers derive from those guidelines learning opportunities to allow students to obtain, to critique, and to communicate information by motivating them to conduct research, to give a presentation, and to draw conclusions (Hunter & Sampson 2015). Lastly, teachers are expected to train students to validate the data. Students need to become able of knowing what counts as evidence in science, how to evaluate the validity of explanation, and how to transform data into evidence.

Teachers who have a solid understanding of NOS aspects are masters of guiding their students' effort to become scientifically literate. Bloom, Binns, and Koehler (2015) consider the improper guidance of students' scientific literacy and NOS understanding as a logical result of the teacher's lack of understanding of NOS. The teachers' conceptions of NOS are dynamic and continuously changing (Lederman et al. 2002). Their knowledge influence their science instruction in the class either directly or indirectly. The type and quality of science instructions are affected by teachers' conceptions of NOS (Bencze et al., 2006; Lotter et al., 2007). Specifically, teachers with desired views of NOS develop this desire in their students (Keys & Bryan, 2001; Bencze et al., 2006).

Since the content knowledge has to be taught in the science education program, NOS aspects have to be definitively presented and discussed. Scholars have identified many factors that hinder teachers from successful teaching of NOS in science classrooms (Sarieddine and BouJaoude, 2014; Vázquez-Alonso et al., 2016; Bloom et al., 2015). Bell, Lederman &Abd-El-Khalick (2000, p.565-566) list four factors that have an influence on teaching NOS in science classrooms: NOS is perceived less significant than science content, prioritization of class management, routine chores, and lack of resources. Concurrently, Bartholomew et al. (2004, p.677) list the five main reasons which prevent teachers from teaching NOS in science classrooms: lack of training, exam preparation, lack of time, confidence in teaching NOS, and focusing on content rather than the process. First, the lack of training inhibits teachers from knowing the techniques that allow them to integrate NOS aspects with science content knowledge. Vázquez-Alonso et al. (2016) insist on the need of including NOS topics in science teacher preparation courses. Training enables teachers to become familiar with practical ideas to plan their lessons and to deliver the content in a successful way. Second, schools are pressuring teachers to focus only on students' attainment in international benchmark assessments. In particular, in Lebanon, all schools demand high success rates in official exams to maintain good reputations and to attract more students. Such a demand makes teachers prioritizing marks without paying attention neither to the quality of learning nor to the approach used to deliver the content to the students. Third, time affects the quality of teaching as well as the depth of the explanation of science topics. Teachers are under a lot of pressure to finish all lessons as planned in their yearly plans. They need to follow specific key steps to stay on time throughout the academic year. Thus, time is a major burden that prevents them from delivering lessons in relation to various aspects such as NOS. Four, the lack of confidence in NOS aspects makes teachers hesitant to teach it. When teachers are ill prepared about any topic, they tend to avoid introducing it with their students. Their lack of knowledge of NOS aspects prevents them from drawing connections between science content knowledge and NOS aspects. Finally, the focus on content knowledge rather than on the process of delivering this content prevents students from building their skills and competencies. Teachers want their students to understand and to have solid knowledge about specific content. Thus, they tend to use direct teaching approaches to deliver the learning objectives on time.

2.4.3b Students' Views of NOS

Students' understandings of NOS was examined and investigated by many scholars (Cil & Cepni, 2016; Muslu & Akgul, 2006; Akerson & Abd-El-Khalick, 2005; Kang, Scharmann & Noh, 2005, Wilcox and Lake, 2018). The results of those studies consistently indicated that students possess a naïve understanding of NOS (Torres et al., 2015; Lederman et al., 2002; Vazquez-Alonso et al., 2016). The experiences that they have had throughout science learning did not show them how NOS is related to scientific knowledge. Students consider NOS aspects as an independent entity which has no relation to scientific discipline.

A huge amount of research was conducted on students' conception of NOS in the last 80 years. In 1954, Wilson (1954) conducted a study using an instrument called Science Attitude Questionnaire with a sample of 43 high school students in Georgia, USA. He concluded that students believe that scientists' goal is to discover natural laws; whereas, scientific knowledge is complete. In 1957, Mead and Metrawx conducted a nationwide study with 35,000 students to assess their NOS conceptions using qualitative methodology. Their conclusion was in agreement with Wilson (1954). Later on, Klopfer and Cooley (1963) developed the Test on Understanding Science (TOUS). They concluded that high school students acquire an insufficient understanding of science and its enterprise. Consequently, Mackay (1971) conducted a study using TOUS with 1,203 Australian secondary students. Again, his findings confirmed the inadequacy of NOS understanding. So many similar findings resulted from studies conducted to investigate students' perceptions about NOS by Liang et al. (2006) using Student Understanding of Science and Scientific Inquiry (SUSSI), Celick & Bayrakceken (2014) using VNOS-C developed by Abd-El-Khalick & Lederman in 2000, Van Griethuijsen et al. (2015) using an open-ended questionnaire, Getahun et al. (2016) using an open-ended questionnaire, and Forawi (2014) using Early Nature of Science Instrument (ENSI). Despite the variety of the used instrumentations, all conclusions pointed out a deficiency in NOS misconceptions among students.

In alignment with past studies, Akerson and Abd-El-Khalick (2005) conducted a mixed method study with a sample of 23 Grade four students over a period of one year in the United States of America (USA). The results of this study indicated that students held misconceptions about various aspects of the NOS. The used tool was "Views of Nature of Science-Form B (VNOS-B)". Besides, Kang, Scharmann & Noh (2005) also conducted a mixed method study with 1702 Grades six, eight, and ten students in Seoul, Korea. The results indicated that an absolutist perspective of the NOS is possessed by the majority of Korean students. The used tool was “Views-on Science-Technology-Society (VOSTS) developed by Aikenhead, Ryan, and Fleming. The results again showed that most of the students held naïve views regarding few aspects of NOS. The used tool was the “Perspectives of Scientific Epistemology (POSE) questionnaire developed by Abd-El-Khalick in 2002.

It is evident, based on all the presented research and among other studies, the lack of proper understanding of NOS aspects among students exists. Students are predominantly experimenting with their teachers to understand the science topics, but teachers are not relating such practices to NOS aspects. Students learn how theories evolve from one era to another due to various factors such as new evidence, technology, and scientists’ findings. They have yet to know how creativity allowed scientists to discover scientific laws and theories. Teachers have to draw the students’ attention to the strategies that scientists use to draw conclusions and to model the various scientific methods that can be used to carry out experimentations. Questioning and dialogues can be used to teach NOS alongside science content. Teachers have to seek any possible opportunity to address NOS ideas while teaching science content knowledge. Students need to be guided to think and share their thoughts. Unfortunately, students have not had the opportunity to understand that those are the fundamental components of NOS.

Many scholars insist that understanding NOS enhances students’ learning activities (Sandoval & Marrison, 2003; Lederman, 1992; Lederman et al., 2003) and the way they understand scientific concepts (Leach, 2006; Hacieminoglu, 2016). Thorough understanding of NOS motivates students to participate in decision-making processes and to connect applied technology and science as active learners. Concepts of NOS learned in science classes offer a solid basis for sensing the limitations and tangibility of knowledge.

Therefore, understanding NOS enlarges the students' scientific curiosity (Leach, 2006; Matthews, 2000). Consequently, this provides concrete case studies demonstrating the dynamics of theory evaluation as well as the nature of scientific reasoning. Thus, NOS is a vital component of scientific reasoning and a center of attention of science educations (Hwang, 2015; Ramnarain & Chanetsa, 2016; Leung et al., 2015). Acquisition of NOS understanding empowers students to be scientifically educated, to understand the role of science in their own societies and cultures, and to increase their ability to acquire science content material (Bloom, Binns & Koehler, 2015). Yacoubian and Khishfe (2018) insist that informed views of scientific knowledge allow students to use argumentation to support claims by evaluating evidence.

Understanding NOS means relying on skills to comprehend scientific knowledge and science. Students become capable of participating in democratic decision-making. Teaching students the development and characteristics of scientific knowledge allows them to break up stereotypic views of science. NOS shows the boundaries of science and reveals science as a human enterprise restricted by cultural and historical conditions. The knowledge of NOS allows students to envision science as a "continuous process of concept development, an interpretive effort to determine the meaning of data, and a process of negotiating these meanings among individuals" (Roychoudhury 1994, p.90).

2.4.4 Approaches to Teaching NOS

A deep understanding of NOS aspects positively affects the students' problem-solving strategies and scientific reasoning (Lin & Chiu, 2004; Sadler et al., 2004). For that reason, many current pedagogical strategies arise to teach explicitly NOS aspects using generic NOS activities (Michel & Neuman, 2014; Abd-El-Khalick, 2013; Brase, 2014; Jenkins, 2013). Students can establish an authentic access to NOS once NOS and science concepts are meaningfully interwoven.

Even though global scholars (Abd-El-Khalick, 2013; Bloom et al., 2015; Çil & Çepni, 2016; Griethuijsen et al., 2015; Khishfe & BouJaoude, 2016; Lederman, Antink & Batros, 2014; Vázquez-Alonso et al., 2016; Wolfensberger & Canella, 2015) are emphasizing to teach NOS aspects, many studies (Akerson, Morrison & McDuffie, 2006; Celik & Bayakceken, 2006; Ibanez-Orcajo & Martinez-Aznar, 2007; Çil & Çepni, 2016) concluded that the approaches used in schools to teach science are not providing students with informed contemporary views of NOS. Various approaches have been discussed to introduce NOS aspects such as modelling, contextualized NOS instruction (Michel & Neuman, 2014), NOS-oriented metacognitive prompts (Peters 2012), guided and explicit approach (McComas, 2004; Khisfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004), and explicit reflective approach (Khishfe, 2008; Kucuk, 2008; Akerson, Hanson & Cullen, 2007). For instance, contextualized NOS instruction can be realized through open or guided inquiry, class discussions, and hands-on-activities (Akerson et al., 2010; Clough, 2006). Research supports, conceptual change approach has shown more effectiveness than explicit reflective inquiry-oriented approach (Cil & Cepni, 2016).

There is an inadequate understanding of NOS (Çil & Çepni, 2016; Miller, 2006) among students in general. Many studies have investigated the perceptions of students about NOS aspects (Krell, Koska, Penning & Krüger, 2015; Biernacka, 2006; Huang, Wu, She & Lin, 2014; Schussler et al. 2013; Çil, 2014; Koerber, Osterhaus & Sodian, 2015; Seckin Kapucu, Cakmakci & Aydogdu, 2015). Different interventions were considered to identify the most effective approach. Yet there is no absolute agreement on a single approach to teaching this subject effectively. However, there are three recommended approaches to teaching NOS: explicit reflective, historical and implicit. The effectiveness of various teaching approaches on students' understanding of NOS was widely investigated (Çil, 2014; Hacieminoglu, 2016; Koerber, Osterhaus & Sodian, 2015; Schussler et al., 2013; Seckin Kapucu, Cakmakci & Aydogdu, 2015). Some scholars (Guerra et al., 2013; Hottecke, Henke & Riess, 2012; Clough, 2011) propose teaching NOS using historical cases and the history of science. In their study, Çil and Çepni (2016) identify three basic approaches for teaching NOS: implicit, historical and explicit reflective. Schussler et al. (2013) consider both inquiry-based and expository pedagogies as the two major pedagogies used for NOS learning.

The explicit approach has curriculum implications. It is neither a didactic nor a direct instruction model. It emphasizes on deliberately teaching NOS while teaching science content knowledge. The findings reported in reviews of literature (Akerson et al., 2000; Hanuscin et al., 2006; Kim et al., 2005; Khishfe & Abd-El-Khalick, 2002) indicate that explicit approaches to NOS instruction is effective in promoting an informed understanding of NOS. Wilcox and Lake (2018) conducted a study and stressed on the need to explicitly incorporate NOS aspects into a variety of activities to develop an adequate understanding of NOS. The explicit discussions revolving around NOS aspects supports students' natural creative potential to acquire a holistic perception of the various aspects of the nature of science. The reflective component added to the explicit approach aim to use structured or unstructured opportunities to encourage students to examine their science learning experiences. Scholars (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2006; Dagher et al., 2004; Lederman, 2006; Smith & Scharmann, 2008; Wolfensberger & Canella, 2015) consider the explicit-reflective teaching approach as the most promising way to teaching NOS. As for the implicit instructional approach, it aims to indulge students in experiences without providing direct reference to NOS aspects. Scholars state that this approach was generally not successful in improving students' conceptions of NOS (Schwartz et al. 2001; Sandoval & Morrison, 2003). Evidence from research in favor explicit approach rather than implicit approach to develop NOS conceptions (Abd-El-Khalick, 2001; Akerson et al., 2000; Khishfe and Abd-El-Khalick, 2002). Though explicit reflective is identified as the most effective approach (Allichin, 2014; Khishfe, 2008; Bloom et al., 2015; Lederman & Lederman, 2014; Wolfensberger & Canella, 2015), they recommend additional modifications to increase its effectiveness in developing students' conceptions of NOS. Interestingly enough, Yacoubian & Khishfe (2018) insist that the success of explicit NOS instructional approaches have been limited.

With this in mind, there are two major approaches to teaching NOS: Implicit teaching and explicit teaching approach. Below are two subsections to discuss each approach in relation to teaching NOS.

2.4.4.a Implicit Teaching Approach

Historically, inquiry-based instruction is a pedagogy developed during the era of the 1960s as a shift towards the discovery of learning. The theory that grounds this pedagogy is the constructivist learning theory developed based on the work of Piaget, Dewey, and Vygotsky as well as others. In the seventeenth century, Spinoza reported that knowledge is the acquisition of facts rather than the transmission of it. In the 18^{th} century, many philosophers (Dewey 1959, 1952) promoted the concept of "learning by doing". Influenced by Dewey, Inquiry-based learning (IBL) principles were established. IBL falls under the umbrella of inductive teaching and learning approaches. Prince & Felder (2006) have made an outstanding review of IBL in relation to inductive teaching and learning opportunities (ITLA). The learning process using an inductive teaching and learning approaches constitutes of four major steps: (1) students collect data from observations and experimentations, (2) gathering and studying of information related to the issue in light of the real world context, (3) generating procedures and guidelines, (4) establishing a rule or a conclusion. Thus, students start with examples to generate a rule. Inductive teaching and learning approach encompasses various methods such as discovery learning, problem-based learning, and inquiry-based learning (Prince and Felder, 2006). An inductive method is a student-centered approach (Kember, 1997; Spronken-Smith, 2012), a learning by doing approach (Gibbs, 1988; Healey & Roberts, 2004; Prince and Felder 2006), and a technique that develops self-directed learning skills. Weaver (1989, p.5) defines inquiry as:

> "The organizing approach will be conceptual inquiry-based instruction exercising the intellect to learn, use, test, and revise ideas, concepts, theoretical constructs, propositions and methodological principles in the active inquiry (p.5)."

The inquiry-based instructional approach is a type of experiential learning. Tairab & Al-Naqbi (2017) consider inquiry-based instruction as an engaging type of instruction that allow students to construct their own scientific knowledge and to find solutions to various issues. Consequently, learning takes place through personal and societal experience. The learner is engaged in questioning, investigating, and experimenting to make meaning. Social interaction is the main aspect of experiential learning as argued by Vygotsky. The inquiry is a multifaceted activity to develop the understanding of science and to activate the goals of scientific literacy (Forawi, 2010). Engaging students in experiments, predictions, and investigations allow them to understand the "how and what" of science. Learning opportunities designed to engage students in scientific investigations contribute to the development of the individuals' abilities and skills (Tairab, 2016). Using experimentations and hands-on activities in teaching a topic develop the knowledge and skills at the same time. Spronken-Smith et al. (2008) state that inquiry-based instructional approach is a pedagogy that enables students to experience the processes of knowledge creation. The learning is driven by questions to discover new knowledge. Whether inquiry-based instruction is in the form of a structured and guided activity or in the form of an independent research, the result is students become self-directed, skillful and lifelong learners (Lee et al., 2004; Spronken- Smith, 2012). Inquiry-based learning (IBL) is an instructional strategy that allows students to discover the knowledge through experiments, simulations, and investigations. Students in an inquiry-based learning environment develop their critical thinking skills to become life-long learners (Crismond, Gellert, Cain, and Wright, 2013; Dalimonte, 2013; Lazaros and Borman, 2013). They discover the concepts through experimenting. Glasser (2011) states that students are motivated and interested when they realize how the scientific laws explain real-world issues. Many scholars (Schwab, 1960; Herron, 1971; Banchi & Bell, 2008) developed various scales to divide inquiry into levels. Inquiry-based instruction engage students in practical experimentations to construct scientific knowledge (Cofré Santibáñez Jiménez Spotorno Carmona Navarrete & Vergara, 2018).

Confirmation Inquiry, Structured Inquiry, Guided Inquiry, and Open/True Inquiry define the four inquiry levels. The confirmation inquiry is a type of inquiry that relies heavily on the teacher. A teacher teaches the science topics, develops questions and learning opportunities, and guides students to draw conclusions. Students follow procedures, collect and record data, and draw conclusions to demonstrate learning. This type of inquiry is similar to the direct explicit teaching which specify each step for students. Students have little opportunities to be creative and innovative. They are dictated by their teachers. Students execute what is planned for them to do rather than being allowed to come up with their own plans to construct their knowledge. The structured inquiry is a type of inquiry that provides flexibility for students to design their own plans to carry out investigations. The teacher provides initial questions and outlines learning opportunities. Students formulate explanations of their findings, collect data and conduct experiments, and evaluate and analyze data. Even though teachers determine the type of the experiments but students have the freedom to use any scientific method to conduct the experiment. This type of inquiry develops critical thinking skills and logical reasoning. Various plans to carry out experiments could be used based on the abilities and interests of the learners. The guided inquiry is a type of inquiry that places students at the heart of their learning process. The teacher is required to provide the research questions only. Students have to design their own procedures, follow their own procedures to test the hypothesis, and communicate the findings. Thus, students become independent learners capable of develop lifelong learning skills. The open inquiry is a type of inquiry totally dependent on students. The teacher acts as a facilitator of learning. They support students to master the content knowledge without dictating them with any processes. Students have to formulate their own research question(s), design a procedure, communicate the findings, and drive their own investigative questions. This enable students to feel in total control of their learning journey. They tend to develop the sense of ownership of what they learn. This creates a sense of pride for the learners since the construction of knowledge was achieved based on their own efforts. Table 4 demonstrates the characteristics of the four levels of inquiry and specifies the teacher's role and the students' role.

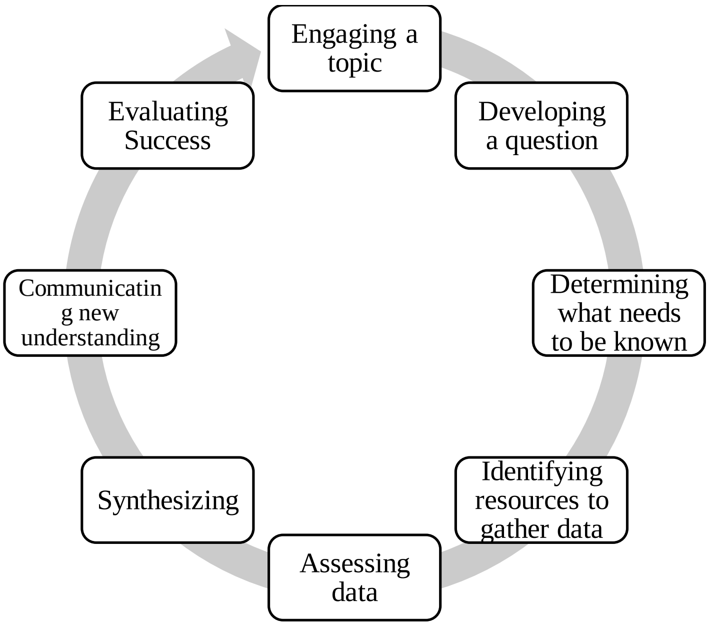
Table (4): Characteristics of the four levels of inquiry

Inquiry Type	Teacher Role / Students Role
Confirmation Inquiry	Teacher Role: • Teaches science topic • Develops questions and learning opportunities • Guides students to draw conclusions
	Students Role: • Follow procedures • Collect and record data correctly • Confirm and deepen understanding
Structured Inquiry	Teacher Role: • Provides initial questions • Outlines learning opportunities
	Students Role: • Formulate explanations of their findings • Collect data and conduct experiments • Evaluate and analyze data
Guided Inquiry	Teacher Role: • Provides research questions or hypothesis
	Students Role:

	• Design their own procedures • Follow their own procedures to test the hypothesis • Communicate the findings
Open/True Inquiry	Teacher Role: • Facilitate the learning process
	Students Role: • Formulate their own research question(s) • Design a procedure • Communicate the findings • Drive their own investigative questions

Science teaching is a process, thus, teaching through inquiry enhances students' understanding of NOS (Forawi, 2010). Spronken-Smith (2012) considers inquiry as a form of self-directed learning. It allows students to determine what they need to learn, to identify needed equipment to be used (Justice et al., 2002), to use resources and record results (Prince & Felder, 2006), and to assess the progress in learning (Justice et al., 2002). Thus, students become able to be analyze a topic, to initiate a question, to decide what information needs to be found, to collect data from various resources, to incorporate findings into discussions, to communicate findings with other people, and then to evaluate the success of the conclusion. As a result, inquiry leads to new interests and more questions. Justice et al. (2002, p.19) presented the model of the inquiry process in figure 4.

Figure (4): Model of the inquiry process

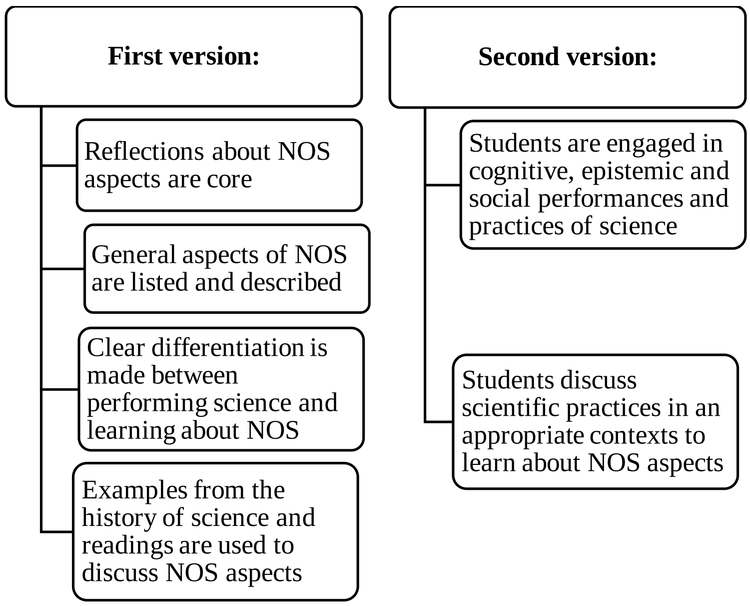


The implicit approach is the use of science-based inquiry and hands-on science activities to teach science without explicit reference to NOS. This approach does not regard NOS understanding as a sole learning product, rather NOS is considered as a secondary by-product. Students develop NOS understanding through exploring science concepts, principles and laws like scientists. The inquiry-based teaching approach is identified as an effective strategy for efficient NOS learning. Inquiry-based learning promotes students' NOS understandings (Moss et al., 2001; Bell et al., 2003; Sandoval & Morrison, 2003; Dagher et al., 2004; Schwartz et al., 2004).Scientific inquiry and NOS are inextricably connected. Implicit approach lacks specific attention to NOS but it includes isolated expressions inserted into instructional activities consistent with a specific view of science (Bell, Lederman & Abd-El-Khalick, 2000; Bell & Linn, 2000). Teaching science facts using lecture approach does not allow students to experience the tentativeness and changeable nature of science (Smith & Scharmann, 2008). Students need to experience and explore scientific knowledge to develop lifelong learning as a habit of mind.

2.4.4.b Explicit Teaching Approach

Explicit teaching consists of intentionally planned objectives, instructional strategies and assessments focusing on aspects of NOS. Explicit NOS teaching happens through guided reflections and specific question discussions. Wilcox and Lake (2018) conducted a study and stressed on the need to explicitly incorporate NOS aspects into a variety of activities to develop an adequate understanding of NOS. The explicit discussions revolving around NOS aspects supports students' natural creative potential to acquire a holistic perception of the various aspects of the nature of science. The teacher clearly states the science concept and connects the learning opportunities to specific aspects of NOS. Learning opportunities and model performance are designed to link the science content knowledge to specific aspects of NOS. Scholars (McComas, 2004; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004) are advocates of using guided and explicit approach to promote NOS aspects. Explicit and guided attention on NOS allows students to achieve deeper understanding of NOS (McComas, 2004; Schwartz et al., 2002) and a rich science education discipline (McComas et al., 1998). As described by Duschl and Grandy (2013), there are two versions of explicit NOS teaching as demonstrated in the figure 5.

Figure (5): Two Versions of Explicit NOS Teaching By Duschl and Grandy (2013)



The explicit teaching approach focuses specifically on various aspects of NOS without being associated with didactic or direct instruction. Wolfensberger and Canella (2015) state that an explicit teaching approach entails the inclusion of NOS learning outcomes in the instructional sequence. Hence, "explicit" has curriculum implications rather than instructional restrictions. Students' conceptions of NOS can only change when they explicitly discuss NOS themes in conjunction with science content knowledge (McComas, 2008; Clough, 2011; Allchin, 2014).

While "explicit" has curriculum implications, "reflective" has instructional implications (Wolfensberger & Canella, 2015). The reflective approach requires structured opportunities to allow students to be engaged in collaborative discourse about NOS aspects (Abd-El-Khalick, 2013; Nussbaum, 2008; Smith & Scharmann, 2008). Learning about NOS is intentionally planned while learning science concepts. The explicit-reflective approach is the most useful model for NOS (Lederman & Lederman, 2014; Bloom et al., 2015). The contextualization of explicit-reflective approach blends NOS with content knowledge (Bell et al., 2012; Clough, 2006; Matkins, Bell, Irving & McNall, 2002) while the de-contextualization leads teachers to view NOS as an add-on component which consumes the instructional time (Clough, 2006; Brickhouse et al., 2002; Bloom et al., 2015). Studies showed that a blend of both contextualized and decontextualized has the most impact on improving NOS understanding (Bloom et al., 2015; Clough, 2006; Abd-El-Khalick, 2001). Thereby, the explicit-reflective teaching approach is the most promising way to teaching NOS (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2006; Dagher et al., 2004; Lederman, 2006; Smith & Scharmann, 2008; Wolfensberger & Canella, 2015).

The explicit-reflective teaching approach can be associated with many pedagogies, however, inquiry-oriented pedagogy is commonly used to develop NOS literature among students (Khishfe, 2008; Akerson, Hanson & Cullen, 2007). Students are engaged in problematic situations by asking questions, investigating ideas, obtaining data, organization and analysis of information, and providing evidence-based answers to the problem situations. Inquiry-based activities are designed to focus on science content and relevant NOS aspects. Abd-El-Khalick, Bell & Lederman (1998) were the pioneers who introduced the explicit reflective approach. Later studies (Khishfe, 2008; Küçük, 2008; Akerson, Hanson & Cullen, 2007) supported this approach.

Historically, Abd-El-Khalick, Bell, and Lederman (1998) introduced the explicit approach in 1998. After which so many scholars (Akerson, Khalick, and Lederman, 2000; Khishfe and Abd-El-Khalick, 2002; Akerson, Hanson and Cullen 2007; Khisfe, 2008) conducted studies to investigate this approach further. They all concluded that explicit instruction means an intentional teaching of NOS in the classroom. Explicit instruction neither indicates a didactic strategy nor a direct instruction. It rather focuses on complex scientific theories, concepts, and skills as well as other elements related to NOS aspects. A wide variety of pedagogical approaches can be used to purposely integrate NOS with science content knowledge. The student-centered, integrated, disciplinary and subject-mattered center approaches are all possibilities that could be used to explicitly teach NOS. Despite all the options available to implement the explicit reflective approach, all the famous historical figures (Akerson Hanson and Cullen, 2007; Khisfe, 2008; Bou Jaoudi et al., 2011; Cil and Cepni, 2016) consider inquiry-oriented approach as the most beneficial. Among all reasons stated in various studies, one important reason is considering inquiry the backbone of science and the most efficient scientific instruction method.

Even though a variety of pedagogies can be used in explicit reflective approach, inquiry-oriented pedagogy is the most widespread (Akerson, Hanson & Cullen, 2007; Khishfe, 2008; Abd-El-Khalick, 2013). Students are educated about target NOS aspects using content-related inquiry activities. Abd-El-Khalick and Akerson (2009) identify the reflective component as a strategy that motivates students to investigate science learning experiences in an epistemological framework. Reflections encounter both oral and written expressions.

2.4.5 Impact of Gender on Views about NOS

In education, there are many factors that affect students' perceptions about the taught subjects in school. Some students tend to invest time and effort in the discipline area that they like while others need continuous support and encouragement. The perceptions that they develop is affected by their intellectual abilities, their intelligence, their interest, and their achievements. Scholars have conducted many studies to understand the complexities in the gender inequities to try to bridge the identified gaps. In specific, science have had a long history in trying to investigate the compatibility of females and males in science education. There seems to be a difference between females and males in their perceptions about science. Scholars (Bowers, 2007; Gopalsingh, 2010; Murphy, 2009; National Center for Education Statistics, 2012; Wagner, 2008) have conducted studies to investigate the achievement gap in science and they concluded that females and males possess different scientific knowledges and skills. In general middle school students conceptualize their ideas according to their relevance to context and social parameters. They investigate new ideas, analyze challenging problems, synthesis information and articulate knowledge. Their understanding of scientific facts is solidified when it is tightly connected with other area of interest which is different for each gender. Alfieri et al. (2011) state that the different genders master the concepts when they find target information is compatible with their interests. Males and females attain similar results in standardized tests when they are trained equally to analyze, synthesis and apply the abstract knowledge they learned to solve word problems. Many researchers such Allen (2007), Burton & Frazier (2013), Schmoker (2006) and Sheninger & Devereaux (2012) indicate that curriculum structure and instructions has the greatest impact on students' achievements and on bridging the gender gap.

With regards to gender inequities in education, it was inevitable that there is a difference in the differential interactions between teachers and girls versus teachers and boys. Sadker et al. (1991) concluded that teachers interact with boys in classroom discussions more than they do with girls. There is a gender gap in the level of engagement of learners in the classroom activities. Males and females don't interact in the same way when they are given specific tasks to do. The designed learning opportunities can either attract students to work or discourage them. While one single experiment might be appealing to females, it might be unappealing for males. The daily life interests of the two genders are different. Hence, the designed learning opportunities for female and male students have to be relevant to what they enjoy doing in their own daily life. Students invest time and effort to master a concept when it is presented using real-life problems. The learning opportunities have to be embedded in practical issues derived from students' daily life experiences (Kuh et al., 2008; Mireles-Rios & Romo, 2010; Marks, 2000). Boys enjoy exploring and trying out all options to draw conclusions, whereas girls seem more focused on how to please the teacher by following her key steps. Goetz (2007) states that girls tend to please adults while boys tend to be more motivated by resources that interest them. Science instruction often marginalizes females (Bianchini et al., 2003; Barton & Tan, 2010; Barton, 2002; Basu & Barton, 2007).

At the early years of study, boys and girls have comparable skills and knowledge. By the time they reach the middle and the high school the gender gap becomes noticeable and significant (Jones et al., 2000; Walper et al., 2013; Baran, 2016). Some high school girl's loss confidence in their academic abilities. Goetz (2007) states that more boys are graduating with science and math degrees than girls. There is an obvious domination for males in the nature of science fields (Baran, 2016; Osborne et al., 2003; Sainz, 2011). Many issues could be behind this undeniable fact such as the confidence in their scientific skills (Dennisen et al., 2007; Goetz, 2007), the interest in science (Krapp, 2002), and the amount of time devoted to improve scientific skills (Bhanot and Jovanovic, 2009).

Kumari and Saraladevi (2014) conducted a study to investigate the gender differences in attitude towards science learning. Their study concluded that there is a significant difference between the two genders. The gender gap is obvious in students' attitudes towards learning science. Girls tend to be less involved in the science classes. They tend to feel that they are incapable of achieving the learning targets. Many people in different societies believe that girls do not have the ability to understand the complexities of the scientific topics (Kumari & Saraladevi, 2014).

Teachers and parents play a major role in the gender stereotypes that have to be broken down to reduce the gender gap. Girls and boys have different learning styles. There has to be a flexibility in dealing with the individual needs of the two genders in the learning environment. The teachers should be versatile enough in order to handle these kind of situations and be prepared with a variety of activities that are best suited with the student. In the classroom, teachers tend to favor boys. Boys are challenged with critical thinking questions, asked to lead the investigations, and appraised for every achievement they make in science classes. Boys have an advantage to be selected to lead the experimentations. The fact that boys have better opportunities to perform makes girls invisible in the classroom (Kumari & Saraladevi, 2014). Equal opportunities have to be given to both genders to express themselves and to play an active role in the learning process. The teacher is required to vary the teaching approaches to include many methods suitable for the two genders. It is the teacher's responsibility to empower girls. Girls need to feel that science is within their reach. Specifically, girls come to the science class with a pre-assumption that science topics are very hard for them. Moreover, girls tend to work at their best when the lesson involves brainstorming, reading, researching and speaking. Hence, girls can maintain and even improve their performance in science once the appropriate approach is used. Boys, on the other hand, work at their best if they are engaged in collaborative learning experiences with their peers.

Apart from that, parents encourage their male offspring to develop a passion for scientific fields more than they encourage their female offspring. They have to model appropriate communication to boast the self-esteem of their female children to overcome any obstacle during their learning journeys. There has to be equity in raising up both genders in the societies otherwise the gender gap shall never vanish. Parents have to challenge their kids equally to get the best out of them. Equal access to education has to be given for all children regardless of their gender or social background. Parents have to believe in their kids and their abilities regardless of their gender. Engaging girls in critical thinking activities increase their situational and personal interests in science.

Taking a closer look at the specific domains of science, it is noted that the gender inequity varies. Kiran and Sungur (2012) found that males perform better in constructing scientific knowledge, females perform better in the special aspects of science, whereas there is no gender difference in dealing with life science. A closer look at the science disciplinary fields indicates that students are more interested in chemistry and biology than physics (Baran, 2016). Males are more interested in physics than females (Tsabari and Yarden's, 2010; Cobern and Loving, 2002, Adams et al., 2006). The most striking differences were found among science aspects related to the relationship between science and cultural and social values. Britner and Pajares (2006) state that the scientific passion of males is unlike females. The review of current research (Khishfe, 2004; Khishfe, 2008) suggested that explicit instruction with a combined instructional approach effectively improves NOS conceptions, yet none of the studies investigated that from the lens of gender.

Looking at the performance of middle school girls and boys in TIMSS, it is evident that there is a gender difference in the achievements (TIMSS, 2011; PISA, 2012). Various factors might be behind this gap. Peer pressure is one of the social factors. At the middle school, boys tend to start having a change in attitude and behavior especially if they start forming a group of friends. It is the responsibility of both the school and the parents to guide students with peer pressure. Another factor is the classroom behavior. If students are inattentive in class, it would be hard for them to understand the lesson and to actively participate in experiments. This problem is resolved through regular communication between male students, their teachers, and their parents to improve the behavior and personal attitudes. Improving students' behavior automatically lead to improving their study habits and performance in class.

2.5 Situated Literature

Forawi (2014) conducted a study to examine K-7th-grade students' concepts of nature of science. 70 students participated in the study and have experienced an explicit NOS teaching approach through guided inquiry science instruction. The study concluded that students' conceptions of NOS improved from pretest to post-test results. Even though young students possessed some knowledge of NOS aspects, explicitly teaching NOS improved participants' knowledge of NOS. This study refuted the idea of the inappropriateness of NOS concepts for young students. High school is not the only suitable place for the development of NOS (Forawi, 2014). Authentic science experiments complement the intentional teaching to articulate the meaning of NOS. This study stressed on the major barriers that hinder the proper development of students' scientific literacy skills such as science textbooks, professional development programs of teachers, and teachers' conceptions of NOS.

Forawi (2010) conducted a study to investigate the impact of using inquiry teaching strategy and incorporating the nature of science instructions to increase pre-service teachers' conceptions of the NOS. Teachers' views of NOS directly affect the science teaching process to develop students' perceptions of NOS. The study concluded that pre-service teachers' beliefs of NOS improved after explicitly integrating NOS aspects with the content and delivering it implicitly.

Vazquez-Alonso, Manassero-Mas, Garcia-Carmona & Montesano De Talavero (2016) concluded that the exclusion of NOS aspects in the curricula is a heavy burden that prevents teachers from developing students' conceptions and knowledge of NOS. While many scholars agreed that students have an inadequate understanding of NOS, Vazquez-Alonso (2016) used a quantitative approach to diagnose epistemological conceptions in a large sample in Panama which indicates that science education alone is inefficient to improve NOS understanding. In brief, the results of their study have set the ground for a reliable, informative and quantitative assessment to measure the conceptions on the epistemology of science in the field of NOS research.

Çil and Çepni (2016) investigated the influence of an explicit reflective conceptual change approach compared with an explicit reflective inquiry-oriented approach on seventh graders'. The authors concluded that explicit reflective inquiry-oriented approach is less effective than explicit reflective conceptual change approach in improving NOS conceptions for students. The retention of knowledge was higher when NOS is taught within explicit reflective conceptual change approach.

Bello and Adedoyin (2017) conducted a study in Nigeria to investigate the influence of gender on the conceptions of ninety-nine undergraduate pre-service biology teachers regarding Nature of Science. It was concluded that gender did not have any impact. In addition, misconceptions about NOS aspects is held by these teachers as a consequence of posturizing NOS aspects in the programs of study.

Karison and Zeidler (2017) conducted a study to examine the combined impact of contextualizing NOS within socio-scientific issues (SSI) framework to improve scientific literacy. They concluded that scientific literacy could be achieved when controversial socio-scientific issues are discussed in conjunction with an explicit attention to various aspects of NOS. Further studies were recommended for future research studies to be conducted to examine how a reflective and explicit approach to teach to teach NOS used together with attention to a relevant socio-scientific issue to improve students' understanding of NOS aspects. It needs to be noted that, this recommendation is the aim of this research study.

Seckin Kapucu et al. (2015) conducted a quasi-experimental study with 113 8^{th}-grade students. The instrument used is the Nature of Science Elementary Level (VNOS-E) questionnaire developed by Lederman and Ko (2004). The experimental group experienced the intentional integration of NOS aspects through six documentary films, while the control group followed a regular science curriculum. The control group has had no significant improvement in their understanding of NOS, whereas, there was a significant difference in the other group. Thus, they concluded that explicitly integrating NOS aspects in teaching science enhanced students' views about NOS.

Haung et al. (2014) conducted a study with 83 middle school students. It was recommended to carry on further investigations to examine the combined effect of explicit instruction and collaborative interaction with peers on NOS perceptions. As a conclusion, they stated: "explicit instruction supports NOS learning" (p.299). This quasi-experimental design study compared students in the synchronous and asynchronous groups. All students regardless of their group have had better science content knowledge as well as enhancing general and content related NOS views.

Cil (2014) conducted a study with 69 Turkish 7^{th}-grade students. This comparative study focused on identifying the most efficient approach in the teaching of NOS. The conceptual change approach cater is based on the acceptance of students' differences and their various learning styles. It concluded that conceptual change approach is better than explicit reflective inquiry-oriented and implicit instructional approach. The increase in students' informed views about NOS did not exceed 10% in the implicit approach group, while a

15% increment was noticed toward using the explicit reflective inquiry-oriented instruction, whereas, the conceptual change group students witnessed an increment between 30 to 60% of informed views for every target NOS aspect.

CHAPTER 3 METHODOLOGY

This chapter outlines the methodology used for this research study describing the study approach and methods. The data was collected in an attempt to answer the following three research questions:

1-What conceptions of the nature of science do Lebanese middle and high school students have?

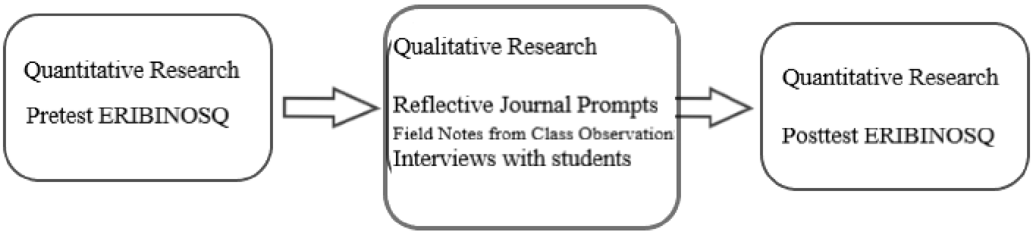
2- How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?

3- How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?

The chapter consists of description and rationale of the research approach, site, sampling, instrumentation, and planning of the quasi-experimental intervention of the combined explicit reflective and inquiry-based instruction, as well as data collection, pilot study, and ethical considerations. The briefing on the research approach focuses on the methods used, the design, and the philosophical rationale. The site and the sampling description provides all details related to the study's context. Furthermore, detailed statement of all the instrumentations used in an attempt to answer the research questions are given. All the planning for the combined explicit reflective and inquiry-based instruction, data collection, ethical consideration, and pilot study are provided. The various components provide the holistic approach to this research study.

3.1 Research Approach

The study approach was proposed to provide the evidence needed to assess which theoretical representation of the internal structure of the NOS data leads to a reliable, interpretable and theoretically grounded measure of middle and high school students' conceptions of NOS. Accordingly, the sequential explanatory mixed method research approach was utilized. The first phase involved conducting the pretest using the semi structured Explicit Reflective Inquiry-Based Instruction Nature of Science Questionnaire (ERIBINOSQ). Both the experimental and the control groups filled the questionnaire before the intervention. The second phase took place while the experimental group was undergoing the intervention. The qualitative data was collected using the reflective prompts, the field note from class observation, and the interviews that were conducted. The final phase involved collected the quantitative data by administrating the ERIBINOSQ for both experimental and control groups. The diagram below show the approach design.



Mixed methods design provides a numerical data to address the "what" (Cohen et al., 2013; Creswell, 2013; Johnson & Christensen, 2014) and the "how and why" (Cohen et al., 2013; Creswell & Plano, 2007). This process focused on collecting, analyzing and mixing both qualitative and quantitative data to capture the dynamics and trends of the research.

In the quantitative research, numerical data was the only source of information. Quantitative methods focused on objective measurements to establish statistical analysis of data collected through using various computational techniques (Hoy & Adams, 2016; Muijs, 2010). Quantitative measures were efficient at capturing the dynamics of social life, driven by the researcher's concerns, and also used statistically to generalize a finding, resulting in producing a hypothesis or a theory. Johnson and Christensen (2014) state that quantitative approach is a very useful means for establishing cause and effect relationships. The use of instruments to provide data through statistical tests was widely common approach to investigate NOS views (Dogan & Abd-El-Khalick, 2008; Lombrozo Thanukos & Weisberg, 2008; Neumann Neumann & Nehm, 2011).

Alternatively, qualitative research provided in-depth information which resulted in a holistic insight about trends. Johnson & Christensen (2014) state that qualitative approach provides rich data about participants' worldviews, and their personal perceptive and subjective meanings. Majority of studies conducted to investigate students' understanding of NOS used predominantly in-depth interviews (Akerson Buck & Quigley, 2011; Akerson & Donnelly 2010; Khishfe, 2008; Şahin & Köksal, 2010; Wu & Wu, 2011). Fraenkel, Wallen and Hyun (2015) state that qualitative studies do not display all the characteristics of the research topic strengths due to the unavoidable subjectivity of the researcher. Qualitative research allows for a more personalized and deep understanding of the variables related to the research subject (Meriam, 2009). Qualitative data is collected using subjective sources (Hancock & Algozzine, 2006; Meriam, 2009) such as interviews, field notes, or document analysis.

In the review of the pertinent literature to investigate middle and high school students' conceptions of NOS, neither qualitative nor quantitative methods were individually sufficient to investigate the complexity of NOS phenomena and topic of this study. It has been found that, determining students' perceptions of NOS requires multiple research methodologies (Kahraman & Karatas, 2015; Koeber et al., 2015; Krell et al., 2015; Torres et al., 2015). Plentiful information about a research topic has to be derived from multiple sources of data (Bell, 2010; Creswell 2013; Glense, 2006; Merriam & Tisdell, 2016; Merriam, 2009). Fraenkel, Wallen & Hyun (2015) state that combining different approaches give a clear picture of what is involved in the research study. Researchers support (Cil, 2014; Cil & Cepni, 2016; Hacieminolgu, 2016; Huang et al., 2014; Hwang, 2015; Kahraman & Karatas, 2015; Koeber et al., 2015; Krell et al., 2015; Torres et al., 2015) using a mixed method approach to generate a comprehensive blend of quantitative and qualitative data to investigate NOS conceptions.

Mixed method provided plentiful information about the topic of the research at hand (Creswell, 2013), information about the topic (Bell, 2010; Glense, 2006) and a clear picture of how the ideas evolved over time (Bowen, 2009). In this particular study, the researcher needs bountiful information about the impact of explicitly teaching NOS in conjunction with the reflection and inquiry-based instruction to have insights onto students' conceptions of NOS. Creswell (2013) insists that mixed method approach provides an in-depth strong understanding of the research at hand. In this context, the qualitative data provided a very intense inspection of the deep-rooted understanding of students to affirm the quantitative data which shall inspect the causes and effects of various variables. Maxwell (2005) insists that qualitative methods provide rich understanding of phenomena and process by which events occur. The quantitative research design was a quasi-experimental design whereby pre and post tests are used to measure the students' conceptions of the nature of science before and after using a combined explicit reflective NOS and inquiry-based instruction to respond to the second research question. Various sources of data provide a variety of information about the research topic (Bell, 2010; Creswell, 2013; Glense, 2006; Merriam, 2009). The qualitative data shall either clarify, illustrate, or validate the quantitative results. Hence seeking NOS conceptions of participants, their depth and understanding of NOS, thus answering the first and third questions was integral to the study. Fraenkel, Wallen and Hyun (2015) state that qualitative data collection is an ongoing process whereas the researcher continually observes people, events and occurrences to uncover the mysterious issues of the phenomenon of interest. The combined strength of qualitative and quantitative methods provided accurate information about the investigated topic. Creswell and Plano (2007) insist that the usage of a mixed method design adopts the qualitative and quantitative methods of inquiry combined together whereas one method compensate for the weakness of the other method. Consequently, the various sources reduced bias and increased precision. Reams and Twale (2008, p.133) state that mixed methods are necessary to uncover information and perception, increase corroboration of the data, and render less biased and more accurate conclusions.

Confirming Creswell and Plano (2007), Denscombe (2008, p.272) considers mixed method research as a means to: (1) increase the accuracy of data, (2) provide a more complete picture of the phenomena under study than would be yielded by a single approach, thereby overcoming the weaknesses and bias of single approaches, and (3) enable the researcher to develop the analysis and build on the original data. Creswell (2013, p. 207) states that:

> "The weight occurs in a mixed methods study through whether qualitative and quantitative information is emphasized first, the extend of treatment of one type of data or the other in the project or the use of primarily an inductive approach (i.e. generating themes in qualitative) or a deductive approach (i.e. testing a theory) (p.207)."

The data collection shall follow a specific sequence where either qualitative or quantitative method is prioritized. This study uses the sequential explanatory mixed method designs. Teddlie and Tashakkori (2009) state that sequential mixed designs adopt qualitative and quantitative approaches which run one after the other as the research requires. Fraenkel, Wallen and Hyun (2015) state that the explanatory design uses qualitative data to refine, to follow up, and to augment the results obtained from quantitative data. Creswell (2013, p.211) defines the sequential explanatory strategy as "The sequential explanatory strategy is a popular strategy for mixed methods design that often appeals to researchers with strong quantitative learnings. A sequential explanatory design is typically used to explain and interpret quantitative results by collecting and analyzing follow-up qualitative data".

In regards to this study, the numeric quantitative data was collected first. Secondly multiple case study qualitative approach was used, and then the quantitative data was collected. Merriam (2009) states that researchers are interested in qualitative research to understand how participants make sense of their world and the experiences they have. The variety of combined data sources from qualitative and quantitative approaches provided an expanded understanding of research problems (Creswell, 2013). The rationale for this approach was to refine and to explain the statistical results by exploring deeply the participants' views as well as to understand the meaning that middle and high school students have constructed about nature of science after the use of a combined explicit reflective and inquiry-based instruction.

The philosophical rationale that tap the strengths of both qualitative and quantitative models of research into one study is pragmatism. Johnson and Christensen (2014) define a pragmatist philosophy as a mixture of multiple research components to resolve the research problem, to address research questions, and to capture the dynamics of the research circumstances. Historically, the philosophy of pragmatism was used by Charles Pierce (1934) for the first time. Pragmatism considers life the basis of knowledge and the world as an absolute unity. John Dewey (1998) reformulated pragmatism into a new version, described his style of pragmatism as "instrumentalism", and wrote:

> "Instrumentalism is an attempt to establish a precise logical theory of concepts, of judgments and inferences in their various forms, by considering primarily how thought functions in the experimental determinations of future consequences. That is to say, it attempts to establish universally recognized distinctions and rules of logic by deriving them from the reconstructive function ascribed to reason. It aims to constitute a theory of general forms or conception and reasoning, and not of this or that particular judgment or concept related to its own content, or to its particular implications. (John Dewey 1998, p.9) "

Pragmatism is a matter-of-fact approach to discover solutions and to address research problems in a practical world (Cohen, Manion & Morrison, 2013). Assumptions are liberally drawn from both qualitative and quantitative resources to have a better understanding of the topic. Pragmatist researchers look to what works (Cohen et al., 2013; Creswell, 2013; Johnson & Christensen, 2014), adopt the approaches suitable with preconceived end results (Creswell, 2013), and draw conclusions based on tangible reality (Cohen, Manion & Morrison, 2013). Pragmatists are constructors of reality. Ghenea (2015) states that pragmatists are agents and builders of truth. Thus, pragmatism has a strong philosophical foothold in the mixed methods. In this particular connection, the usage of mixed method to capture the dynamics of the learning environment in science classes leaned on the ethos of pragmatist philosophy which clear the way to different compilations of student-teacher collaboration data. For the mixed method researcher, pragmatism provides the opportunity to use several methods, to investigate distinct worldviews, to test various assumptions, and to collect different forms of data (Creswell 2013). Supporting his claim, Cohen, Manion and Morrison (2013, p.22) stress on the need for a mixed method approach to investigate real world issues since the world has qualitative and quantitative data which has to be analyzed and interpreted.

The understanding of conceptions of humans has the possibilities of disagreement with many variations based on contextual differences. Inevitably, the understanding of the students' conceptions of NOS is inherently bound to pragmatic evaluations and decisions. Originally, the aim of this study is not simply a matter of inventing a theory or describing a phenomena, but a complex process that unavoidably has a pragmatic dimension. This study shall investigate the impact of a holistic intervention on students' conception of NOS. The influence of using a combined explicit reflective and inquiry based instruction on students' perceptions shall only be investigated after the intervention is implemented based on the qualitative and quantitative data analysis results. Cohen et al. (2013, p.23) state that "pragmatism prefers utility, practical consequences and outcomes, and heurism over the singular pursuit of the most accurate representation of reality". In particular, the usage of reflective learning techniques in conjunction with teaching explicitly NOS in an inquiry-based instruction setup to deepen students' conceptions of NOS is a complex process that requires a pragmatic approach to build a truthful reality that addresses promptly the research questions. Consequently, the pragmatic philosophy underpinning this study allowed for a systematic application of the most useful approach to address the research questions. Fraenkel, Wallen and Hyun (2015) state that pragmatists propose that researchers use whatever serve the purpose of their study to answer the research questions. Thus, this study adopted the instruments that served its purpose to answer the research questions.

3.2 Context

The research context was a K-12 private school located in South Lebanon. There were 433 students in the school that followed the national curriculum set by the Center for Educational Research and Development (CERD) for classes that undergo official exams, Grades 9 and 12, while other classes followed the standards set by Next Generation Science Standards (NGSS) framework. In 2016, the Ministry of Education in Lebanon released reports to outline the new science curriculum reform. The reformation places more emphasis on the NOS aspects than on memorizing scientific facts (CERD 2011).

The study was conducted in South Lebanon, Marjoyoun. This area consists of 53,040 people (OCHA 2016). According to OCHA (2016), 19,982 people in this region are above poverty line, 32,880 people deprived Lebanon, and 178 people are Lebanese returnees. There 11.1% females and 12.5% males whose age is between 6 and 17 years old. Hence, the total number of 6-12 years old people is 12,517 people.

As reported in the academic year 2016-2017 when the pilot study was conducted, the school had 400 students enrolled with 85 middle school students and 83 high school students. All students enrolled were Lebanese students with Arabic Language as the mother tongue. As reported in the academic year 2017-2018 when the actual study was conducted, the school had 433 students enrolled with 99 middle school students and 70 high school students. All students enrolled were Lebanese students with Arabic Language as their mother tongue.

All students registered at the school were Lebanese, and teachers were experts in the subject discipline that they teach. In addition, 25% of them had teaching diplomas. They were all Lebanese with Arabic as their mother tongue language. Thus, there is no cultural differences among students. Reveles and Brown (2008) state that cultural differences affect the answers that participants provide whether written or verbal.

All classes were mixed and constituted equally of boys and girls. The medium of instruction in a science class is English. Every science teacher has had an English proficiency certificate as well as a Bachelor Degree of Science. Additionally, some teachers have a teaching diploma. The school were the study was conducted was keen on engaging teachers in professional development programs, in-service training, and professional learning communities. Best practices were shared among the staff through round table meetings.

The subject coordinators regularly met to discuss best practices to share with teachers and improve teaching and learning.

In particular, the science department had a well-structured processes led by a subject coordinator whose had twenty years of experience. Teachers meet with the subject coordinator once per week to discuss the planning, to moderate the learning activities, and to design extra-curricular activities that aims to relate science topics to real world problems. The subject coordinator provides all teachers with the required resources to implement the intended science activities. At the school site, there are four science labs. The elementary school has its own junior science lab, whereas, the middle and high school have access to three independent labs: biology, chemistry, and physics laboratories. The Science Coordinator ensures the readiness of the labs and assists teachers when they conduct experiments with students.

The science textbooks used are provided by an American publishing company aligned with the standards of the Next Generation Science Standards (NGSS) curriculum Framework. Each student had two resources: a textbook and a standard practice book. The science lesson starts with an activity to introduce the concept to the students based on the specified tasks on the students standard practice book. Each student performed the specified task and record his observation on the standard practice book. The science teacher checks the progress of each student independently and provides constructive feedback to stimulate students' thoughts and makes them think critically.

3.3 Sampling

According to the General Report Lebanese MEHE 2016, there are 116 schools in South Lebanon divided into 41 free private schools and 75 payable private schools. In Marjayoun, there are 11 schools divided into 5 free private schools and 6 payable private schools. The study was conducted at a K-12 payable private school located in South Lebanon, Marjoyoun. The school adopted the Next Generation Science Standards (NGSS) and Common Core State Standards for science and English respectively for all classes except Grade 9 and Grade 12 as they had to undergo official exams. Grade 9 and Grade 12 follow the National Lebanese Curriculum set by CRDP. The table below shows the number of private schools available in South Lebanon- Marjoyoun as per the Ministry of Education records in Lebanon (General report Lebanese MEHE 2016).

Table (5): List of schools in South Lebanon (General report Lebanese MEHE 2016)

Region	Number of Private Schools	Type of School
South Lebanon	116 schools	41 free Private 75 payable Private
Marjayoun	11 schools	5 free Private 6 payable Private

At the site, there were 8 middle school classes with 150 students and 6 high school classes with 120 students. Five science teachers were in charge of teaching those sections. All those teachers were potential participants who could take part in this study if they were interested to volunteer. The principal received a letter to agree to allow the researcher to conduct the study at the school (refer to Appendix A). The science teachers received a letter to agree to participate in the study (refer to Appendix B). Students who took part in this study received “A letter to parents and students” where the parent was required to sign the “Parent Consent Form” and the student was required to sign the “Student Consent Form” (refer to Appendix C).

The participants were selected based on their willingness to join the study. The selected convenient sample was representative of the whole population. Johnson and Christensen (2014) state that the sample is representative when the sampling method is random. Rich information to study a research topic in an in-depth manner is obtained only if the participants sample is representative (Bell 2010; Creswell 2013; Hoy & Adams 2016; Merriam 2009; Meriam & Tisdill 2016; Mujis & Reynolds 2011).

The sample relationship criterion is an identical sample relation. Qualitative and quantitative phases of the investigation were done with the same participants. Johnson and Christensen (2014) state that identical sample relation occurs when the same participants are involved in both the quantitative and qualitative phases of the study.

3.4 Instrumentation

In this mixed method study, the synergy of the utilization of four instruments of both qualitative and quantitative methods achieved a thorough description of reality to answer the research questions: ERIBINOSQ questionnaire, an interview, the reflective journal prompts, and the field notes of class observations. Bowen (2009) stated that accessibility to multiple resources of data allow the researcher to compare, identify and get a clear picture of how the ideas evolved over time. Mixed method studies require time and effort (Arizon & Cameron, 2010), allow researchers to understand deeply the phenomenon of interest (Creswell, 2013; Fraenkel et al., 2015; Johnson & Christensen, 2014), and build on the strengths of both the qualitative and quantitative approaches (Bell, 2010; Creswell, 2013; Fraenkel et al., 2015).

In the first phase, the numeric quantitative data were collected using Explicit Reflective Inquiry-Based Instruction Nature of Science Questionnaire (ERIBINOSQ). The introductory pretest questionnaire was administered to the control and the experimental groups to investigate the middle and high school students' conceptions of NOS. In the second phase, a qualitative multiple case study approach was used to collect data through reflective journal prompts, interview, and field notes from class observations. In the last phase, quantitative data was collected using post-test ERIBINOSQ. The table below shows the instruments used to collect the data in relation to the research questions and the purposes of the study.

Table (6): Research Questions, Data and Data Analysis

Research Questions	Instrument	Analysis
Research Question 1: What conceptions of the nature of science do Lebanese middle and high school students have?	-ERIBINOSQ	*Qualitative data* a. listing *Quantitative data* a. Descriptive statistics b. SPSS (multivariate analysis of variances, independent t-tests) coding c. conceptually clustered matrix d. Emerging themes
Purpose: Investigate middle and high school students' conceptions of the nature of science (NOS)		
Research Question 2: How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?	-ERIBINOSQ -Reflective Journal Prompts -Student Interview -Field notes from class observations	*Qualitative data* a. listing *Quantitative data* a. Descriptive statistics b. SPSS (multivariate analysis of variances, independent t-tests)
Purpose: Examine the impact of combined explicit reflective NOS and inquiry-based instruction on middle and high school students' understanding of the nature of science		
Research Question 3: How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?	-ERIBINOSQ -Reflective Journal Prompts -Student Interview -Field notes from class observations	*Qualitative data* a. listing *Quantitative data* a. Descriptive statistics b. SPSS (multivariate analysis of variances, independent t-tests) coding c. conceptually clustered matrix d. Emerging themes
Purpose: Investigate middle and high school students' conceptions of the nature of science regarding demographic variables		

3.4.1 Explicit Reflective Inquiry-Based Instruction Nature of Science Questionnaire (ERIBINOSQ)

A central goal for science education is to develop the views of students of nature of science (NOS). Although scientists and science educators have emphasized the importance of developing informed conceptualization of NOS (Lederman et al., 2002; Lederman, 2007a).

The proper development of the desired understandings of NOS is not attained unless the structure of the instrument used to investigate students' views about NOS is well designed. Whether it is semi-structured or structured, its aim is to investigate the students' understanding about NOS. Explicit Reflective Inquiry-Based Instruction Nature of Science Questionnaire (ERIBINOSQ) was used as pretest and posttest to collect the quantitative data (refer to Appendix D). Descriptive statistics provide sufficient information about numerical values (Muijs, 2010). Confirming Mujis claim, Mills (2007) believed that descriptive statistics provides a lot of information about numerical values. One month prior to the start of the treatment, both experimental and control groups administered to ERIBINOSQ as a pretest.

ERIBINOSQ was developed after an extensive review of the literature review related to students' conceptions of NOS such as the 114-item Views on Science-Technology-Society (VOSTS) (Aikenhead & Ryan, 1992), the Critical Incidents Scale (Nott & Wellington, 1995), Views about Sciences Survey (VASS) (Halloun & Hestenes, 1998), Thinking about Science Survey Instrument (TSSI) (Cobern & Loving, 2002; Cobern, 2002) and Views on Science and Education (VOSE) (Chen, 2006b). The questionnaire included three sections. The first section seeks to collect demographic information about participants, the second section consisted of closed-ended questions, and the third section consists of open-ended questions. The second section consisted of 46 five-Likert items with SD=Strongly Disagree, D=Disagree more than agree, U=Uncertain or not sure, A=Agree more than disagree, SA=Strongly Agree. The questionnaire had 12 clusters that were appropriately measured students' conceptions of the nature of science who experienced a combined explicit reflective and inquiry-based instruction. The last section consisted of three open ended questions related to science, nature of science, and science learning approaches.

3.4.1.1 Cluster 1: Scientific Method

The first cluster aimed to explore how scientific investigation uses a variety of methods. It investigated students' perceptions of the usage of a variety of methods to conduct scientific investigations. It consisted of 3 items. These items focus on the elements of the scientific methods, the importance of using advanced tools to conduct experimentations, and the logical reasoning used to analyze data and draw conclusions. This cluster focused on the characteristics of scientific inquiry in relation with the scientific methods used to conduct empirical experimentations. The items were "Scientific investigations use different methods and procedures to obtain data and produce new knowledge", "Technology and advanced tools improve scientific knowledge", and "A common set of values characterizing scientific inquiry are: open-mindedness, objectivity, replicability of results, logical thinking, and ethical reporting of findings".

3.4.1.2 Cluster 2: Empirical Evidence in Relation to Scientific Knowledge

The second cluster aims to explore how empirical evidence forms the basis for scientific knowledge. It investigates students' perceptions of the role of empirical evidence in the formation of scientific knowledge. It consisted of 4 items. These items focus on the vital role that observations and experimentations play to explain natural phenomena, the existence of multiple sources of data, and the various patterns of evidence that results in new conclusions to support current theories. The items were, "Science knowledge is based on observations and experiments", "In science, there are common rules of evidence used to evaluate explanations about nature", "Science arguments require multiple sources of evidence to support explanation", and "Science connects the patterns of evidence to current theories".

3.4.1.3 Cluster 3: Tentativeness of Scientific Knowledge

The third cluster aimed to explore how scientific knowledge is open to revision in light of new evidence. It investigates students' perceptions of the tentativeness of scientific knowledge. It consisted of 4 questions. These items focused on the importance of evidence derived from experiments. Whether the evidence was new or based on a different interpretation for existing data, it changed the validity of the current scientific theories. The items were, "Scientific knowledge is subject to change", "Scientific knowledge changes based on new evidence", "Scientific knowledge changes based on reinterpretation of existing evidence", and "Scientific discussions are based on logical arguments".

3.4.1.4 Cluster 4: Scientific Laws, Models, and Theories

The fourth cluster aims to explore how science models, laws, mechanisms, and theories explained natural phenomena. It investigates students' perceptions of the difference between science models, theories, and laws. It consisted of 7 items. These items focused on investigating the distinction among laws, theories, and models. Theories are validated by evidence whereas time doesn't transform theories into facts or laws. The items were, "Theories and laws explain natural phenomena scientifically", "Theories do not become laws or facts with time", "Scientific theory is based on a body of facts that has been repeatedly confirmed through experiments and observations", "Science community accepts a scientific theory once it is validated by empirical evidence", "Scientific theory is modified when new evidence is discovered that the theory does not accommodate for", "Scientific theory is dependent on models, mechanisms, and explanations" and "Scientists use hypotheses to test and enhance explanations and theories".

3.4.1.5 Cluster 5: Nature of Science

The fifth cluster aimed to explore how science is a way of knowing. It investigated students' perceptions of the nature of science. It consisted of 4 items. These items investigate students' perceptions about science and the mechanism of explaining natural systems. Science is a process, a route, and a skeptical review of everything that the ancestors have discovered and set as laws of nature. The items were, "Science explains the mechanism of natural systems", "Science provides the process that can be used to refine, elaborate, revise and extend their knowledge", "Science is one of the ways of knowing", and "Science uses logical arguments, skeptical reviews, and empirical standards".

3.4.1.6 Cluster 6: Truthfulness of Scientific Knowledge

The sixth cluster aimed to explore how scientific knowledge assumes an order and a consistency in natural systems. It investigated students' perceptions of the truthfulness of scientific knowledge. It consists of 2 items. These items focus on the chronological progression of scientific knowledge and the interrelation between universal laws. The items were, "Scientific knowledge assumes that natural laws operate consistently the same in the past, present and future", and "The universal laws of science form one system of consistent laws".

3.4.1.7 Cluster 7: Cultural and Social Embeddedness of Scientific Knowledge

The seventh cluster aimed to explore how science is a human endeavor. It investigated students' perceptions of the relationship between science and social values. It consisted of 5 items. These items investigated the connections between social values and science. Technology, social values, cultural believes, imagination, and creativity either have a direct or an indirect influence on science. At the same time, science affects the society and the developments that certain civilizations witness in any era. The items were, "Scientific knowledge stems from imagination, creativity, and human investigations", "People from different cultures and backgrounds contribute to advances in science", "Cultural, social, and individual values of scientists influence their scientific work", "Science and technology are interrelated and influence each other", and "Society influences and is influenced by science".

3.4.1.8 Cluster 8: Theory-Laden Nature of Scientific Knowledge

The eighth cluster aimed to explore how science addresses questions about the natural and material world. It investigates Students' Perceptions of the nature of scientific knowledge. It consisted of 2 items. These items aimed to highlight on the authenticity of scientific knowledge. Scientific knowledge is concerned with reality and what happens in everyday life. It does not provide neither predictions nor forecasts. The items were "Science disciplines do not provide answers for all questions", and "Science knowledge explains what happen in natural systems rather than what should happen".

3.4.1.9 Cluster 9: Learning Environment in a Science Classroom

The ninth cluster aimed to explore the attitudes towards science learning. It investigated students' perceptions of the learning environment in a science classroom. It consisted of 3 items. These items investigate students' practices in science classrooms. Conducting experiments, thinking logically, and finding explanations are at the core of science learning. The items were, "As a student, I am unwilling to change my ideas when evidence shows that my ideas are poor", "I prefer to ask the teacher to explain science topics rather than find answers by doing experiments", and "I think scientific content knowledge we study in school is boring".

3.4.1.10 Cluster 10: Instructional Approach in Science Classroom

The tenth cluster aimed to explore the instructional approaches used in the science classes. It investigated students' perceptions of the learning activities and tasks in science classes. It consisted of 4 items. These items were, "I draw conclusions from experiments, simulations, and modeling in science”, “In science experiments, I collaborate with my peers to conduct scientific experiments”,“ In science experiments, I collaborate with my peers to report expected and unexpected results”, “In science experiments, I listen to my peers’ opinion, find scientific facts out from experiments, and draw logical conclusions” and “In science class, I have the possibility to try my own ideas, to debate or discuss, to work on models, and to explain my ideas”.

3.4.1.11 Cluster 11: Inquiry-Based Instructions in a Science Classroom

The eleventh cluster aimed to explore the social cognitive interaction among students in a science classroom. It investigated students’ perceptions of using inquiry based instructions in a science classroom. It consisted of 4 items. These items were, “When I reflect about my learning experience I understand the concepts better”, “Collaborating with my peers in group work allows me to discuss all the inquiries”, “Science experiments are easy to do”, and “The projects that I do in science are connected to the real-world”.

3.4.1.12 Cluster 12: Real Life Connections of Science Concepts

The twelfth cluster aimed to explore the relationship between science and real world experiences. It investigated students’ perceptions of the real life application of scientific concepts. It consisted of 3 items. These items were, “The instructions in science class are built around real-world problems”, “The science tasks resemble the tasks of scientists and real workers”, and “Science lessons are interesting and engaging due to their relevance to everyday life”.

The close-ended questions minimize the potential effects of writing abilities or cultural differences in participants’ responses, however they cannot provide justification for students’ answers. For that reason, open-ended questions should be part of the questionnaire. Open-ended questions provide clues that demonstrate whether a respondent understands the question correctly and provides key responses (Fraenkel et al. 2015). Consequently, open-ended questions engage participants in a live discussion. Bias conclusions come as a result of pre-determined answers of close ended questions. Thus, the existence of open-ended questions in a questionnaire leaves room for free responses. As a result, the questions aimed to investigate students' perceptions about the eight understandings of NOS in NGSS were openly demonstrated in the review of the literature. The questionnaire was piloted to test its validity and reliability. The results are presented later in this chapter.

3.4.2 Interview

All students were interviewed using an interview form (refer to Appendices E and F). There were two versions of the interview: middle school version and high school version. Both interview forms consisted of three questions. Firstly, students were asked to define the nature of science and to specify some of its characteristics. Secondly, they were asked to talk about the process used to learn science and the procedure adopted in the science class. Thirdly, they were asked to talk about the impact of various factors on the development of scientific knowledge. In regard to the third question in the middle school questionnaire version, students were asked about their perceptions of the influence of science on humans, while in the high school version it focused on the interrelation between science and social and cultural values. The three questions were compared to the open ended questions in the ERIBINOSQ to confirm students' responses about three major themes representing the core purpose of the study.

The interview allowed the researcher to elaborate on their written responses to clarify ambiguity in the interpretations. All interviews were audiotaped and transcribed. The production of a solid study requires a clear record of critical details by keeping a track of collected information (Emerson, Fretz & Show, 2011). During the interview, notes were taken to provide the basis for follow-up questions. Interviews were conducted in confidential areas within the school. Phellas et al. (2012) states that participants tend to provide more information when interviewed which result in enriching the qualitative research. The interview gathered information about perceptions from the students. Fraenkel et al. (2015) state that interviewing allows the researcher to check the accuracy of information gathered about the studied issue. The interviews provide an in-depth insight on the participants' points of views. Interview encourage participants to state their thought on freely (Sabah et al., 2014), to establish two-way conversation (Maree, 2007), and to reflect and to react (Creswell, 2013; Phellas, Bloch & Seale, 2012). Two science teachers revised the items of the interview tool for its appropriateness and content validity. The interviews were coded and analyzed in an attempt to find themes related to the research questions and to gain a deeper meaning from students. Fraenkel et al. (2015) consider an interview as a technique to explore out what is on the minds of participants, what they think, and how they feel about an issue.

3.4.3 Field Notes from Class Observation

Class observations were planned for every class in the experimental group. One class was observed systematically using class observation cycles. A class observation cycle is a series of consecutive class observations for the same learning environment (Merriam, 2009). Each observation cycle included five consecutive class observations on multiple days. Class observations provide an empirical evidence of association between students' engagement in inquiry-based instruction and the depth of students' conceptions of NOS. Field notes provide rich information of phenomena and process by which the phenomenon occurs (Fraenkel et al. 2015; Maxwell, 2005). It is a tool to capture the dynamics of the collaboration between students and teachers in the science learning environment. Field notes of classroom observations were documented using a predeveloped form called Nature of Science Class Observation Form “NOSCOF” (refer to Appendix G).

NOSCOF consisted of five sections: (a) lesson introduction emphasis, (b) modes of instruction during lesson, (c) questioning level, (d) teacher behavior, and (e) instructional materials used during lesson. The “lesson introduction emphasis” section examined whether the teacher provided an overview, a related idea to the lesson, or/and an assessment of prior knowledge. The “modes of instruction during lesson” section examined the strategies used inside the science class which could be a whole class, a recitation, a lecture, a note-taking, a reading, a homework/class work, a review/correction, a review, a drill and practice, a hands-on activity, seat work, teacher demonstration, small group, group presentation, cooperative group work, an open-ended inquiry, a data collection/manipulation, or a note-book entry of log. The “questioning level” section aimed to investigate the questioning style used which could be simple – knowledge, comprehension, procedural, complex – application, synthesis, analysis, evaluation, or affective. The “teacher behavior” section focused on the dynamics of the learning environment and the way the teacher acted. The related elements investigated whether the teacher explained and directly guided activity, circulated and asked questions, emphasized on the relations to real life, used ongoing embedded assessment, and/or manages the materials/ resources. Lastly, the “instructional materials used during lesson” section provided a clear idea about the resources used to deliver the content knowledge. the resources expected to be used in a science classroom were: (a) printed reading materials (books, articles, stories, etc.), (b) computer or computer technology, (c) overhead projector, LCD projector, video, films, music, (d) chalk board, white board, chart tablet, (e) demonstration models, (f) science equipment/manipulatives (hands-on materials), (g) worksheets, data sheets , and (g) science notebooks.

The teacher's behavior column in every section was rated using the criteria (+) which indicates "present" and (-) which indicates "lacking". Additionally, the "evidence of NOS column" in every section focused on eight categories": (a) scientific investigations use a variety of methods, (b) scientific knowledge is based on empirical evidence, (c) scientific knowledge is open to revision in light of new evidence, (d) science models, laws, mechanisms, and theories explain natural phenomena, (e) science is a way of knowing, (f) scientific knowledge assumes an order and consistency in natural systems, (g) science is a human endeavor and (h) science addresses questions about the natural and material world. Each category was rated using four judgements: (a) IBI = Inquiry-Based Instruction, (b) T =Traditional, (c) (-) = none, and (d) (+) =Mixed C (C is Combined explicit reflective) and T (Traditional explicit).

3.4.4 Reflective Journal prompts

Reflective journal prompts aimed to reveal the enthusiastic engagement of students in inquiry-based instruction science classes. Reflective process allowed the researcher to discover the world through the eyes of the participants (Çimer et al., 2013; Maree, 2007). Students were expressing themselves freely in every science lesson. The variety of data sources in this study increased the trustworthiness of the findings. Every student in the experimental group was provided with a booklet having reflective prompt forms to be used during the science classes throughout the whole treatment period. Students' reflective prompts were analyzed to create themes.

Students were provided with a 250-word prompt card to reflect on their learning. Reflections were filled every two weeks, thus, every student had seven reflections over the fourteen weeks of conducting the study. Mainly, the prompt cards consisted of three open ended questions. The first question focused on the main idea discussed in the science class. The students' reflections in this question shall show the depth of their understanding of the content knowledge. The second question focused on the instructional strategy used in the classroom while science learning is taking place. Students' reflections in this question shall provide clear illustrations the dynamics of science learning environment, the interactions between students and their teacher, and the suitability of the used approach from student's point of view. The third question focused on the nature of science aspects that were discussed in relation to the science objectives. This question provided a clear idea about the change in students' perceptions about NOS aspects from one week to another.

The reflective journal prompts allowed participants to speak their own peace of mind without having presumptions that restrict them from saying exactly what they want. The spontaneous responses were providing a clear idea about what was going on in the science classrooms from students' point of view. This practice became a habit for students who were in the experimental group. The answers in the first and second questions provided a clear indication about the approaches used in the class to deliver the science content. When this indication was compared to the lesson planning done by teachers, the evidence of integrity of doing what was planned is validated. Whereas, the answers in the first and third questions provided information about the intentional embeddedness of NOS aspects within science content knowledge. When this fact is compared to the lesson plan done by teachers, the evidence of explicit approach is indicated.

Even though teachers have had several forms of coordination to assure the unity of planning, the students' reflections provided an accurate idea of the amount of learning that had happened in the classroom. For instance, a teacher might plan for an inquiry based activity but when this activity is implemented, the students are dictated a certain way of working rather than given the freedom to explore. For that reason, when the reflective journal prompts are compared with field notes from classroom observations as well as lesson planning, then the data becomes truly reflective of the dynamics of learning.

The questionnaire instrument had a set of closed ended questions. When students completed the pretest ERIBINOSQ, they reported feeling stuck with so many clusters. They were choosing from the available options without having any opportunity to state their own belief about science and NOS. When reflective prompts journals were distributed, students felt free to write anything they wanted. Therefore, the interpretations of the participants' responses after the pretest were validated by the compiled and analyzed reflective prompt journals.

3.5 Pilot Study

Validity of instruments is of a paramount importance (Adejimi et al., 2011; Maree, 2007; Kothari, 2004) to obtain reliable research results (Merriam, 2009). Two experts in the science field have revised the "Explicit Reflective Inquiry-Based Instruction Nature of Science" (ERIBINOSQ) questionnaire to confirm the face validity of the instrument. Their feedback was focused on eliminating confusing terms and removing sophisticated scientific terminology that might confuse students when attempting to complete the questionnaire.

Moreover, the pilot study was conducted in the second semester of the academic year 2016-2017. This initial stage provided an evidence that the instruments were valid in a practical research environment where the research study was conducted. The pilot study aimed to validate the ERIBINOSQ which provided the quantitative data to answer the research questions of this study. The pilot study determined if the questionnaire operated properly before using it in the research study. An instrument becomes a valuable research tool if it is capable of detecting the dynamics of the research field through measuring the impact of the intervention and the changes in people's perceptions. Johnson & Christensen (2014) considered trying out the questionnaire as a cardinal rule. The questionnaire was piloted with one high school class (22 students) and one middle school class (24 students) at the private K-12 school in South Lebanon where the actual study took place. Johnson and Christensen (2014) insist on the need of piloting the questionnaire with a group of people who share the same characteristics similar to those who participated in the actual research study.

The pilot study was conducted in May 2017, during the academic year 2016-2017 at the same private school were the actual study took place. As reported in the academic year 2016-2017 when the pilot study was conducted, the school had 400 students enrolled with 85 middle school students and 83 high school students. All students enrolled were Lebanese students with Arabic Language as their mother tongue. One high school class and one middle class constituting of 22 and 24 students respectively participated in the pilot study. The classes were mixed classrooms and they constituted equally of boys and girls. The medium of instruction in the science class was English. The science teachers have had an English proficiency certificate as well as a bachelor degree in Science. The high school science teacher had a Teaching Diploma. The data collected using the ERIBINOSQ was analyzed using the SPSS.

The reliability statistics tests gave 0.62 Cronbach's alpha value. Table 7 provides the summary of analysis.

Table (7): Reliability Statistics Test Results for the Pilot Study

Case Processing Summary

		N	%
Cases	*Valid*	23	100.00
	Excluded	0	.00
	Total	23	100.00

Reliability Statistics

Cronbach's Alpha	*N of Items*
.62	46

Reliability Statistics

Cronbach's Alpha	*N of Items*
.62	46

As a result, some items in the questionnaire had been revised to clear out unclear items such as items I19, I21, I24, I27 and I35. Students were able to complete the questionnaire within 20 minutes. The rating scale was reported as confusing for students especially the "D=Disagree more than agree" and the "A=Agree more than disagree". In addition, in the demographic section, the question related to the mother tongue language was noted as unusual for the students since they are all Lebanese which implies that their mother tongue language is Arabic.

Reliability test was conducted again after the actual study was conducted and the Cronbach's alpha value was 0.88 as indicated in table 8 which indicate that the instrument is a reliable tool.

3.6 Trustworthiness Criteria

The trustworthiness criteria consist of a set of four criteria. The first criteria is the credibility. Macnee and McCabe(2008) defined credibility as the confidence placed in the truth if the research findings. It is achieved in this study by engaging the researcher in a substantial involvement in the setting in which the study was conducted. The intervention of this study was implemented over fourteen weeks during which numerous interviews, class observations, and reflective journal prompts were collected on a weekly basis. Hence, the rapport was well established since the contact with both the participants and the context site was frequent and substantial.

The second trustworthiness criteria is the transferability. Transferability was attained in this study by providing a detailed description of all the aspects of the study in the context and site sections in chapter 3. The provided information allow the readers to make their own judgements about the transferability of the study. The thick description of the site, the curriculum used in science learning, the data collection process, and the context allows other researchers to decide if this study can be replicated in other settings. A rich nd extensive set of details concerning the context and the methodology is a key aspects for the transferability of a study (Shenton, 2004; Li, 2004).

The third trustworthiness criteria is the dependability. The sample, the instrumentations, the design of the intervention, and the data collection process were tightly aligned. An independent researcher in Lebanon was overseeing the whole study process to ensure that the techniques for meeting credibility and transferability standards have been followed. In addition, prior to the fieldwork, the class observation form and the interview form were discussed, reviewed and refined by the researcher's supervisors. Moreover, the pretest and posttest questionnaire and the individual student's interview forms have had code-recorded number to track the influence of the intervention on student's perceptions of NOS in the qualitative methodology.

The fourth trustworthiness criteria is the confirmability. In this study, all the transcripts of the field notes from class observations, the interviews and the reflective journal prompts were kept to allow cross-checking to occur. The results section of this thesis included accurate quotes from the participants' transcripts to provide an accurate information about the student's conceptions of NOS, in addition to the researcher's interpretations of this discourse. Therefore, the data, the interpretations and the outcomes were rooted in the context and the sample of this study rather than being a figment of the evaluator.

3.7 Intervention Design

3.7.1 Sampling Procedure

Classes were divided into two groups: an experimental group and a control group. The control group consisted of two middle school classes and two high school classes with a total number of students equal to 58 students. Likewise the experimental group consisted of two middle school classes and two high school classes with a total number of students equal to 58 students. All students shared the same socio-economic and cultural background. All classes experienced the inquiry-based instruction approach to explore the science content knowledge. While only the experimental group received the treatment of explicitly embedding NOS in a reflective manner to explore the science discipline.

3.7.2 Planning for a Combined Explicit Reflective and Inquiry-Based Instruction

The researcher cooperated together with the science teachers to analyze and design the main components of lesson plan such as learning objectives, cooperative learning activities, experiments, real life connections, cross curricular links, and evaluation strategies in an attempt to unify the inquiry-based instructions among all the science classes taking part in this study.

Throughout the fourteen weeks, the duration of this study, science teachers met weekly with the researcher and the head of science department to design the lesson plans. Teachers were keen about following the details specified in their yearly plan. Their major worry was about the time needed to cover the science content knowledge and to use inquiry-based instructions to deliver it. Some teachers were proactive in designing creative activities that allow students to experiment and draw conclusions while others were simply stating explicitly the steps of the experiments. Even though all teachers agreed on the need for using inquiry-based instruction as a strategy in all science classes, however each teacher had a different definition for it. Thus, teachers were engaged in round table discussions to unify their perceptions about this strategy and to agree on the principle elements that characterized it.

Hence, a planning process for the application of inquiry-based instruction was established for this purpose. The planning included planning for activities, learning opportunities and implementation of the inquiry-based instruction. Teachers discussed extensively the process of implementing the designed cooperative learning activities. They have had different perceptions about inquiry-based instructions. Forawi (2014) considers the open-ended inquiry as an essential feature of a science class instruction. They were skeptical about their role versus students' role. They discussed the dynamics in the class, the obstacles, and the needed resources. Two teachers modeled a science lesson in front of the rest of the teachers who acted as students to show them the dynamics of the learning environment in practice.

Towards the end of the series of meetings that all teachers have had, they worked on the lesson plan template that they used to design their plans for the lessons that they wanted to teach. Many versions were discussed and the final template that they adapted was based on the five E-learning cycle strategy which consists of: engagement, exploration, explanation, elaboration and evaluation. This planning strategy specify all the components needed for an inquiry synergy in the science classroom.

The experimental group experienced learning science content in conjunction with NOS aspects being clearly identified throughout the science classes. Teachers emphasized the relationship between NOS aspects and the learning outcome outlined in the NGSS framework. Learning opportunities were designed to allow students to experiment, explore and investigate in a collaborative inquiry-based learning set-up. Reflective prompts were designed and provided to students to stimulate their thinking to connect NOS aspects to the content knowledge of science lessons.

3.8 Data Collection

The administration of the pretest using the Explicit Reflective Inquiry Based Instruction Nature of Science Questionnaire (ERIBINOSQ) was done beginning of October, 2017. The pretest was administered one month before the beginning of the intervention. All students who belonged to both the control and the experimental groups completed the pretest. Middle school students took approximately 35 minutes to complete it, whereas high school students took approximately 30 minutes to complete it. Simultaneously, science teachers of both groups delivered NGSS science lessons using inquiry-based instructions. Creswell (2013) states that comparisons between experimental and control groups is possible only if they have same qualifications. The delivery of the science content was done using the inquiry-based instruction. Furthermore, the delivered plan by the teachers of both group was designed and moderated ahead of time when group meetings happened between science teachers and their science coordinator.

The lesson plan for the experimental group included an explicit explanation of NOS aspects in relation to the science topics. Students in the experimental group were provided with reflective sheets to express themselves and to state the aspects of NOS in relation to the science content knowledge. To sum it up, the intervention lasted for three months and two weeks-fourteen continuous weeks- during which teachers explicitly included NOS aspects in their explanation, teachers used inquiry-based instructions to deliver the content, and students used reflective journal prompts to express their scientific beliefs. As a matter of fact, the inquiry-based instruction approach was used for both the experimental and the control group. On top of that, the experimental group has experienced the explicit reflective and the inquiry-based instruction. For that reason, the control group has had an intervention but it was not as strong as the experimental group.

The researcher conducted a consecutive series of class observation visits for every class in the experimental group. In February, all students who belonged to both control and experimental groups completed the posttests.

3.9 Data Analysis

The data collected using the sequential explanatory mixed method was utilized to provide the evidence needed to investigate the impact of the combined explicit reflective and inquiry-based instruction on middle and high school students' conceptions of NOS. The quantitative data was collected using the ERIBINOSQ instrument 5-likert scale items whereas the qualitative data was collected using the ERIBINOSQ open ended questions, the reflective journal prompts, the field noted from class observation, and the interviews.

Two different types of analysis were conducted in this research study. The first analysis was done for the quantitative data using Statistical Package for the Social Sciences (SPSS). The analysis of the pretest results of all participants allowed the researcher to determine the NOS conceptions of the Lebanese middle and high school students. The quantitative data was analyzed using the paired sample t-test, one-way ANOVA test and the descriptive statistics test. The paired t-test analysis was conducted to determine if there is a significant difference at the 0.05 level from pretest to posttest for each group. The one-way ANOVA was used to determine if there is a significant difference when various groups are compared to investigate middle and high school students' conceptions of the nature of science regarding demographic variables

The qualitative data collected was analyzed to generate themes and illustrative quotes. The qualitative data was obtained from four various sources. First, there was a presentation of the analysis of the open-ended items of the ERIBINOSQ instrument for themes related to the research items. Then, the analysis of the reflective journal prompts was done using code descriptions and exemplars about the natures of science as well as the approaches used to learn science from student's perceptions. Next, the analysis of the field notes from class observations was presented. The components of the protocol for class observation were analyzed using the stated criteria specified in the Nature of Science Class Observation Form (NOSCOF). Teacher's behaviors and classroom discourse were analyzed using "+: present" and "–: lacking". Additionally, the evidence of NOS was analyzed using "IBI=inquiry-based instructions", "T=traditional", "– = none", and "+=mixed C and T". Finally, the analysis of the interviews with students was presented.

The analysis of the data collected using the various instruments shall be presented in chapter four. Both, the qualitative and the quantitative analysis, provided ample information about the research topic.

3.10 Ethical Considerations

All the work involved in this research study gained written consents. Since the research study took place in a school where the participants are students under 18 years old, sufficient information about the research topic, confidentiality, and participants' rights was shared with participants and parents. The Principal and the science teachers were engaged in round table discussions to discuss all the details outlined in the timeline related to the research study. The work plan was shared with them to provide them with a clear idea of the pace, the requirements, and the preparatory stage.

The researcher encouraged students and teachers to participate in this research study, explained to them the benefits of the study on the scope of education, and discussed the purpose of the study research and the impact on scientific literacy. One of the research priorities was to show ample respect for the school and the participants throughout the study period. An official request form was submitted to the school authorities to get their informed consent before conducting the research treatment. A student informed consent form was given to the participants for approval.

Confidentiality and anonymity were major ethical considerations. A high respect for the privacy of the participants (Cohen et al., 2013) and the confidentiality of information (Waters-Adams, 2006) is expected when other people are involved in a research study. The names of students were stripped from the data and replaced with numbers. The location of the study was not revealed. The individual responses of all participants was kept anonymous even when the summary data was disseminated to the professional community.

The Principal of the school was contacted and preliminary approval was obtained using "a letter to the Principal" form (refer to Appendix A). The Principal of the school introduced the researcher to the Head of Science Department, and to the middle and high school science teachers. The researcher explained the aim of the study of the thesis in which they would have a chance to take part in.

Science teachers and the Head of the Science Department read the letter from the university to the school as it clarified whom is the researcher and the purpose behind the study (Refer to Appendix H). Teachers were interested in taking part in this research study. As a constant, the principal and all teachers who participated in the study signed a consent form. The consent forms introduced the researchers, the aim of the study, and the ethical considerations related to the anonymity of the data.

It is worth mentioning that both the experimental and the control groups were using inquiry-based instructional approach to learn science. All participants were entailed to learn science using implicit inquiry approach. This prevented withholding participants who belong to the control group from benefitting from the instructional strategy that allows them to discover the knowledge through experiments, simulations, and investigations. The researcher cooperated together with the science teachers to analyze and design the main components of lesson plan such as learning objectives, cooperative learning activities, experiments, real life connections, cross curricular links, and evaluation strategies in an attempt to unify the inquiry-based instructions among all the science classes taking part in this study. Thus, the implicit inquiry approach was used with all participants in the control and the experimental groups which minimized the ethical issues that arise from using a treatment with one group while retrieving the other group from the benefits of that treatments. The only difference between the two groups was the intentional integration of the eight understandings of NOS with the science topics for the experimental group. The experimental group experienced learning science content in conjunction with NOS aspects using the combined explicit reflective and inquiry-based instruction approach.

CHAPTER 4 DATA ANALYSIS & RESULTS

This chapter provided a comprehensive analysis of the data collected to assess the impact of combined explicit reflective and inquiry-based instruction on middle and high school students' perceptions of the NOS aspects. Findings from the analysis aimed to answer the research items of this study are:

1-What conceptions of the nature of science do Lebanese middle and high school students have?

2- How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?

3- How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?

The first section focuses on the analysis of the quantitative data obtained from the ERIBINOSQ instrument that was used as a pretest and a posttest. The different analysis was carried out to examine the variations that happened throughout the study period among the control and the experimental groups. The analysis focused on the students' perceptions in the experimental group who represents the group which experienced the combined explicit reflective and inquiry-based instruction approach and the students' perceptions in the control group who represents the group which experienced the inquiry-based instruction approach. Various data analysis were conducted between the groups as well as within each of the two groups. In this study, the control group presents a group of students who experienced a partial intervention.

The second section focuses on the qualitative data obtained from the four various sources. First, there is a presentation of the analysis of the open-ended items of the ERIBINOSQ instrument. Then the analysis of the reflective journal prompts is done using code descriptions and exemplars about the nature of science as well as the approaches used to learn science from the student's perceptions. Next, the analysis of the field's notes from class observations is presented. Finally, the analysis of the interviews with students and teachers is granted.

4.1 Analysis of the quantitative data

Middle and high school students' responses to the ERIBINOSQ instrument used as a pretest and posttest were analyzed using Statistical Package for Social Science (SPSS) version 25. Various tests were done for the collected data to obtain a holistic overview of the effectiveness of the intervention. First, Cronbach's alpha analysis was done to show the internal consistency of the five-Likert scale items. Then, the paired t-test was used to do multiple comparisons between the posttest and pretest results of the two groups. Finally, descriptive statistics was used to provide an analysis of the variations due to the demographic factors. All tests were done using liberal alpha level of 0.05.

4.1.1 Cronbach's alpha

A reliability analysis was carried out to calculate the reliability coefficient for the ERIBINOSQ instruments using the 5-Likert-type response sets. Cronbach's alpha showed that the ERIBINOSQ instrument had an acceptable reliability, α=0.880. Table 8 shows the reliability test results indicating that the ERIBINOQ is a highly reliable instrument to measure middle and high school students' perceptions of nature of science.

Table (8): Reliability Test for ERIBINOSQ instrument

Reliability Statistics	
Cronbach's Alpha	N of Items
.880	50

4.1.2 Paired t-test Analysis

The paired t-test analysis was conducted to compare the responses of: (a) all participants pretest analysis, (b) the scores of the pretest versus the posttest of the experimental group, (c) the scores of the pretest versus the posttest of the control group, and (d) the scores of the posttests of the experimental group versus the scores of the posttests of the control group, and (e) the analysis of data based on the demographic variables.

4.1.2.1 High and Middle School Students' Perceptions of NOS

The Lebanese students' perceptions in the middle and high school private school were analyzed based on the results of the analysis of the ERIBINOSQ pretest that all students filled in both groups to answer the first research question. The data were analyzed using t-test analysis and it indicated that female and male Lebanese students have the same perceptions about NOS aspects with no significant difference t=0.579, p-value=0.564. Apart from this, table 9 shows that high school students possess a better understanding of NOS aspects than the middle school students. The results of the t-test analysis indicated a significant difference t=-3.168, p-value=0.002.

Table (9): The Conceptions of Middle and High School Students about NOS

Item	Mean	Standard Deviation	Paired t-test Statistics
Overall	M = 3.53	0.50	T = 0.579 P-value = 0.564
	F = 3.47	0.49	
Overall (grade)	M = 3.27	0.62	T = -3.168 P-value = 0.002
	H = 3.63	0.42	

The descriptive statistics for the results of the first eight clusters of the pretest gave a mean value ranging between 3.24 and 3.9. This implied that all students have an adequate understanding of NOS conceptions. The total average mean of those clusters is 3.52 as shown in table 10. The mean value of the remaining four clusters ranged between 2.91 and 3.78.

Table (10): Middle and High School Students' Descriptive Statistics Data Analysis

Clusters	N	Mean	Std. Deviation
Cluster 1	116	3.90	0.64
Cluster 2	116	3.77	0.63
Cluster 3	116	3.35	0.75
Cluster 4	116	3.48	0.60
Cluster 5	116	3.76	0.78
Cluster 6	116	3.43	0.64
Cluster 7	116	3.24	0.94
Cluster 8	116	3.24	0.94
Cluster 9	116	2.91	0.97
Cluster 10	116	3.63	0.67
Cluster 11	116	3.56	0.73
Cluster 12	116	3.78	0.77

4.1.2.2 Students' Perceptions of the Combined Explicit Reflective and Inquiry-Based Instruction Group

To determine the impact of using the combined explicit and inquiry-based instruction on middle and high school students' conceptions of the NOS the results of the pretest and posttests of the experimental group were compared using paired t-test. The paired t-test analysis of all the clusters was conducted to determine the impact of using the combined explicit reflective and inquiry-based instruction. Table 11 shows that there was a significant difference in students' scores from the pretest to the posttest, t=-2.353, p-value=0.022. The mean value of the posttest was 3.57 while the mean value of the pretest was 3.37.

Table (11): Students Perceptions of the Combined Explicit Reflective and Inquiry-Based Instruction Group

	N	Mean	Standard Deviation	**Paired t-test Statistics**
Overall	58	Pretest=3.37	0.53	T = -2.353 P-value = 0.022
	58	Posttest = 3.57	0.39	

The results of the analysis of the pretests and the posttests of the experimental group in each cluster of the ERIBINOSQ is presented below. The twelve clusters are: Cluster 1: Scientific Method, Cluster 2: Empirical Evidence in Relation to Scientific Knowledge, Cluster 3: Tentativeness of Scientific Knowledge, Cluster 4: Scientific Laws, Models, and Theories, Cluster 5: Nature of Science, Cluster 6: Truthfulness of Scientific Knowledge, Cluster 7: Cultural and Social Embeddedness of Scientific Knowledge, Cluster 8: Theory-Laden Nature of Scientific Knowledge, Cluster 9: Learning Environment in a Science Classroom, Cluster 10: Instructional Approach in Science Classroom, Cluster 11: Inquiry-Based Instructions in a Science Classroom, and Cluster 12: Real Life Connections of Science Concepts. In addition, the results of the analysis of the pretests and the posttests of the experimental group for every item within every cluster is also presented to show the impact of the treatment.

4.1.2.2.a Cluster 1: Scientific Method

A paired-sample-t-test was conducted to determine the impact of the combined explicit reflective and inquiry-based instruction on students' perceptions about the scientific methods used. The mean of the students' responses for cluster 1 of the posttest was 3.97 while that in the pretest was found to be 3.77. Table 12 shows that there was no significant difference, t=-1.648, p-value=0.105. The mean values of students' scores for the posttest is

3.97 while the mean value for the pretest is 3.77. Thus, the intervention did not significantly change students' traditional views to contemporary views of NOS.

Table (12): Students Perceptions of the Experimental Group for Cluster 1

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 1: Scientific Method	58	Pretest=3.77	0.66	T = -1.648 P-value = 0.105
	58	Posttest = 3.97	0.66	

In specific, the results of the paired-sample-t-test conducted for the three items in this cluster demonstrated an increase in the mean value. The mean values in the posttest of I1, I2, and I3 were 4.1, 4.17 and 3.62 respectively, while the mean values of these items in the pretest were 3.9, 3.86 and 3.55 respectively. Table 13 shows that there was no significant difference between the pretest and posttest of any of the items of this cluster.

Table (13): Students Perceptions of the Experimental Group for Items 1, 2, And 3

Items	Mean	Std. Deviation	Paired t-test Statistics
I1: Scientific investigations use different methods and procedures to obtain data and produce new knowledge	Pretest = 3.90	0.97	T = -1.137 P-value = 0.260
	Posttest = 4.10	1.05	
I2: Technology and advanced tools improve scientific knowledge	Pretest = 3.86	1.13	T = -1.563 P-value = 0.124
	Posttest = 4.17	1.13	
I3: A common set of values characterizing scientific inquiry are: open-mindedness, objectivity, replicability of results, logical thinking, and ethical reporting of findings	Pretest = 3.55	0.86	T = -0.389 P-value = 0.698
	Posttest = 3.62	1.17	

4.1.2.2.b Cluster 2: Empirical Evidence in Relation to Scientific Knowledge

The mean value of the students' responses for cluster 2 in the posttest was 3.84 while that of the pretest was found to be 3.63. Table 14 shows that there was no significant difference in students' scores using pair t-test, t=-1.566, p-value=0.123. Thus, the intervention did not significantly change the students' perceptions from traditional views to contemporary views of NOS. This indicates that students have had acquired the same perceptions about the role of empirical evidence in the formation of scientific knowledge. Therefore, their views about the role that observations and experimentations play to explain natural phenomena, the existence of multiple sources of data, and the various patterns of evidence that results in new conclusions to support current theories remained invariant.

Table (14): Students Perceptions of the Experimental Group for Cluster 2

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 2: Empirical Evidence in Relation to Scientific Knowledge	58	Pretest=3.63	0.67	T = -1.566
	58	Posttest = 3.84	0.77	P-value = 0.123

The results for the paired-sample-t-test for the four items in this cluster demonstrated an increase in the mean values for three items and a decrease in the mean value of one item. Three items had no significant difference while one item had a significant difference. Table 15 shows that there was no significant difference in students' scores using pair t-test for I4, t=-0.667, p-value=0.507 and for I6, t = -1.105, p-value = 0.274. Additionally, the mean values of their posttests were found to be 4.38 and 3.34 while the mean values for their pretests were 4.26 and 3.12 respectively.

Essentially, the results of the paired-sample-t-test for item 7 showed that there was no significant difference in students' scores using pair t-test, t=-2.77, p-value=0.008. The mean in the posttest was found to be 3.88 while that in the pretest was 3.29. This item focused on the vital role that the evidence plays in supporting explanations and validation of natural phenomenon. Nevertheless, the results of the paired-sample-t-test for item 5 showed no significant difference between the pretest and the posttest, t = 0.476, p-value = 0.636. This accompanied a decrease in the mean value that was 3.78 for the posttest and 3.86 for the pretest.

Table (15): Students Perceptions of the Experimental Group for Items 4-7

Items	Mean	Std. Deviation	Paired t-test Statistics
I4: Science knowledge is based on observations and experiments	Pretest = 4.26	0.97	T = -0.667
	Posttest = 4.38	0.91	P-value = 0.507
I5: In science, there are common rules of evidence used to evaluate explanations about nature	Pretest = 3.86	0.91	T = 0.476
	Posttest = 3.78	1.23	P-value = 0.636
I6: Science connects the patterns of evidence to current theories	Pretest = 3.12	0.96	T = -1.105
	Posttest = 3.34	1.19	P-value = 0.274
I7: Science arguments require multiple sources of evidence to support explanation	Pretest = 3.29	1.20	T = -2.77
	Posttest = 3.88	1.16	P-value = 0.008

4.1.2.2.c Cluster 3: Tentativeness of Scientific Knowledge

A paired-sample-t-test was conducted and showed that there is no significant difference in students' scores t=-1.997, p-value=0.051 as indicated in table 16. The mean value of the students' responses for cluster 3 in the posttest was found to be 3.44 while that of the pretest was 3.19. Thus, the intervention did not significantly change students' traditional views to contemporary views of NOS. Students still acquired the same perceptions about the tentativeness of scientific knowledge. They had the same views about the impact of having a new evidence or a different interpretation for existent data on the validity of current scientific theories.

Table (16): Students perceptions of the experimental group for Cluster 3

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 3: Tentativeness of Scientific Knowledge	58	Pretest=3.19	0.70	T = -1.997
	58	Posttest = 3.44	0.65	P-value = 0.051

In specific, the results of the paired-sample-t-test conducted for the four items in this cluster showed that there is no significant difference between the pretest and the posttest as demonstrated in table 17. Apart from that, the mean values of the students' scores of all the items witnessed an increase from the pretest to the posttest.

Table (17): Students Perceptions of the Experimental Group for Items 8 - 11

Items	Mean	Std. Deviation	Paired t-test Statistics
I8: Scientific knowledge is subject to change	Pretest = 2.83	1.22	T = -1.787
	Posttest = 3.17	1.24	P-value = 0.079
I9: Scientific knowledge changes based on new evidence	Pretest = 3.47	1.22	T = -1.517
	Posttest = 3.78	1.08	P-value = 0.135
I10: Scientific knowledge changes based on reinterpretation of existing evidence	Pretest = 3.00	1.06	T = -1.502
	Posttest = 3.28	1.06	P-value = 0.139
I11: Scientific discussions are based on logical arguments	Pretest = 3.48	1.08	T = -0.252
	Posttest = 3.53	1.30	P-value = 0.802

4.1.2.2.d Cluster 4: Scientific Laws, Models, and Theories

The paired-sample-t-test was conducted and showed that there is a significant difference in students' scores, t=-2.331, p-value=0.023. Table 18 shows that the mean values of the posttest were found to be 3.55 while that of the pretest was 3.33. This means that students' perceptions about the differences between science models, theories, and laws witnessed a significant change. They were able to understand that theories are validated by evidence whereas time doesn't transform theories into facts or laws. Their involvement in inquiry-based instruction allowed them to experience how science models, laws, mechanisms, and theories explain natural phenomena.

Table (18): Students perceptions of the experimental group for Cluster 4

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 4: Scientific Laws, Models, and Theories	58	Pretest=3.33	0.61	T = -2.331 P-value = 0.023
	58	Posttest = 3.55	0.49	

In specific, the results of the paired-sample-t-test conducted for the seven items in this cluster demonstrated an increase in the mean value. Six items have had no significant difference while one item, I16, has had a significant difference, t=-2.716, p-value=0.009. Table 19 shows that the mean value of the posttest was 3.69 while that of the pretest is 3.21. The mean in the pretest was found to be 3.21 while that in the posttest was 3.69. This item focuses on the changing nature of scientific theory in light of new arising evidence. The mean values of I12, I13, and I14 were 3.57, 3.22 and 3.79 in the posttest whereas they were 3.45, 3.00 and 3.67 in the pretest. Apart from that, the mean values of I15, I17 and I18 were 3.48, 3.47 and 3.66 in the posttest whereas they were 3.16, 3.19 and 3.64 in the pretest.

Table (19): Students Perceptions of the Experimental Group for Items 12 - 18

Items	Mean	Std. Deviation	Paired t-test Statistics
I12: Theories and laws explain natural phenomena scientifically	Pretest = 3.45	1.08	T = -0.548
	Posttest = 3.57	1.19	P-value = 0.586
I13: Theories do not become laws or facts with time	Pretest = 3.00	1.14	T = 1.105
	Posttest = 3.22	1.29	P-value = 0.274
I14: Scientific theory is based on a body of facts that has been repeatedly confirmed through experiments and observations	Pretest = 3.67	1.25	T = -0.578
	Posttest = 3.79	1.04	P-value = 0.566
I15: Science community accepts a scientific theory once it is validated by empirical evidence	Pretest = 3.16	1.34	T = -1.105
	Posttest = 3.48	1.06	P-value = 0.274
I16: Scientific theory is modified when new evidence is discovered that the theory does not accommodate for	Pretest = 3.21	1.02	T = -2.716
	Posttest = 3.69	1.01	P-value = 0.009
I17: Scientific theory is dependent on models, mechanisms, and explanations	Pretest = 3.19	1.37	T = -1.146
	Posttest = 3.47	1.23	P-value = 0.257
I18: Scientists use hypotheses to test and enhance explanations and theories	Pretest = 3.64	1.19	T = -0.078
	Posttest = 3.66	1.18	P-value = 0.938

4.1.2.2.e Cluster 5: Nature of Science

A paired-sample-t-test was conducted and showed that there is a significant difference in students' scores, t=-2.070, p-value=0.043. Table 20 shows that the mean of the students' responses for cluster 5 in the posttest was found to be 3.93 while that of the pretest was 3.67. Thus, the intervention had a significant change in students' perceptions about science and the mechanism of explaining natural systems. Students were able to see science as a process, a route, and a skeptical review of everything that the ancestors have discovered and set as laws of nature. Their responses had been significantly different when the pretest and posttest responses had been compared.

Table (20): Students Perceptions of the Experimental Group for Cluster 5

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 5: Nature of Science	58	Pretest=3.67	0.83	T = -2.070 P-value = 0.043
	58	Posttest = 3.93	0.70	

In specific, the results of the paired-sample-t-test conducted for the four items in this cluster demonstrated no significant difference between the pretest and posttest but there was an increase in the mean values as demonstrated in table 21. In the posttest, the mean values of I19, I20, I21, and I22 were 3.57, 3.22, 3.79 and 3.48 respectively. Adding to this, the mean values of the pretest of I19, I20, I21, and I22 were 3.45, 3.00, 3.67 and 3.16 respectively.

Table (21): Students Perceptions of the Experimental Group for Items 19 - 22

Items	Mean	Std. Deviation	Paired t-test Statistics
I19: Science explains the mechanism of natural systems	Pretest = 3.55	1.37	T = -0.76 P-value = 0.451
	Posttest = 3.72	1.27	
I20: Science provides the process that can be used to refine, elaborate, revise and extend their knowledge	Pretest = 3.50	1.14	T = -1.844 P-value = 0.070
	Posttest = 3.86	1.10	
I21: Science is one of the ways of knowing	Pretest = 4.10	1.17	T = -0.499 P-value = 0.62
	Posttest = 4.19	0.95	
I22: Science uses logical arguments, skeptical reviews, and empirical standards	Pretest = 3.52	1.19	T = -1.955 P-value = 0.055
	Posttest = 3.93	1.01	

4.1.2.2.f Cluster 6: Truthfulness of Scientific Knowledge

A paired-sample-t-test was conducted and showed that there is no significant difference in students' scores, t=-0.229, p-value=0.820. Table 22 shows that the mean value of the students' responses for cluster 6 in the posttest was found to be 3.32 while that of the pretest was 3.28. Thus, the intervention did not significantly change students' traditional views to contemporary views of NOS. Students' perceptions of the truthfulness of scientific knowledge did not indicate any change. They had steady views about the chronological progression of scientific knowledge and the interrelation between universal laws.

Table (22): Students Perceptions of the Experimental Group for Cluster 6

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 6: Truthfulness of Scientific Knowledge	58	Pretest=3.28	0.63	T = -0.229
	58	Posttest = 3.32	0.99	P-value = 0.820

In specific, the results of the paired-sample-t-test conducted for the two items in this cluster have indicated no significant difference but an increase in the mean value of the students' scores was evident. Table 23 shows that the mean values of I23 and I24 in the posttest were 3.26 and 3.38 whereas the mean values were 3.16 and 3.34 respectively.

Table (23): Students Perceptions of the Experimental Group for Items 23 and 24

Items	Mean	Std. Deviation	Paired t-test Statistics
I23: Scientific knowledge assumes that natural laws operate consistently the same in the past, present and future	Pretest = 3.16	1.21	T = -0.531
	Posttest = 3.26	1.19	P-value = 0.597
I24: The universal laws of science form one system of consistent laws	Pretest = 3.34	1.09	T = -0.153
	Posttest = 3.38	1.24	P-value = 0.879

4.1.2.2.g Cluster 7: Cultural and Social Embeddedness of Scientific Knowledge

A paired-sample-t-test was conducted and showed that there is a significant difference in students' scores, t=-2.878, p-value=0.006 as shown in table 24. The mean value of the students' responses for cluster 7 in the posttest was found to be 3.47 while that of the pretest was 3.04. Thus, the intervention had a significant change in students' perceptions about the relationship between science and social values. Students experienced how technology, social values, cultural believes, imagination, and creativity either have a direct or an indirect influence on science. The experimentations made them recognize that science affects the society and the developments that certain civilizations witness in any era.

Table (24): Students Perceptions of the Experimental Group for Cluster 7

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 7: Cultural and Social Embeddedness of Scientific Knowledge	58	Pretest=3.04	1.00	T = -2.878 P-value = 0.006
	58	Posttest = 3.47	0.60	

In specific, the results of the paired-sample-t-test conducted for the five items in this cluster demonstrated an increase in the mean value for four items while one item has had a decrease in the mean value. Four items had no significant difference, while I26 has had a significant difference. Table 25 shows that there was a significant difference in students' scores using pair t-test, t=-2.654, p-value=0.010 for I26. The mean in the posttest was found to be 3.71 while that in the pretest was 3.26. Students had been indulged with various inventions and discoveries from scientists of various nationalities. They saw how a theory starts as a hypothesis with one scientist in one country then further investigations are carried out with another scientist in a different country. This allowed them to see that different cultures and nations contribute to scientific knowledge formation.

For I25, I26, and I27, there were no significant difference between the pretest and posttest as demonstrated in table 25. Adding to that, the mean values of the posttest were found to be 3.78, 3.45 and 3.22 respectively, while that in the pretest were 3.52, 3.16 and 3.03 respectively. Surprisingly, for I28 there were no significant difference, t=1.113, p-value=0.270 and a decrease in the mean values of the posttest 3.21 and the pretest 3.43. This means that students concluded how technology enabled scientists to collect accurate data to support their claims, yet, they could not figure out how science affects technology.

Table (25): Students Perceptions of the Experimental Group for Items 25 - 29

Items	Mean	Std. Deviation	Paired t-test Statistics
I25: Scientific knowledge stems from imagination, creativity, and human investigations	Pretest = 3.52	1.19	T = -1.45
	Posttest = 3.78	1.24	P-value = 0.152
I26: People from different cultures and backgrounds contribute to advances in science	Pretest = 3.26	1.07	T = -2.654
	Posttest = 3.71	1.09	P-value = 0.010
I27: Cultural, social, and individual values of scientists influence their scientific work	Pretest = 3.16	1.11	T = -1.242
	Posttest = 3.45	1.23	P-value = 0.219
I28: Science and technology are interrelated and influence each other	Pretest = 3.43	1.23	T = 1.113
	Posttest = 3.21	1.12	P-value = 0.270
I29: Society influences and is influenced by science	Pretest = 3.03	1.11	T = -0.806
	Posttest = 3.22	1.17	P-value = 0.423

4.1.2.2.h Cluster 8: Theory-Laden Nature of Scientific Knowledge

Table 26 shows that there was no significant difference in students’ scores using pair t-test, t=-1.254, p-value=0.215. The mean of the students’ responses for cluster 8 in the posttest was found to be 3.25 while that of the pretest was 3.04. Thus, the intervention did not significantly change students’ traditional views to contemporary views of NOS. Their perceptions about the nature of scientific knowledge remained the same. Although they have experienced so many experimentations that showed what happens in everyday life, they did not see scientific knowledge as neither a prediction nor a forecast.

Table (26): Students perceptions of the experimental group for Cluster 8

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 8: Theory-Laden Nature of Scientific Knowledge	58	Pretest=3.04	1.00	T = -1.254 P-value = 0.215
	58	Posttest = 3.25	0.90	

Bearing this in mind, the results of the paired-sample-t-test conducted for the two items in this cluster revealed no significant difference between the results of the students' scores. Interestingly, I30 demonstrated an increase in the mean value while I31 remained invariant as indicated in table 27.

Table (27): Students Perceptions of the Experimental Group for Items 30 and 31

Items	Mean	Std. Deviation	Paired t-test Statistics
I30: Science disciplines do not provide answers for all items	Pretest = 2.74	1.33	T = -1.708 P-value = 0.093
	Posttest = 3.16	1.40	
I31: Science knowledge explains what happens in natural systems rather than what should happen	Pretest = 3.34	1.28	T = 0 P-value = 1
	Posttest = 3.34	1.28	

4.1.2.2.i Cluster 9: Learning Environment in a Science Classroom

The paired-sample-t-test was conducted and showed that there is no significant difference in students' scores, t=-0.823, p-value=0.414. Table 28 shows that the mean value of students' responses in the posttest was 2.98 while that of the pretest was 2.86. Thus, the intervention did not significantly change students' traditional views to contemporary views of NOS.

Table (28): Students Perceptions of the Experimental Group for Cluster 9

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 9: Learning Environment in a Science Classroom	58	Pretest=2.86	0.96	T = -0.823
	58	Posttest = 2.98	0.95	P-value = 0.414

On top of that, the results of the paired-sample-t-test conducted for the three items in this cluster showed that there is no significant difference between the students' results. The mean values for I32 and I34 increased while it decreased for I33 as indicated in table 29. Consistently, I32 and I34 have had the same mean values of 2.88 in the posttest and of 2.67 in the pretest. Regarding I33, the mean value of the posttest was 3.19 while the pretest was found to be 3.24. This meant that students enjoyed finding answers for themselves after the intervention rather than considering the teacher as the main source of information.

Table 29: Students' Perceptions of the Experimental Group for Items 32 - 34

Item	Mean	Std. Deviation	Paired t-test Statistics
I32 As a student, I am unwilling to change my ideas when evidence shows that my ideas are poor	Pretest = 2.67	1.39	T = -0.834
	Posttest = 2.88	1.48	P-value = 0.408
I33: I prefer to ask the teacher to explain science topics rather than find answers by doing experiments	Pretest = 3.24	1.42	T = 0.242
	Posttest = 3.19	1.30	P-value = 0.810
I34: I think scientific content knowledge we study in school is boring	Pretest = 2.67	1.46	T = -0.898
	Posttest = 2.88	1.44	P-value = 0.373

4.1.2.2.j Cluster 10: Instructional Approach in Science Classroom

Table 30 shows that there was a significant difference in students' scores, t=-2.086, p-value=0.041. The mean value of the students' responses for cluster 10 in the posttest was found to be 3.71 while that of the pretest was 3.48. Thus, the intervention resulted in a significant change in students' traditional views to contemporary views of NOS. Students' were excited about the learning activities and tasks that they were engaged in during the science lessons. They enjoyed collaboration, experimentation, and communication. The designed learning activities stimulated their curiosity and motivated them to draw conclusions using logical reasoning.

Table (30): Students' Perceptions of the Experimental Group for Cluster 10

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 10: Instructional Approach in Science Classroom	58	Pretest=3.48	0.73	T = -2.086 P-value = 0.041
	58	Posttest = 3.71	0.66	

With regard to the items in this cluster, the results for the paired-sample-t-test indicated an increase in the mean values for four items and a decrease in the mean value of one item. Table 31 shows that three items had no significant difference while two items had a significant difference.

The results of the paired-sample-t-test for I35 and I36 showed an increase in the mean value with a significant difference between the Pretest and the Posttest with t=-2.131, p-value=0.037 and t=-2.506, p-value=0.015 respectively. Table 31 shows that the mean values of the posttest of I35 and I36 are 3.72 and 3.69 respectively, while, the mean values in the pretest were 3.28 and 3.16 respectively. This meant that students drew conclusions from experiments, simulations, and modeling in science. They reported the existence of collaboration in the science classes to conduct scientific experiments with their peers. In addition, they were more agreed that collaboration allowed them to learn science proficiently.

There was no significant difference between the pretest and posttest for I38 and I39 despite an increase in the mean values. In the posttest, the mean values for I38 and I39 were 4.00 and 3.81, likewise, the mean values in the pretest were 3.64 and 3.74 respectively. Apart from this, I37 results showed no significant difference and a decrease in the mean value of the students' scores. Table 31 shows that the mean value in the posttest was 3.34 whilst in the pretest was found to be 3.6. This decrease demonstrated the lack of proper collaboration to report the findings of the experiments. One of the striking oppositions here is the difference of results of I36 and I37. Comparing the results of both items indicated that students collaborate while conducting the experiments but they did not collaborate when they drew conclusions to report the results.

Table (31): Students Perceptions of the Experimental Group for Items 35 - 39

Items	Mean	Std. Deviation	Paired t-test Statistics
I35: I draw conclusions from experiments, simulations, and modeling in science	Pretest = 3.28	1.24	T = -2.131
	Posttest = 3.72	1.04	P-value = 0.037
I36: In science experiments, I collaborate with my peers to conduct scientific experiments	Pretest = 3.16	1.23	T = -2.506
	Posttest = 3.69	1.16	P-value = 0.015
I37: In science experiments, I collaborate with my peers to report expected and unexpected results	Pretest = 3.60	1.15	T = 1.137
	Posttest = 3.34	1.24	P-value = 0.260
I38: In science experiments, I listen to my peers' opinion, find scientific facts out from experiments, and draw logical conclusions	Pretest = 3.64	1.13	T = -1.99
	Posttest = 4.00	0.97	P-value = 0.0510
I39: In science class, I have the possibility to try my own ideas, to debate or discuss, to work on models, and to explain my ideas	Pretest = 3.74	1.18	T = -0.333
	Posttest = 3.81	1.26	P-value = 0.740

4.1.2.2.k Cluster 11: Inquiry-Based Instructions in a Science Classroom

A paired-sample-t-test was conducted and showed that there is no significant difference in students' scores, t=-0.672, p-value=0.504 as indicated in table 32. The mean value of the students' responses for cluster 11 in the posttest was found to be 3.61 while that of the posttest was 3.53. Thus, the intervention did not significantly change students' traditional views to contemporary views of NOS. The social cognitive interaction among students in a science class did not seem interesting to students. Their perceptions of using inquiry-based instructions in a science classroom were static.

Table (32): Students' Perceptions of the Experimental Group for Cluster 11

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 11: Inquiry-Based Instructions in a Science Classroom	58	Pretest=3.53	0.79	T = -0.672 P-value = 0.504
	58	Posttest = 3.61	0.73	

The results for the paired-sample-t-test for the four items in this cluster demonstrated an increase in the mean values for two items and a decrease in the mean value of one item while one item has had an invariant mean value. For I41 and I42, the mean values of students' scores in the posttest were found to be 3.71 and 3.19 respectively, whereas the mean values in the pretests were 3.43 and 3.09 respectively. The results of the paired-sample-t-test for I40 showed no significant difference, t = 0.216, p-value = 0.829 with a decrease in the mean values. Table 33 shows that the mean value of the posttest was 3.62 while the mean value of the pretest is 3.67. Surprisingly, the mean values of I43 in the pretest and posttest were the same.

Table (33): Students Perceptions of the Experimental Group for Items 40 - 43

Items	Mean	Std. Deviation	Paired t-test Statistics
I40: When I reflect about my learning experience I understand the concepts better	Pretest = 3.67	1.22	T = 0.216
	Posttest = 3.62	1.36	P-value = 0.829
I41: Collaborating with my peers in group work allows me to discuss all the inquiries	Pretest = 3.43	1.27	T = -1.24
	Posttest = 3.71	1.20	P-value = 0.220
I42: Science experiments are easy to do	Pretest = 3.09	1.41	T = -0.483
	Posttest = 3.19	1.30	P-value = 0.631
I43: The projects that I do in science are connected to the real-world	Pretest = 3.93	1.17	T = 0
	Posttest = 3.93	1.30	P-value = 1

4.1.2.2.l Cluster 12: Real Life Connections of Science Concepts

Table 34 shows that there was no significant difference in students' scores using pair t-test, t=-1.239, p-value=0.221. The mean value of the students' responses for cluster 12 in the posttest was found to be 3.79 while that of the pretest was 3.62. Thus, the intervention did not significantly change students' traditional views to contemporary views of NOS. Students considered science and real-life practices lightly related. They did not see the science content knowledge and real-life issues interconnected.

Table (34): Students Perceptions of the Experimental Group for Cluster 12

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 12: Real Life Connections of Science Concepts	58	Pretest=3.62	0.80	T = -1.239
	58	Posttest = 3.79	0.78	P-value = 0.221

The results for the paired-sample-t-test for the three items in this cluster demonstrated an increase in the mean values with no significant difference as indicated in table 35. The mean values in the posttests for I44, I45, and I46 were 3.72, 3.59, and 4.07 respectively, whereas the mean values of students' scores in the pretest were 3.64, 3.26, and 3.97 respectively.

Table (35): Students Perceptions of the Experimental Group for Items 44 - 46

Items	Mean	Std. Deviation	Paired t-test Statistics
I44: The instructions in science class are built around real-world problems	Pretest = 3.64	1.07	T = -0.404
	Posttest = 3.72	1.17	P-value = 0.688
I45: The science tasks resemble the tasks of scientists and real workers	Pretest = 3.26	1.10	T = -1.514
	Posttest = 3.59	1.16	P-value = 0.136
I46: Science lessons are interesting and engaging due to their relevance to everyday life	Pretest = 3.97	1.27	T = -0.497
	Posttest = 4.07	1.17	P-value = 0.621

4.1.2.3 Overall Analysis of Students' Perceptions in the Implicit Inquiry-Based Instruction Group

The students in the control group had experienced the inquiry-based instructional approach without explicit implication to any NOS aspects during science classes. The results of the pretest and the posttest of the control group were analyzed to determine the impact of using an implicit inquiry-based instruction on students' conceptions of NOS. The results of the paired t-test indicated that there is no significant difference, t=-1.579, p-value=0.120. Table 36 indicates that the mean value of the students' responses to the posttest is 3.76 while the mean in the pretest is 3.63.

Table (36): Overall Analysis of Students' Perceptions in the Implicit Inquiry-Based Instruction Group

	N	Mean	Std. Deviation	Paired t-test Statistics
Overall	58	Pretest =3.63	0.42	T = -1.579 P-value = 0.120
	58	Posttest = 3.76	0.46	

The results of the paired-sample-t-test conducted for the clusters have indicated no significant difference between the pretest and the posttest for all clusters except cluster 7. Table 37 shows that there was a significant difference in students' scores, t=-2.472, p-value=0.016. The experimentations made them recognize that science affects the society and the developments that certain civilizations witness in any era. Students' responses indicated that they see a lot of value in technology and its interrelated nature with science.

Table (37): Cluster 7 analysis of students' perceptions in the implicit inquiry-based instruction group

	N	Mean	Std. Deviation	Paired t-test Statistics
Cluster 7: Cultural and Social Embeddedness of Scientific Knowledge	58	Pretest =3.42	0.84	T = -2.472 P-value = 0.016
	58	Posttest = 3.78	0.74	

The results for the paired-sample-t-test comparing the pretest and posttest of the experimental group and for the control group show that cluster 7 has had a significant difference between pretest and posttest with the posttest more agreed than pretest. Furthermore, the results for the paired-sample-t-test demonstrated an increase in the mean values from the pretest to the posttest. But this increase was not a significant difference between the pretest and the posttest.

4.1.2.4 Differences According to Demographics among the Explicit Reflective and Inquiry-Based Instruction Group

The one-way ANOVA Test was used to examine the differences according to demographics among the explicit reflective and inquiry-based instruction group. Table 38 indicates that it is a significant difference for all clusters between gender in the experimental group, t=1.902, p-value=0.060. The mean value of the male scores was 3.54 while the mean value of female scores was 3.37. Additionally, there was no significant difference between the middle and high school Lebanese students in the experimental group after the intervention, t=-1.029, p-value=0.305.

Table (38): Differences According to Demographics among the Explicit Reflective and Inquiry-Based Instruction Group

	Mean	Std. Deviation	one-way ANOVA Test
Overall Clusters	Male = 3.54	0.48	t = 1.902 P-value = 0.060
	Female = 3.37	0.45	
Overall Clusters	Middle = 3.43	0.55	t = - 1.029 P-value = 0.305
	High = 3.52	0.36	

As shown in table 39, the mean value of the male students' scores was 3.5355 while the mean value of the female students' scores was 3.3678. Similarly, the median value of the scores of male students (median=3.4909) was greater than the median value of the scores of the female students (median=3.3941). Table 39 presents the descriptive analysis for the experimental group by gender.

Table (39): Descriptive Analysis for the Experimental Group by Gender

	Male	Female
Mean	3.5355	3.3678
Std. Error of mean	0.05638	0.06644
Median	3.4909	3.3941
Variance	0.226	0.203
Std. Deviation	0.47508	0.45064
Minimum	1.28	1.37
Maximum	4.49	4.2
Range	3.21	2.83
Skewness	-1.187	-1.804
Std. Error of Skewness	0.285	0.35
Precentiles_25	3.2816	3.1579
Precentiles_50	3.4909	3.3941
Precentiles_75	3.8497	3.6145

As shown in table 40, the mean value of the high school students' scores was 3.518 while the mean value of the middle school students' scores was 3.4281. Similarly, the median value of the scores of high school students (median=3.4869) was greater than the median value of the scores of the middle students (median=3.4262). Table 40 presents the descriptive analysis for the experimental group by grade level. Middle school students have M=3.4281, SD=0.54686, while high school students have M=3.518, SD=0.36202. Further descriptive analysis results are presented in appendices J and K.

Table (40): Descriptive Analysis for the Experimental Group by Grade Level

	Middle School	High School
Mean	3.4281	3.518
Std. Error of mean	0.0689	0.04926
Median	3.4262	3.4869
Variance	0.299	0.131
Std. Deviation	0.54686	0.36202
Minimum	1.28	2.72
Maximum	4.49	4.45
Range	3.21	1.73
Skewness	-1.495	0.212
Std. Error of Skewness	0.302	0.325
Precentiles_25	3.1967	3.2464
Precentiles_50	3.4262	3.4869
Precentiles_75	3.68	3.8032

4.2 Qualitative Data Analysis

The qualitative data was obtained from four various sources. First, there was a presentation of the analysis of the open-ended items of the ERIBINOSQ instrument. Then, the analysis of the reflective journal prompts was done using code descriptions and exemplars about the natures of science as well as the approaches used to learn science from student's perceptions. Next, the analysis of the field notes from class observations was presented. Finally, the analysis of the interviews with students was presented.

4.2.1 Open-Ended Items Pretest and Posttest Responses of ERIBINOSQ

Reading through the written free responses that followed the closed five-Likert items, it was evident that most of the student responses witnessed a significant growth from the pretest data to the post-test data. Students were stating what they know about science and the aspects of science based on their experiences in the science classes. While some students were clueless about what they have to write in the pretest about the meaning of science and the aspects of the nature of science, those same students had provided informed answers in their posttest. Furthermore, some students did not answer those questions when they were completing their posttest since they thought that writing the answers in the pretests were enough.

The simplest question “what is science?” seemed weird for almost all students when they had to complete the pretest. Their responses showed that they have never thought that they would be asked such a question. Science, for them, is a name of a subject. It is a label that they have heard about since they were born. They had never thought that one day they will be asked to define it or discuss it neither in school, nor in their real life. Moreover, they had never thought it has a definition. Asking about the definition of science, to them, was the same as asking about the definition of their own name.

After completing the pretests, students were occupied in discussions with their teachers and classmates trying to figure out what does science means and what are the aspects of the nature of science. The researcher observed students doing a research using the internet to find out answers for these questions. Few days after completing the pretests, there were posters in the classrooms with various definitions about science and a corner for posting personal reflections about those definitions. The science teacher reported an increase of inquiries during science classes about the relationship between what they are studying and nature of science. Students were curious to know and to become able to speak confidently about those topics. Even when the researcher collected field notes from class observations, students in their groups were keen about clarifying to each other so many misconceptions about the nature of science in relation to the discussed science content knowledge.

Not only did the experimental group witness change in students responses but also the responses of students in the control group changed. The fact that those two groups were learning science using an inquiry-based instruction approach allowed students to work collaboratively together and to discuss ideas and issues. The use of three categories rubrics, the responses of the students from the pretest and posttest for the open-ended items were categorized as naïve, traditional or advanced. Some of the responses from either the posttests or the pretests are stated here to give an idea about students' responses. Below is a listing for some of the answers that the students provided for each one of the three questions seperately.

Regarding question 1: "What is science?", students provided various definitions based on their collective experience in class as well as real life. From their perceptions science is not like any other subject taught in the class since it resembles a blend of theories and practical experiences. This created a big confusion for them. Even though they thought at first that the science definition is simple, when they started writing their definitions they were either disciplinary specific or practical. Some students defined science as a mere source of knowledge that is to say: *"Science is one of the ways of knowing. Science is the knowledge of everything in the world around us discovered by brilliant scientists", "Science is the way of obtaining knowledge about facts that happen in our everyday life. Science is a subject which is very important to learn since it explains the mechanisms of nature", "Science is the matter of knowing the reasons for everything happening in life, that's why it's made up of 3 parts: Physics, Chemistry and Biology that we can't know anything without them.", "Science is a subject that tells us about many things like nature of science and its mechanisms.", "Science is one of the ways of knowing.", "Science is the knowledge based on observations and experiments and it explains the mechanism of natural systems.",* *"Science is one of the ways of knowing, it explains the mechanism of natural systems using logical arguments, skeptical reviews, and empirical standards."*

Others envisioned science as a systematic justification of the natural phenomena using well-proven theories. This was exemplified by: *"Science connects the patterns of evidence to current theories and it required multiple sources of evidence to support the explanation."*, *"Science is the study of phenomena that happen in this world, it is used to solve incomplete evidence and theories."*, *"Science is the reason why everything happens. It is the set of laws that define life."*, *"Science connects the patterns of evidence to current theories and it provides the process that can be to define, elaborate and extend your knowledge."*

Another group of students considered science an embedded element in their real-life issues. Science provided them with answers and allowed them to live in harmony with nature in an attempt to fit in its harmonic systems. This was illustrated by: *"Science is the explanation of everything happens in life, every phenomenon has a reason and science is the reason of everything like science is the answer of why and how."*, *"Science is the gate to change unsolved arguments and results. Moreover, it is the knowledge you need in everything you do in your daily life."*, *"Science is to know about the real world if we do not have scientists and technology, we cannot know what is the world is about."*, *"Science is a scientific experiment and that results to know more and more about our world."*, *"Science is the study of things in nature in order to conclude, do analysis and discover new things."*

Regarding question 2: "What is the nature of science? Can you specify some of its characteristics?", students provided a definition based on their experiences in the science classes as well as daily life. Mainly, students considered experimentations and observations as the major aspect of the nature of science. Naturally, students understood the practical aspects that they experienced in their everyday life as it is more relevant to their taught, for instance, they said: *"It's a language that talks about living things and it needs experiments to prove every information and science talks about physics, chemistry, and biology."*, *"The nature of science is the rules and facts about science and some characteristics are that it's about completing tasks and doing experiments."*, *"Science is a group of facts that must be proved by experiments. Experiments, facts, and ideas."*, *"Nature of science focus on theories, scientific knowledge. It values observations and experimentations to prove scientific theories."*, *"Nature of science is based on what we see and discover. The experiments shape up science by providing evidence to support or falsify the scientific theories."*, *"Science is the scientific reasons done by scientists. Its characteristics: (1) Help the students think in a scientific way to prove scientific reasons, (2) Help in doing experiments from daily life to prove the scientific reasons are the best to explain a natural phenomenon."*

Furthermore, some students, especially in the high school, has reported the usefulness of resources to reach to accurate conclusions and to develop scientific knowledge theories further. Hence they said: *"Science is influences and technologies. It helps us to know new things."*, *"Nature of science shows how science develops from one generation to another. It focuses on the value of society, technology, and resources."*

Some were impressed by the falsification aspect of NOS. Thus, they said: *"Nature of science has many characteristics. Some of its characteristics: helps in understanding ideas, results in new discoveries, and provides knowledge."*, *"Scientists use the hypothesis to test and prove their explanations and theories."*, *"Nature of science shows how science is dynamic. It changes based on new evidence. Science aims to resolve global issues by* *investigating.", "Nature of science aspects are a scientific theory, scientific method, and tentativeness of science concepts based on new evidence."*

Very few numbers of responses demonstrated an adequate understanding of the scientific method. To demonstrate that, they said: *"Science comes from knowing the reason of every scientific item.", "It's a group of logical conclusions that will lead to other ideas and thoughts."*

Regarding the question item, "How do you best know and learn about nature of science?, students mostly referred to experimentation and observations as the main sources to learn and know about the nature of science. The practical way of learning science used the implicit inquiry-based instruction provided them with a vast experience in the development of scientific knowledge. Experiments were the catalyst of their science learning. The venue for science learning had promoted the laboratory or nature. This was evident in all their responses, for instance, they said: *"I understand science more when we perform experiments in the laboratory", "By doing experiments and explaining new hypothesis will be the best way to learn.", "I learn and know about the nature of science by listening to other opinions. In addition to the experiments performed.", "By researching, experiments, school trips and maybe help.", "I do learn and know about nature of science through experiments, trips, picnics in nature and going to the laboratory.", "We best learn about the nature of science by making experiments.", "I do watch a lot of videos to see how a specific theory developed from one generation to another.", "I conduct experiments myself, record data, and I compare my conclusions with the scientific theories.", "By making projects, explaining, making experiments or showing figures.", "By observations, experiments, and theories.", "By doing experiments, analyzing them to reach a conclusion and study what we took in school.", "In my opinion, I learn about NOS from my school at first and from the daily life that teaches the person."*

In a broader context, students relied on the internet to discover and strengthen their ideas about any issue they faced in their lives. Some of them said that the discovered NOS aspects using technology. Thus they said: *"I search on google, watch experiments on YouTube and more exercises."*, *"By doing experiments that allow me to understand, also by searching on google and of course by listening to the teacher's explanations."*, *"Dive through the internet."*, *"I either ask my teachers or use the internet if I was really curious."*, *"I use google to see how a theory was proven false."*

4.2.2 Reflective Journal Prompts

The reflective journal prompts were qualitatively investigated for themes related to the research items. The themes were derived directly from the data. Two main categories naturally emerged from the data: nature of science aspects related comments and comments that unveiled approaches used to learn science from students perception. Within each one of the two categories, subthemes emerged. Descriptions of the codes and exemplars about the natures of science comments are presented below in table 41. Whereas, descriptions of the codes and exemplars about the approaches used to learn science from students perception comments are presented below in table 42. Exemplars from the reflective journal prompts of high school students and middle school students are labeled RJP-H and RJP-M respectively. Table 41 demonstrates students' responses to the nature of science aspects.

Table (41): Code Descriptions and Exemplars about the Natures of Science

Code	Description of Code comments include:	Exemplar
Scientific Method	Given words used specifically about the variety of methods used to investigate a phenomenon	"NOS explains methods about nature." (RJP-M) "Scientific method allows scientists to discover new ideas, draw conclusions, and interpret natural phenomena." (RJP-H) "Scientists have a scientific mind, they use the scientific method to conduct experiments." (RJP-M)

		"Scientific method can consist of many different steps." (RJP-M) "Scientists use systematic steps to conduct experiments. If the same incident happens with a scientist and a normal person then the scientist will conclude something while the normal person will ignore it." (RJP-H) "The steps used to know new relationship among elements allows the formation of new knowledge in science." (RJP-M)
Empirical Evidence	Given words used specifically to show the importance of observations and experimentations	"Experiments allow us to understand how nature function and to identify the factors that cause a change in nature." (RJP-M) "NOS is all about experiments by scientists." (RJP-H) "Scientists conduct experiments and observations to draw conclusions." (RJP-M) "NOS is tightly embedded in experiments and observation." (RJP-M) "Experiments and observations are at the heart of NOS. The evidence is the essence of NOS, nothing else." (RJP-M) "Experiments and evidence provide evidence, thus the scientific knowledge changes and changes forever." (RJP-H) "Acting like junior students and conducting experiments." (RJP-M) "Observation provides evidence. If a scientist does not observe then he will not know anything." (RJP-M) "Discuss ideas, explanations and experiments are what makes science real and alive." (RJP-M)
Tentativeness	Given words used specifically to stress the changing nature of scientific knowledge	By experiments, we do new activities that help us know nature of science and how it change." (RJP-M) "Information about crops-aphids-lady birds and earthworms is obtained through experiments which allow us to know things that we did not know before." (RJP-H) "Science is interesting, it is something nice because it continuously changes. It is true but it can be wrong if new evidence comes in the way of a scientist." (RJP-M)
Laws and Theories	Given words used specifically to show the different ways	"More information is acquired about natural phenomena by experiments. These facts are classified into definitions, laws, and theories." (RJP-M)

	used to explain natural events	"Experiments, observation and empirical evidence allow scientists to prove theories." (RJP-H) "Models and laws demonstrate how natural phenomena functions." (RJP-M) "Models allow scientists to show their ideas and conclusions." (RJP-H) "Models and hypothesis demonstrate how natural phenomena are interrelated." (RJP-H) "NOS depends upon senses (hearing, touching, tasting) to discover scientific theories." (RJP-M) "Problems motivate scientists to write a hypothesis and test them." (RJP-M) Environmental changes are the main motivation to try to come up with new ways to reduce pollution." (RJP-H)
Meaning of Science	Given words used specifically demonstrating what scientific knowledge is all about	"Science allows us to know accurate information about constants that relate various substances (pH=+0.5)." (RJP-H) Science is nature and daily life experience." (RJP-M) "Experiments help to understand science and draw conclusions." (RJP-M) "Observations is what makes science special." (RJP-H) "Science takes all information from practices we do in our lives." (RJP-M) "Nature is an image of science, thoughts, and concepts." (RJP-M) "Science is nature." (RJP-M) "Science gives us very important information and ideas using evidence from experiments." (RJP-H) "Nature of science describes nature, how it works and the natural laws. Nature is mysterious if it was not for science which is telling us how it works." (RJP-H)
Universal Consistence	Given words used specifically to show that scientific knowledge is the same everywhere	"Scientists do experiments and observations to know about paramecium and tell us about it. All around the world we share the same understanding about paramecium." (RJP-M) "Science is universal, what they discover in any country becomes a fact for all nations." (RJP-H)

Human Endeavor	Given words used specifically to point out the factors that affect science such as imagination, curiosity, technological advances…	“Scientists’ curiosity allowed them to discover about paramecium. So nature of science is all about the curiosity and imagination of the scientists.” (RJP-M) “Curiosity of scientists is the driving force.” (RJP-H) “Usage of resources and how the advanced resources allow scientists to discover scientific knowledge.” (RJP-M)
Inquiries about Natural World	Given words used specifically to show the ethical values, cultural contexts and social values in relation to science	“NOS aspects are related to a society where the scientist conduct experiments.” (RJP-M) “Science and culture are related. The scientist makes discoveries when its environment allows for this. The inventions become valuable only if the society accepts them.” (RJP-H) “Daily life and social life affects the development of scientific knowledge. If the scientist says something and the community consider it a sin then he cannot continue.” (RJP-H)

Students’ perceptions from the reflective journal prompt showed the holistic experience that they had throughout the intervention period. The explicit reflective and inquiry-based instruction group was easily connecting the science concepts to NOS aspects and smoothly writing about it. This clarity allowed the coding of those reflections to be done accurately. All the eight aspects of the NOS were strongly evident in the reflections for both middle and high school students. Science concepts appeared as the opening key for the hidden NOS aspect in every science class. The diversity of the learning opportunities allowed the construction of students’ epistemic knowledge. Students were engaged in lively discussions to distinguish between observations and inferences, scientific laws and theories, and the characteristics of scientific knowledge. Certainly, students’ ability to conduct investigations, to analyze critically and to follow systematic approaches was shaped up by means of exploring NOS aspects in science classes.

Apart from that, students specified their role versus the teacher’s role in every science class throughout the intervention period. Even though the researcher cooperated together with the science teachers to analyze and design the main components of lesson plan such as learning objectives, cooperative learning activities, experiments, real life connections, cross curricular links, and evaluation strategies in an attempt to unify the inquiry-based instructions among all the science classes taking part in this study. The implementation of those planned lessons were not accurately executed in all science classes. Looking at the learning environment from students' perceptions enable the researcher to evaluate the type of inquiry that was used in the science classroom. Thus, the data provided a realistic idea about which type of inquiry-based instruction was used as an approach. Table 42 includes comments that unveiled approaches used to learn science from students perception.

Table (42): Code Descriptions and Exemplars about the approaches used to learn science

Code	Description of Code comments include:	Exemplar
Confirmation Inquiry	Students are involved in a structured learning setup designed by the teacher	"The teacher started with a warm-up then she explained the lesson and we were required to solve all exercises in groups of two." (RJP-H) "Talking about scientists and the progress that they made to discover the theory related to how paramecium cells reproduced. The work done by scientists is logical and driven by data. Evidence count for everything they conclude." (RJP-M) "I learned science today from the explanation my teacher provided in class. The teacher explained the concepts and used flashcards to demonstrate the key concept. I and my friend played a game with the cards. It was fun! ." (RJP-M) "I learned science by communicating with my friends the objectives." (RJP-M) "Science was boring for me today because all that we did was moving around the school to collect garbage and do sorting for garbage." (RJP-H)
Structured Inquiry	Students conduct experiments while the teacher	"The teacher divided the class into two teams and we had a competition game. Each team was provided with a set of organs and a poster for a human body. My team was the

	provides the initial items	winning team because we were very fast in sticking the organs in the right place." (RJP-M) "I learned science by doing experiments and presenting my conclusion to the teacher." (RJP-M) "Today it was a hectic science period. After listening to the teacher, we were sitting in groups of four. The teacher gave my group a long article and asked us to summarize it and to identify key facts then present to the class." (RJP-M) "I had to use my brain a lot! I learned science today by trying to figure out what the keyword is just by having some information about it. It was so strange to me to discover the topic just by having some few details." (RJP-H) "The science lesson today was pretty much an English class. The teacher had a story with many volumes that explains mitosis and meiosis. Each group of four took a volume. At the end of the period, each group went to the board and presented their volume." (RJP-M) "I helped my friends to understand better by modeling the experiment in front of them." (RJP-M)
Guided Inquiry	Students test the hypothesis provided by the teacher	"The teacher walked in with a huge set of items that she got from the moon! The items were weird because any answer is accepted. I and my friends have had a lot of debates about the items. It was interesting because we learned a lot of facts that we have not heard about them before." (RJP-M) "The science class today was similar to an art exhibition, the teacher filled the classroom walls with so many pictures and visual charts. She asked us to move around and try to understand the aim. Even though the sentences were complicated but when walking around we were discussing those sentences together. My friends were helping me a lot. One friend was stubborn and he thought what he understood is right but one poster allowed me to know everything in a simple way." (RJP-H) "The teacher explained the concept and then we started paling a puzzle. In each corner, there were a puzzle and the facts would lead us to the correct piece. It was the first time we have such a thing in the class." (RJP-M) "I learned today science by discussing how the science topics are interdependent. All science topics are facts that we can have discovered. The teacher presented what scientists discovered and how they interpreted the data." (RJP-M) "The period started with a scientific video. We watched the video and then we discussed what we saw with each other. The video was very interesting because it was speeding up the process to show us what will happen across different

		timeframes. We had to do all the work and present the plan and conclusions for the teacher" (RJP-M) "Science was so fun today because we collected garbage and we sorted them out. After that, we have burred them under the soil to see which will decompose and which will remain. The teacher said after 3 months we will dig and check." (RJP-M)
Open/ True Inquiry	Students discover the targets while the teacher facilitates the learning	"Today all that we do is critique what scientists discovered and concluded, I compared and contrasted what my friends did as a model to demonstrate the respiration using a sponge and plastic tubes." (RJP-H) "Going to the lab and conducting experiments. Today we spend the whole science period observing cells splitting under the microscope. I filled my lab report with the data based on what I saw and measured. The accuracy is what makes all my conclusions either correct or wrong." (RJP-H)

The planning process for the intervention aimed to ensure that the approach used is the inquiry-based instruction. Teachers were delivering the science lesson plans in a confident way. The discussions that they had during the preparatory stage made them feel confident about what they are doing in the classroom. Based on the above-mentioned responses in table 42, various types of inquiry were evident in the classroom. While teachers planned for open/true inquiry-based instruction, their implementation in the class have had some missing elements that made students feel guided and directed. Students provided the accurate level of inquiry since they reported what they experienced in the class.

The usage of the reflective journal prompts encouraged students to express their taught and to feel that they are playing an active role in their own learning process. They wrote what they experienced together while conducting experiments, how they have supported each other to draw conclusions, and the type of challenges that they have faced. The peer discussions in the different groups were focused on the validity of the scientific conclusions. Students were writing feedbacks for each other on the reflective journal prompts. They were adding more details to document every single step that allowed them to master the learning objectives. Students were proud to talk about the content of the reflective journal prompts. They were open to peer criticism and eager to hear the feedback of the teacher. In addition to that, teachers were surprised to read the reflections of their students. The comments in their reflective journal prompts were a clear evidence for the level of learning in the science classroom.

4.2.3 Field Notes from Class Observations NOSCOF

The components of the protocol for class observation were analyzed using the stated criteria specified in the Nature of Science Class Observation Form (NOSCOF). Teacher's behaviors and classroom discourse were analyzed using "+: present" and "–: lacking". Additionally, the evidence of NOS was analyzed using "IBI=inquiry-based instructions", "T=traditional", "– = none", and "+=mixed C (Combined Explicit and Reflective) and T (Traditional)".

The analysis of the five consecutive class observations conducted for each of the two middle classes and the two high school classes which constituted the experimental group gave a clear idea about the learning environment and the dynamics of the relationship between the teacher and the students. The total number of class observations was 20. The analysis of the five sections of this protocol is presented below.

Initially, the lesson introduction emphasis section shed the light on the overview provided, lesson relations with other topics, and the assessment of prior knowledge. In almost all classes, the overview of the objectives of the lesson were provided verbally and written on the board to act as a reference point for teachers and students throughout the lesson. In the high school, the science teachers used brainteasers and riddles to deduct the main objectives of the lesson. In the middle school, the overview was teacher driven. With regard to the lesson relations with other topic, teachers intentionally connected science to English through focusing on the meanings of the scientific words. Moreover, connections were made to real-life applications and to technology. For instance, in one class the teacher discussed the fermentation by saying: *"Now after we have discussed the concept of fermentation, I want you to divide into three groups and leave the class to collect garbage from all around the school. This collected garbage needs to be categorized as plastic, food waste or paper. Once you are done, dig three holes and bury each type in one separate hole. In three months from now, we shall dig the holes and observe the fermentation of the buried material. Reflect and connect to what you experience in everyday life."*

In another class, the objective of the class was related to waves, so the teacher took her students to the music room and she asked the music teacher to explain the sound waves. She introduced: "*When music is played inside this music room it reverberates off the walls. There will be the constructive interface between the bouncing sound waves if the band is playing in harmony, whereas, there will be destructive interference if the team is not playing in harmony. Let's show you how…….".*

All teachers assessed prior knowledge using open-ended iteming techniques. Teachers were using prior knowledge as a starting point to determine the starting point of the students and to place students in the appropriate groups based on their interest and readiness. The NOS aspects that were mainly evident in the lesson instruction emphasis section were mainly (a) science is a way of knowing, (b) science models, laws, mechanisms, and theories explain natural phenomena, (c) science addresses items about the natural and material world, and (d) scientific knowledge assumes an order and consistency in natural systems.

Secondly, the modes of instruction during lesson section included eighteen specific types of instruction. More than one mode of instruction was evident in one single lesson.

Teachers used a variety of modes to keep students engaged and enthusiastic about science learning. Among the twenty observed classes, 75% of the classes had experienced teacher demonstration instruction approach, 5% of the classes had experienced lecture instruction approach, and 80% of the classed had experienced cooperative group work. The open-ended inquiry was evident in 40% of the observed classes, while data collection/manipulation had been used in 65% of the classes. Some instruction approach such as recitation, drill and practice, review/correction, and note-book entry of log was not seen in any of the observed classes. Note-taking and whole class were equally used in 50% of the observed classes. The NOS aspects that were evident in the modes of instruction during lesson section were mainly (a) science is a way of knowing, (b) scientific investigations use a variety of methods, (c) science addresses items about the natural and material world, and (d) scientific knowledge is open to revision in light of new evidence.

The iteming level section focused on the iteming level used in the science classes. Teachers were using iteming techniques for the warm-up, connecting prior knowledge to lesson objectives and to motivate students to think and investigate further. In all classes, comprehension and procedural iteming levels were used. Analysis iteming level was used in high school science classes rather than the middle school science classes. Synthesis iteming level was used in 70% of the observed classes. Additionally, evaluation iteming level was used in 40% of the classes. The NOS aspects that were mainly evident in the iteming level section were mainly (a) science addresses items about the natural and material world, (b) science models, laws, mechanisms, and theories explain natural phenomena, (c) science addresses items about the natural and material world, and (d) scientific knowledge assumes an order and consistency in natural systems.

Next, the teacher behavior section included five main criteria that best described the dynamics of the teacher in an inquiry-based instruction science classes. In all the middle school classes, the teachers were explaining and guiding the activities directly. This scenario was completely different in the high school science classes. At that level, teachers were allowing students to plan their experiments, carry out with the investigations, and draw their own conclusions based on the collected data. All teachers were circulating among students and asking both closed-ended and open-ended items. Moreover, teachers were stressing on the relationships between the science content knowledge and real-life applications. The warm-up of the lesson was done through a real-life example and cyclically the activities were derived from real life issues. The usage of ongoing embedded assessment was rarely observed. Teachers had used rubrics to allow students to do self-evaluations for their own progress within the science class. Furthermore, the management of the resources and the class material was assigned to students. All in all, teachers acted as facilitators while students were placed at the heart of their science learning. The responsibilities were continuously assigned to specific individual students or groups of students to enhance their skills and competencies. The NOS aspects that were mainly evident in the teacher behavior section were mainly (a) science is a way of knowing, (b) science models, laws, mechanisms, and theories explain natural phenomena, (c) science addresses items about the natural and material world, and (d) scientific knowledge assumes an order and consistency in natural systems.

Lastly, the instructional materials used during lesson section included all the physical, technological, and demonstration models. The science classes where the study was conducted took place in the science lab. There were a biology, a physical, and a chemistry laboratories. Every time students had science, they went to the lab where their teacher was present there at all times. The lab was equipped with an overhead projector, computer, interactive board, science equipment, and printed reading materials. In every science class, all the motioned resources available at the lab were used in different parts of the session.

4.2.4 Interviews with Middle and High School Students in the Explicit Reflective and Inquiry-based Instruction Group

All middle and high school students in the experimental group which experienced the intervention of a combined explicit reflective and inquiry-based instruction were interviewed. The focus of the interview was to understand their perceptions about NOS aspects. Each student had an independent interview with the researcher. Students felt excited about having the chance to talk to the researcher individually. A notably important note from the students was the lack of proper understanding of the link between what they learned and their understanding of NOS. They did understand the importance of experimentation to come up with hypothesis, yet, they did not see that as the basic component for scientific discoveries. Surprisingly, most of them thought that science had fixed theories that can never be falsified. A middle school student said: *"I used to enjoy experimentation and observation but I have never though that the scientific knowledge was established in this same way. Theories were so abstract for me and obsolete, but now after I linked them to real-world experiences and experiments they make more sense to me and look so real."* For them, social and cultural values were existing factors, but they thought they had nothing to do with scientific evolutions. Some students were looking at science from another angle when they witnessed the changes that have happened to science from one generation to another. The social and cultural factors had redirected scientists' thoughts to look at their initiatives from the nationwide traditions rather than their own perception. A high school student said: *"I used to think that when a scientist discovers something directly people believe it and start implementing it. When the teacher presented case studies about many inventions that were rejected based on the social and cultural belief, I started thinking about my ideas to resolve the issue of garbage in Lebanon. My ideas have to be practical, realistic, and acceptable to all people around me otherwise it will be useless. My* *imagination can provide innovative science ideas but those ideas might be rejected by society."* Students expressed their concerns regarding the lack of proper awareness of the interconnected relationship between science and society. A middle school student said: *"The aspects of science present science as a practice rather than a theory, as a solution rather than a theory, as a fact rather than a myth, and as a reality rather than a dream. Science in its nature provides evidence to improve society and resolve real world issues such as environmental issues. For me, when I learn scientific ideas I immediately think of how and where this can be implemented to improve the society. I do not see a contradiction between society and science, I rather consider them the complements of one another."*

Students were fluently listing the aspects of NOS with reference to what they were learning in science classes. Some were excited to show what they discovered through what they experienced with their teachers. Others were showing how the collaboration with their peers enabled them to build a strong understanding of what NOS is and how it relates to science. For them, the discussions that they had together were the most influential factor that gave meaning for their learning. One middle school student said: *"Nature of science is about the variety of scientific methods, the empirical evidence to support the claims, the social values related to scientific knowledge, and the tentativeness of the scientific ideas. When I discussed the ideas with my classmates, I was more convinced that scientific theories are changeable in their nature. In science nothing is fixed. The data collected from scientific experiments can affect the theories. Either it strengthen the theory or it makes it false. One more thing I want to say, NOS is dynamic. NOS is alive and tightly connected to all the accuracy of the tools used to provide new data which was not known before."* In other reflections, students were talking about the aspects in a confident way which reflects the adequacy of their perceptions after they were involved in the intervention program. One middle school student said: *"the teacher ignited the NOS flame and motivated me to* *understand science through the principles of NOS. Although every time I was conducting science experiments in a new way but I have never thought about the multifaceted of the scientific method. Taking about the imagination of scientists made me understand how Newton was affected by the drop of the apple while millions of people saw the apple falling down but it meant nothing to them."* The NOS aspects that they spoke about were not limited only to empirical evidence. Students were excited about the freedom that they had to design their own plan to conduct the experiments without being dictated by the teacher. Scientific method was explained in detailed by most of them in a very comprehensive way. The logical argumentations was evident when they explained the differences between scientific laws and theories. The learning opportunities allowed them to understand the phases of constructing scientific knowledge. Students experienced science as a dynamic subject. All of the NOS aspects of Lederman's conceptualization model were demonstrated in their responses in the interviews.

Another point that students raised in their interview was the lack of seriousness in answering the open-ended items of the ERIBINOSQ instrument. Almost all students thought that since they answered those items when the pretest was conducted then they did not need to answer them again in the posttest. A middle school student said: *"When I filled the ERIBINOSQ pretest, I wrote everything I know about science and the aspects of the nature of science, when the teacher gave us the posttest I left those questions empty since I my same ID number was written on the questionnaire. I did leave the answers of the questions empty."* Besides, students felt shocked that they were asked to define science. For them, science is a terminology that does not need to be defined. A student said: *"I felt that it was so weird for me to define science, like what do you mean? Science is life. When I eat I use science and nutrition facts. When I move I use science and friction and physics* *laws. While sleeping, my conscious and subconscious is science. Science is learning, experiments, observations, laws, methods….everything…"*

The definitions that students provided for nature of science were so creative. To a certain extent, their ideas were predictive of some analysis results. Their answers connected the NOS aspects to the approach used in the class. Students felt that the inquiry-based instructional approach that is used during the science classes allowed them to become practitioners. At the same time, this approach created difficulties for them to think in an abstract and theoretical way about scientific topics. A student said: *"I was happy to experiment, reflect and collaboratively evaluate my progress with my classmates in the class. I could easily understand some aspects of NOS such as tentativeness, empirical evidence, a variety of scientific method, and consistency in natural systems. Yet, it was hard for me to understand the differences between theories and laws."* Students were excited to explore through the inquiry-based activities, but at the same time, they valued the intentional connections that teachers drew between the NOS aspects and the scientific concepts. A high school students said: *"During the science experiments, me and my friends were concluding the importance of imagination and creativity of scientists when we were doing activities. But we were not sure of how to connect this NOS. When the teacher explained the connection we were able to become more confident about it."* Speaking their freedom of mind during the science class motivated students to excel in their learning. The reflective journal prompts allowed students to take ownership of their learning. One middle school student said: *"I liked the way we learned science about. I wrote what I understood and discovered nit what the teacher wants me to write. It was me who discovered NOS aspects after the experiments and the explanation of the teacher. I do not like to be dictated, I am a grown up and I can learn by own. I wrote what I understood using my own words,* *pictures and diagrams. My reflective notes makes full sense to me. This is something I feel proud of."*

4.3 Summary

The analysis of the data collected using the various instruments was presented in this chapter. Both, the qualitative and the quantitative analysis, provided ample information about the research topic. This information was used to answer the three research questions of this study.

The first question of this research study was: "What conceptions of the nature of science do Lebanese middle and high school students have?". In this regards, ERIBINOSQ questionnaire was used with middle and school students was conducted using a sample of 116 participants in a private school in Lebanon. This question was answered using two sets of data. Firstly, the quantitative analysis of the ERIBINOSQ instrument of the pretest results of all the participants who took part in this research study. The results indicated that students acquire an adequate understanding of NOS aspects since the mean values of all clusters ranged from (M=2.91, SD=0.97) and (M=3.9, SD=0.64). The analysis indicated that female and male Lebanese students have the same perceptions about NOS aspects with no significant difference t=0.579, p-value=0.564. Apart from this, high school students possess a better understanding of NOS aspects than the middle school students. The results of the t-test analysis indicated a significant difference t=-3.168, p-value=0.002. Secondly, the qualitative analysis of the open-ended items of the ERIBINOSQ instrument indicated that all students have a solid understanding of science and the aspects of NOS. Students had provided traditional definitions as well as innovative definitions. They used sophisticated terminologies to show the logical connections to demonstrate their understanding of NOS. This strongly support the results obtained from the analysis of the quantitative data.

The second question: “How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students’ conceptions of NOS?” was answered using multisets of data. The first set of data was derived from the quantitative analysis of the pretest and posttest results of the experimental group which experienced the combined explicit reflective and inquiry-based instruction approach intervention. To start with, the results of the ERIBINOSQ pretest and posttest were meticulously analyzed for the middle and high school students in the explicit reflective and inquiry-based instruction group through analyzing the overall data, each cluster independently, and each question within each cluster. The overall analysis using paired t-test analysis shows that there was a statistically significant difference in students’ scores from the pretest to the posttest, t=-2.353, p-value=0.022 from pretest (M=3.37, SD=0.53) to the posttest (M=3.57, SD=0.39). This implied that students’ perceptions of NOS witnessed a significant change due to the intervention program. All the mean values of students’ scores from the pretest to the posttest increased for all clusters. Besides, the fourth, fifth, seventh, and tenth clusters witnessed a significant change. Secondly, the overall analysis of students’ perceptions in the implicit inquiry-based instruction group paired t-test indicated that there is no significant difference, t=-1.579, p-value=0.120 as indicated in table 36. This implied that using implicit inquiry-based instruction solely does not have a strong impact on improving students’ perceptions of NOS. The qualitative data collected from the interviews, field notes from class observations, reflective journal prompts, and open-ended items of ERIBINOSQ instrument supported the results obtained from the quantitative data. The field notes from class observations provided detailed descriptions of the dynamics of the learning environment inside the science class which placed students at the heart of their learning process using the inquiry-based instruction approach. Among the twenty observed classes, 75% of the classes have experienced teacher demonstration instruction approach, 5% of the classes have experienced lecture instruction approach, and 80% of the classed have experienced cooperative group work. The open-ended inquiry was evident in 40% of the observed classes, while data collection/manipulation have been used in 65% of the classes. Some instructional approaches such as recitation, drill and practice, review/correction, and note-book entry of log was not seen in any of the observed classes. Note-taking and whole class were equally used in 50% of the observed classes. Then, the reflective journal prompts results showed the truthfulness of students' perceptions since they were expressing themselves freely in every science class throughout the intervention period. Two main categories naturally emerged from the data: nature of science aspects related comments and comment that unveiled approaches used to learn science from students perception. All the eight aspects of the NOS were strongly evident in the reflections for both middle and high school students. Science concepts appeared as the opening key for the hidden NOS aspect in every science class. Finally, the analysis of the interviews conducted with all students in the experimental group clarified the inconsistency of their responses in the pretest and posttest of the open ended questions of the ERIBINOSQ instrument. Students were fluently listing the aspects of NOS with reference to what they are learning in science classes. Some were excited to show what they discovered through what they experienced with their teachers. Others showed how the collaboration with their peers enabled them to build a strong understanding of what NOS is and how it relates to science.

The third question was: "How do demographic variables of gender and school level influence middle and high school students' conceptions of nature of science?". This question was answered using two sources of data. The first source was obtained from the quantitative analysis of the demographic variables of the ERIBINOSQ instrument. Using one-way ANOVA test, it was indicated that it is a significant difference for all clusters between gender in the experimental group, t=1.902, p-value=0.060. The mean value of the male scores was 3.54 while the mean value of female scores was 3.37. Additionally, there was no significant difference between the middle and high school Lebanese students in the experimental group after the intervention, t=-1.029, p-value=0.305. The mean value of the male students' scores was 3.5355 while the mean value of the female students' scores was 3.3678. The mean value of the high school students' scores was 3.518 while the mean value of the middle school students' scores was 3.4281. Whereas the second source was obtained from the qualitative analysis of the data obtained from the interviews, field notes from class observations, reflective journal prompts, and open-ended items of ERIBINOSQ instrument. The coding of the reflective journal prompts of high school students and middle school students were labeled RJP-H and RJP-M respectively. The high school students used sophisticated wording to express themselves while middle school students were using simple sentence structure. The four various inquiry-based instructional approaches were visible in both middle and high school science classes. The interviews conducted with students showed that the males acquire a better comprehensive understanding of NOS aspects than the female students. Middle and high school males were logically describing the processes used in the science classroom.

CHAPTER 5: DISCUSSION AND CONCLUSION

This study investigated the impact of a combined explicit reflective NOS and inquiry-based instruction on middle and high school students' conceptions of nature of science. The intervention was designed by the researcher to enhance students' perceptions of the nature of science. The previous chapter presented the results in an elaborate manner to provide a plentiful bundle of information about the analyzed data. This chapter presents, in the first section, the discussion of the main findings of the research study. The second section draws in the final conclusions of the study. The third section presents the recommendations and the suggested areas for future research. The last section shows the limitations of this research study.

5.1 Discussion

The purpose of this chapter is to interpret the research findings in relevance to the reviewed literature and previous studies that were conducted about Lebanese middle and high school students' perceptions of NOS. The discussion focuses on the planning process of science and the instructional approaches in relation with NOS. This was addressed by filling the existing gap within the Lebanese literature that does not succeed to examine the impact of explicit reflective inquiry-based instruction on students' conception of NOS. The alignment between the curriculum and the instructional strategies allows for the successful implementation of a holistic practice to develop scientific literacy skills through acquiring an adequate understanding of NOS. Basically, the study has threefold purpose to: (1) investigate middle and high school students' conceptions of the nature of science (NOS), (2) examine the impact of combined explicit reflective NOS and inquiry-based instruction on middle and high school students' understanding of the nature of science, and (3) investigate the impact of demographic variables of gender and school level on middle and high school students' conceptions of the nature of science. Additionally, the findings obtained using the qualitative and quantitative instruments is presented to address the following three research questions:

1-What conceptions of the nature of science do Lebanese middle and high school students have?

2- How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?

3- How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?

This study investigated the Lebanese middle and high school students' perceptions of the NOS and whether there was a significant change to these views after being in the explicit reflective inquiry-based instruction group. The combined explicit reflective and inquiry-based instruction intervention was designed by the researcher to investigate its impact on achieving a contemporary NOS understanding and an adequate growth of the scientific literacy skills of all citizens. This section presents the discussion related to each research question independently.

The first question was answered using the results of the data analysis from the ERIBINOSQ pretest. The analysis of the pretest results of all participants allowed the researcher to determine the NOS conceptions of the Lebanese middle and high school students. The quantitative data was analyzed using the paired sample t-test statistics and the descriptive statistics data. Furthermore, the qualitative data obtained from the open-ended questions of the ERIBINOSQ were analyzed using code descriptions and listing.

The second question was answered using the results of the ERIBINOSQ pretest and posttest results, reflective journal prompts, field notes from class observations, and students' interviews of the experimental group. This questions aimed to examine the impact of the combined reflective NOS and inquiry-based instruction on middle and high school students' understanding of the nature of science. Thus, the data collected from the experimental group were analyzed and interpreted. The pretest and posttest results were compared to specify the changes that happened due to the intervention. Paired-sample-t-test statistics were used to determine the overall impact of all clusters, of each individual cluster, and of each question within each cluster. The field notes from the class observations provided a clear idea about the dynamics inside the learning environment throughout the intervention. Additionally, the reflective journal prompts and the interviews allowed the researcher to understand clearly the depth of students' thoughts about NOS. Away from all of that, the results of the ERIBINOSQ pretest of the control group were compared to their post test results to identify the impact of the implicit inquiry-based instruction alone. Those results shows the limited impact of the implicit inquiry-based instruction in comparison to the intervention used in this study.

The third question was answered using the results of the data collected from the ERIBINOSQ posttest of the experimental group. The one-way ANOVA test was used to examine the differences according to demographic variables among the explicit reflective and inquiry-based instruction group. In addition, the descriptive analysis for the experimental group by grade and by gender were used to answer this question. In addition, the qualitative data collected from the reflective journal prompts and the interviews provided data about the differences according to demographic variables.

5.1.1 Research Question 1

Research Question 1: What conceptions of the nature of science do Lebanese middle and high school students have?

It was found that Lebanese middle and high school students possessed an inadequate understanding of the NOS, the mean values were ranging between (M=3.24, SD=0.94) and (M=3.9, SD=0.64) for the first eight clusters of the ERIBINOSQ focusing on the NOS aspects. The data collected form the pretest was examined and interpreted to provide a clear picture of middle and high students' conceptions of NOS aspects. Interestingly, middle and high school students were very cautious about their answers when they filled the pretest. They were reading the questions carefully to provide accurate answers in both closed-ended and open-ended questions. Interestingly, they wanted to show their factual understanding of NOS aspects.

The quantitative data analysis indicated that students have an inadequate understanding of NOS aspects. That was evident in the analysis of the first eight clusters of the ERIBINOSQ focusing on the NOS aspects. The mean values were ranging between (M=3.24, SD=0.94) and (M=3.9, SD=0.64). Students acquire a shallow understanding about the scientific method, empirical evidence, scientific knowledge, cultural and social values, scientific models and theories, and tentativeness of scientific knowledge. Their beliefs about scientific knowledge reflected their conceptions of NOS. Scholars (Karisan & Zeidler, 2017; Kampourakis, 2016; Ramnarian & Chanesta, 2016) consider the strong acquisition of scientific knowledge and scientific endeavors as the essence of NOS. The proper understanding of NOS of the students were evident in the clear segregation they made between the states of the world (data) and ideas (hypothesis, theories). As stated in the literature, the argumentations used to support claims by evaluating evidence reflects students' views of scientific knowledge (Hacieminoglu, 2016; Yacoubian and Khishfe, 2018). Students were able to identify science as the epistemology of science and a way of developing scientific knowledge. Thus, NOS aspects were acquired through the process of learning science concepts. Evidence suggests that nature of science is the foremost foundation of science activities (Wolfensberger & Canella, 2015; Ramnarain & Chanetsa, 2016; Fouad et al., 2015; Lederman, 2006) and a crucial factor in developing the scientific literacy (Vázquez – Alonzo et al., 2016). The compatibility of the processes used to deliver the science content allowed students to learn the intrinsic values of science. Students use evidence to provide explanations, observe how the universe operates, and develop models based on proposed theories. As a result of all of this, they develop to become knowledgeable of some NOS aspects. Suggestions from previous studies (Krell, Koska, Penning & Krüger, 2015; Clough, 2011; Çil & Çepni, 2016; Khishfe & BouJaoude, 2016; Vázquez-Alonso et al., 2016) state that students acquire sophisticated knowledge of NOS aspects when they understand proficiently science content and its processes.

The qualitative data analysis indicated that students were able to define science. Those definitions were either traditional or innovative. They connected science to various subjects as well as to real-life applications. Students were valuing the concepts that they have explored in science classes. They were in agreement about the fundamental terminologies that define science. Students could not demonstrate through their answers how they envision science as a way of knowing. Furthermore, they were all able to define the nature of science, yet, they were unable to state all its various aspects. All their answered were focused on one single aspect which is empirical evidence. Almost all students stated that experiments and observations are the only aspects of NOS. Science does not merely rely on empirical evidence to make scientific claims (Lederman, 2007a; Lederman & Lederman, 2014; Lederman et al., 2002). Very few students wrote other answers such as scientific methods, tentativeness, and differences between hypothesis and theories. Students were able to tell that scientific knowledge is based upon evidence and it can change over time, yet they could not specify the role of creativity and social values in the development of scientific knowledge. That is, the participants revealed an understanding of the epistemology of science. This is supported by the findings of the studies which consistently concluded that students possess a naïve understanding of NOS (Torres et al., 2015; Lederman et al., 2002; Vazquez-Alonso et al., 2016).

Going back to the quantitative data analysis of the last four clusters that aimed to investigate the learning environment and instructional approach in the science classroom indicated that students were unsatisfied with their experiences. The mean values were ranging between (M=2.91, SD=0.97) and (M=3.78, SD=0.77). Students were eager to draw their own paths when experimenting. They wanted to design their own experiments, to prepare the material, and to explain their ideas using their own logical arguments. As reported by them, the collaboration opportunities during the science classroom strengthen their understanding of NOS aspects. They were interested in learning science concepts when the delivery approach allows them to discover and to conclude. The review of the literature indicated that inquiry-based instruction allows students to relate scientific knowledge to the issue in light of the real world context (Dalimonte, 2013; Lazaros and Borman, 2013; Cofré Santibáñez Jiménez Spotorno Carmona Navarrete & Vergara, 2018). Tairab & Al-Naqbi (2017) consider inquiry-based instruction as an engaging type of instruction that allow students to construct their own scientific knowledge and to find solutions to various issues. Students were expressing their understanding based on how science was delivered. They were clearly stating their desire to be indulged in inquiry-based learning opportunities. This is supported by the findings of studies (Moss et al., 2001; Bell et al., 2003; Sandoval & Morrison, 2003; Dagher et al., 2004; Schwartz et al., 2004) in which inquiry-based learning is considered a fundamental component to promote students' NOS understandings. The inquiry is a multifaceted activity to develop the understanding of science and to activate the goals of scientific literacy (Forawi, 2010). Engaging students in experiments, predictions, and investigations allowed them to understand the “how and what” of science.

There are grounds for believing that students have not experienced science concepts as relevant issues in everyday life. This prevent students from becoming able to resolve innovatively daily life problems. The mean value was M=3.56, SD=0.73. They fail to see science as a collection of interesting topics that guides them in becoming scientifically skillful citizens able to take responsible daily decisions to resolve various issues. This finding is backed up with the recommendations made by (Torres et al., 2015; Smith et al., 2012; Serdar Koksal &Tunc Sahin, 2014; Forawi, 2011) about the need to prepare students to take decisions as informed citizens regarding social issues by connecting the science content to real world issues. The aim of science education is not a pure acquisition of knowledge. It has to be focused on enhancing students’ scientific literacy using a conventional approach. As indicated in the review of the literature, very little attention is paid in the Lebanese school to use approaches to deliver science content knowledge and to improve their understanding of NOS aspects (BouJaoude et al., 2011; BouJaoude, 2003; BouJaoude, Abd-El-Khalick & El-Hage, 2009).

As a conclusion, Lebanese students’ conceptions of NOS is inadequate and it needs further development. They were so focused on one aspect of NOS. This indicates that there is a need to enhance their traditional views of the NOS conceptions. These findings are in agreement with those obtained by many researchers stating that in Lebanon, students’ have various conceptions of the aspects of NOS (Griethuijsen, Eijick, Haste, Brok, Skinner, Mansour, Gencer & BouJaoude, 2015; Sarieddine & BouJaoude, 2014). Despite the responses obtained in the quantitative data, the qualitative analysis revealed the inadequacy of the conceptions of the participants. This result confirms what was concluded in the research studies conducted in Lebanon which concluded that students hold inadequate conceptions of NOS that tend to have traditional views of NOS (BouJaoude et al., 2011; BouJaoude, 2003; BouJaoude, Abd-El-Khalick & El-Hage, 2009).

5.1.2 Research Question 2

Research Question 2: How does a combined explicit reflective NOS and inquiry-based instruction influence middle and high students' conceptions of NOS?

Lebanese middle and high school students have experienced the combined explicit reflective and inquiry-based instruction intervention. The duration of the intervention was fourteen weeks. This intervention was designed to entail the enclosure of NOS learning outcomes in the curriculum mapping design as well as the instructional sequence. The explicit reflective has had the curriculum implication and the inquiry-based instruction has had the instructional implications. Together the combined explicit reflective and inquiry-based instruction intervention provided a holistic intervention to change students' traditional and non-traditional views of NOS into more contemporary.

The findings of this study indicated that the combined explicit reflective and inquiry-based instruction has significantly enhanced students' conceptions of NOS aspects. The paired t-test analysis of all the clusters indicated that there was a significant difference in students' scores from the pretest (M=3.37, SD=0.53) to the posttest (M=3.57, SD=0.39), t=-2.353, p-value=0.022. The intervention has impacted significantly the students' NOS views. This finding is consistent with the results obtained by Lederman & Lederman, 2014; Bloom et al., 2015, Wolfensberger & Canella, 2015, Khishfe, 2008; Akerson, Hanson & Cullen, 2007. The association of explicit-reflective teaching with inquiry-oriented pedagogy allowed students to be engaged in problematic situations that developed their NOS perceptions. Even the most recent review of literature appraised the use of NOS-explicit and implicit NOS instructional approaches instructional to improve participants' views of NOS (Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018; Cil & Cepni, 2016; Karison & Zeilder, 2017). Thereby, the explicit-reflective teaching approach is the most promising way to teaching NOS (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2006; Dagher et al., 2004; Lederman, 2006; Smith & Scharmann, 2008; Wolfensberger & Canella, 2015). Wilcox and Lake (2018) stress on the need to explicitly incorporate NOS aspects into a variety of activities throughout the process of science learning. Although the explicit-reflective teaching approach could be associated with many pedagogies such as modelling approach, experiential learning approach, and direct teaching approach. However, the success of this designed intervention confirmed that inquiry-based instruction approach is very compatible with the explicit-reflective teaching approach. Many researchers (Khishfe, 2008; Akerson, Hanson & Cullen, 2007, Khishfe, 2008; Küçük, 2008; Akerson, Hanson & Cullen, 2007, Bou Jaoudi et al., 2011; Cil and Cepni, 2016) consider inquiry-oriented approach as the most convenient way to implement the explicit reflective approach.

The analysis of the clusters demonstrated a significant difference in the results of four clusters. Firstly, students' perceptions about scientific models and theories have changed significantly. In particular, their perceptions of the differences between science models, theories, and laws significantly developed. They were able to distinguish between laws, theories, and models with a clear understanding that Theories are validated by evidence whereas time doesn't transform theories into facts or laws. They valued empirical evidence as a body of facts that have been repeatedly confirmed through experiments and observations. In addition to that, students were able to see in practice how scientific theories to explain natural phenomena scientifically. This aspect is considered a fundamental component in establishing an adequate understanding of NOS. This result concur with many studies (Lederman, 2007b, Lederman, 2007a, Karisan & Zeidler, 2017, Krell, Koska, Penning & Krüger, 2015; Clough, 2011; Çil & Çepni, 2016; Khishfe & BouJaoude, 2016; Vázquez-Alonso et al., 2016) conducted in the past which sought to stress on the importance of recognizing the tentativeness of scientific theories in relation with empirical evidence to establish a strong NOS understanding.

Additionally, students' perceptions about the nature of science have changed significantly. Students were connecting their experience in the science learning environment to establish a multi-dimensional definition of science. They were able to see science as a process, a route, and a skeptical review of everything that the ancestors have discovered. For them, science was not only a set of laws to explain natural phenomena scientifically, but it was also a logical process that refines, extend, and enhance their knowledge. Students were confident about providing logical justifications to resolve issues. This finding is in line with the literature that highlights the role of develop scientific literacy and adequate views of NOS which results in assuring informed and active citizens (Et & Memis,2017; Torres & Vasconcelos, 2015; Forawi, 2011; Forawi, 2010; Forawi & Liang 2011; Serdar Koksal &Tunc Sahin, 2014; Forawi, 2011).

Thirdly, high and middle school students' perceptions about the relationship between science and social values have witnessed a significant change. The explorations that they have made allowed them to realize that technology, social values, cultural believes, imagination and creativity either have a direct or an indirect influence on science. Students were using a variety of resources to investigate the hypothesis in an attempt to draw conclusions. They were roaming around the school to collect artifacts and through testing the collected evidence they discovered the concepts. They concluded that science affects the society and the developments that certain civilizations witness in any era. The technology tools allowed them to look back to the early era when the scientific knowledge started to evolve. This allowed them to understand the relationship between different cultures and backgrounds and the advancement of science. Students collaborated together to conduct experiments. Sometimes they were in agreement and other times they have had conflicts in opinions. This created debates and arguments, but eventually, they were able to draw similar conclusions.

Fourthly, high and middle school students valued the inquiry-based instruction approach used in the science class. They were excited about the learning activities and tasks which placed them at the heart of their learning process. They collaborated, discussed, and tried their own ideas. For them, science was alive through experimentations and observations. They ended up looking at science as a stimulation process rather than a mere collection of facts. Scientific experiments ignited in them the curiosity to look for more when collecting information. They were conducting experiments eagerly to unfold the mystery behind the theories stated in their textbooks. For them, collaboration played a very important role in allowing them to understand the differences and similarities of their thoughts and opinions. Additionally, students were excited about proposing new ways to conduct their experiments. They designed models from recyclable material, collected items to reuse it, and wrote procedures to reduce the consumption of resources at the school. The result of these practices is tightly connected to the theoretical framework of this study which considers social interaction as a catalyst that allows the development of thoughts in the light of what individuals experience in their everyday life (Amineh & Asl, 2015; Vygotsky, 1986; Bailey & Pransky, 2005; Karisan & Zeidler, 2017).

The analysis of the items of the ERIBINOSQ indicated an increment in the mean values of all questions. This clearly demonstrates that the intervention has improved students traditional and non-traditional conceptions of NOS. This confirms the review of the literature which concluded that the explicit-reflective teaching approach is the most promising way to teaching NOS (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2006; Dagher et al., 2004; Lederman, 2006; Smith & Scharmann, 2008; Wolfensberger & Canella, 2015).

Two items in the ERIBINOSQ aimed to investigate students' perceptions about the singularity of the evidence collection methods in science and the willingness of being dependent on the teacher as the main source of information in the science class. The mean values of those questions decreased from the pretest to the posttest. For the first item, the decrease demonstrates the positive change in students' perceptions about the singularity of evidence collection. This question raises the inquiry about the possibility of having only one single way to collect and interpret the evidence. After the intervention, students were more convinced that there are multiple ways of collecting and interpreting evidence about a natural phenomenon. For the second item, the decrease in a mean value was expected because students prefer to discover the scientific facts by themselves rather than being dependent on the teacher. Before the intervention, students indicated that they prefer to rely heavily on the teacher to understand science topics. They have considered the teacher as the main source of information. After they have experienced the inquiry-based instruction approach, they felt more interested in discovering everything on their own. This indicates that they were enjoying the new approach that was designed for the aim of this study. The results of the qualitative data collected using the reflective prompts, the field noted from class observation, and the interviews provided an in-depth understanding of students' perceptions of NOS aspects.

The findings from the ERIBINOSQ open-ended questions indicated that students' expressed views of the aspects of NOS were aligned with their expressed views of the similar items of the ERIBINOSQ. This support the quantitative results that indicated that students have an in-depth conceptions of NOS and the possession of a solid scientific knowledge background. They defined accurately science and the aspects of the nature of science to show that the views that they have developed are neither traditional nor naïve. After being indulged in inquiry-based instructional approach, students became self-directed, skillful and lifelong learners. Evidence from a literature review (Crismond, Gellert, Cain, and Wright, 2013; Dalimonte, 2013; Lazaros and Borman, 2013) state that students in an inquiry-based learning environment develop their critical thinking skills to become life-long learners. Students were able to understand the content and processes of science through experiments, predictions, and investigations. The personal and social experience allowed them to develop a holistic perception of science. Given the importance that the social interaction, cultural influence, and the real-life experiences as main components of the individual's knowledge acquisition. Much research has been done in the past to emphasize on the theoretical perceptions of Vygotsky's social cognitive theory that envisions collaboration and communication as the basis of learning (De Vaenzuela, 2002; Oakes and Lipton, 2003; Amineh & Asl, 2015; Woolfolk et al., 2010). Culture and social interaction have a deep impact on learning and knowledge (Mvududu & Thiel-Burgess, 2012; Amineh & Asl, 2015).

In a broader context, students were keen on stating all the aspects of NOS and relating them to the learning experiences that they had as indicated in chapter 4, section 4.2.2. They specified in their reflective journal prompts how they have established the relationships between the eight understandings of the nature of science. This indicates that students have moved towards an informed view of NOS due to the structured opportunities that allowed students to be engaged in collaborative discourse about NOS aspects. As anticipated from the literature review, reflective teaching is a strategy that motivates students to investigate science learning experiences in an epistemological framework (Abd-El-Khalick and Akerson 2009, Akerson, Hanson & Cullen, 2007; Khishfe, 2008; Abd-El-Khalick, 2013).

Students strengthened their understanding through discussing scientific practices in an appropriate science context and reflecting about the problematic situations by asking questions, investigating ideas, obtaining data, organization, and analysis of information, and providing evidence-based answers to the problem situations.

Moreover, when observed in the classrooms, students were more argumentative than receptive. They were at the heart of experiencing the process of knowledge creation. Thus, they became skillful in collecting data from observation, generating procedures, and drawing accurate conclusions. The implicit inquiry-based instruction approach used allowed students to see in practice how the scientific laws explain real-world issues, yet it doesn't have a significant difference in enhancing students' conceptions of NOS unless NOS aspects are intentionally discussed in relation with science content knowledge. Research indicates that Students in an inquiry-based learning environment develop their critical thinking skills to become life-long learners (Crismond, Gellert, Cain, and Wright, 2013; Dalimonte, 2013; Lazaros and Borman, 2013; Cheung, Slavin, Kim & Lake, 2017; Chinn, 2017; Khishfe, Alshaya, BouJaoude, Mansour & Alrudiyan, 2017; Adedoyin & Bello, 2017; Et & Memis,2017).

The final construct, the combined explicit reflective and inquiry-based instruction have caused a major improvement in students' views of the NOS aspects. This intervention was successful at all levels since it has a curriculum implication and an instructional approach. The intentional explicit discussions of NOS themes using inquiry-based instructional approach caused a change. The intervention was designed carefully with a clear identification of the relationship among articulated assumptions, designed intervention, and required outcomes. Given the importance of the Theory of Change and other researchers (Stein and Valters, 2012; Weiss, 1995) in creating an authentic foundation for the designed intervention with clear criteria lists and guidelines. Even though NOS does not exist independently as a prominence but the connections to science topics are either listed in the crosscutting connections section or the practices section of the foundation box. The results of this study come to confirm the recommendation done by McComas & Nouri (2016) which state that a wholesale revision for NGSS framework is needed to include NOS aspects explicitly rather than embed them within sections.

5.1.3 Research Question 3

Research Question 3: How do demographics variables of gender and school level influence middle and high school students' conceptions of nature of science in the context of a combined reflective explicit NOS and inquiry-based instruction?

As evidenced by the findings outlined in the results and analysis chapter, gender was the most influential variable among all other demographic variables. There was a significant difference between males and females not only at the level of the results of the quantitative data but also at the level of the qualitative results. Males are more inclined than females to stress their prior knowledge and personal qualities. They were looking for evidence using logical steps to draw systematically organized conclusions. Males were trying hard to draw conclusions while females were reluctant about the way they design and execute their plans. Changes in NOS understandings of males compared with males were not equal. Students of both genders have different gains. The most striking differences were found among science aspects related to the relationship between science and cultural and social values. Britner and Pajares (2006) states that the scientific passion of males is unlike females. The review of current research (Khishfe, 2004; Khishfe, 2008) suggested that explicit instruction with a combined instructional approach effectively improves NOS conceptions, yet none of the studies investigated that from the lens of gender. Females feel that science is not as appealing to them as a subject, thus they tend to invest little effort and time to solidify their understanding. It has been documented that science instruction often marginalizes females (Bianchini et al., 2003; Tan & Barton, 2010; Barton, 2002; Basu & Barton, 2007).

With regards to the grade levels, there was no significant difference between middle and high school students. Both possessed the same perceptions of NOS. Both groups felt that doing science is refining their scientific literacy skills. Specifically, targeted NOS aspects provided an opportunity for students to see science as a body of knowledge. The comparative analysis of the data from the pretest and the posttest indicated that all students had improved significantly whether they were high or middle school students. This indicates that the designed intervention is suitable for both the middle and high school age groups. The use of the implicit inquiry-based instructional approach created a positive learning environment that empowered students to participate in authentic learning opportunities that improved their skills and competencies. In specific, the designed activities helped students to cross the borders between the scientific knowledge acquired in the classroom and the experienced scientific knowledge in their daily life. Whether being a middle or a high school student, the learning opportunities encouraged the development of scientifically literate students through improving their understanding that the scientific endeavor is tentative and creative with multiple interpretations to explain the natural phenomena. The field notes from class observations confirmed the students' abilities to make informed decisions and to decide about the quality of scientific claims. Several studies have been brought to light that a scientifically literate person is expected to make informed decisions about scientifically-based issues, to weigh the claims and evidence, and to compare the characteristics to the nature of science aspects (Lederman, Antink & Bartos, 2014; Wolfensberger & Canella, 2015; Lederman, 2007a). The inquiry-based instructions used to intentionally focus on NOS aspects resulted in developing the informed views of NOS and at the same time in applying these views of NOS in their science classroom practices. Previous research has concluded that scientific literacy aims to provide students with scientific knowledge foundations (Forawi, 2010; Forawi, 2011; Forawi & Liang, 2011) and to prepare them to make decisions as informed citizens regarding scientific and social issues (Torres et al., 2015; Smith et al., 2013; Serdar Köksal & Tunç Şahin, 2014; Forawi, 2011).

5.2 Conclusion

The continuously evolving global demands are requiring skillful citizens capable of resolving various challenging issues. In specific, Lebanon is continuously facing various challenges related to economic crisis and environmental pollution. Thus, deliberate speed must be taken to enhance the scientific literacy of citizens in an attempt to become capable of taking logical decisions to as members of the society. The achievement of this noble goal happens only when the youth uses the science content and practices in the real world. This calls for the need of integrating NOS, which is the backbone of scientific literacy, intentionally in K-12 science education and using an implicit approach to implement it.

The purpose of this study was to examine the impact of a combined explicit reflective NOS and inquiry-based instruction on middle and high school students' conceptions of nature of science. From the findings of ERIBINOSQ questionnaire, reflective journal prompts, field notes from class observations and interviews, it can be concluded that the combined explicit reflective and inquiry-based instruction has a major positive impact on enhancing middle and high school Lebanese students' perceptions of NOS aspects. The findings of this study suggest many implications for the instruction of NOS. Mainly, three major conclusions were drawn based on the results of this study. Each one of those conclusions is discussed in depth in the following paragraphs.

5.2.1 Cultural and Social Development in relation with Implicit Teaching Approach

The first conclusion relates to the observations made for both the experimental and the control group. It was notable that both groups had significant improvements in the perceptions about the interrelation of social and cultural values and science. This suggests that the unified implicit inquiry-based approach used for both groups have provided the same impact in one specific cluster. Implementing inquiry processes allows students to design explorations but it is not enough to provide insightful ideas about NOS. NOS views do not necessary develop by an inquiry based science class (Ayvaci, 2007; Abd-El-Khalick, 2013). Students' views about the vital role that the social values play in the development of scientific knowledge have changed significantly. The learning opportunities allowed students to have a hands-on experience while mastering the content knowledge. Previous research has found that inquiry-based learning is a form of self-directed learning that develops the students' critical thinking skills to become life-long learners (Crismond, Gellert, Cain, and Wright, 2013; Dalimonte, 2013; Lazaros and Borman, 2013) and at the same time, it strengthens their NOS understandings (Moss et al., 2001; Bell et al., 2003; Sandoval & Morrison, 2003; Dagher et al., 2004; Schwartz et al., 2004; Spronken-Smith, 2012). The inquiry-based instructional approach created an environment conducive to learning science by doing. Students were experimenting in their own environment and interpreting data using their own social values. This allowed them to compare their own judgments against what is documents in the resources. Hence, they concluded in a practical way the influence of science on social and cultural values. Previous research considers inquiry-based instruction as an inductive method is a student-centered approach (Kember, 1997; Spronken-Smith, 2012), a learning by doing approach (Gibbs, 1988; Healey & Roberts, 2004; Prince and Felder, 2006), and a technique that develops self-directed learning skills. This conclusion is in agreement with various studies conducted by Forawi (2010), Cil & Cepni (2016), Adedoyin & Bello (2017) and Sproken-Smith (2012).

Inquiry based instruction approach allows students in both experimental and control groups to explore scientific knowledge and to develop lifelong learning as a habit of mind. Students developed NOS understanding through exploring science concepts. For them, their learning took place through personal and social experience. Guided by Vygotsky's Social Cognitive Theory, the social construction of knowledge happens in the light of what individuals experience in their everyday life. The collaboration among a group of students allow each member to reflect about the learning targets and to hear the point of views of other peers. It allows students to come up with their own explanations to draw logical conclusions together. The peer discussions brings students closer to establish knowledge of scientific inquiry.

Moreover, justifying the conceptualization of Duschl and Grandy (2013) expilict NOS instruction model in its second version, this conclusion confirms the necessity of engaging students in learning science to develop scientific knowledge. Duschl and Grandy (2013) insist in the urgency for all learners to connect concepts through discussing controversial issues about evolving nature of knowledge.

5.2.2 Combined Curriculum and Instructional Implications

While working on the curriculum mapping design is an important planning component, but this does not ensure the development of the skills of students. From another angle, using a student-centered strategy without having a well-designed plan does not provide the teacher with clarity on what needs to happen in the class. The curriculum implications and the instructional implications have to be paired. A clear connection between the learning opportunities and the aspects of the nature of science lead to strong student conceptions pertaining to the differences among the prior NOS conceptions. Thus, the two components have to be well designed ahead of time. The strength of the study relies in allowing students to develop strong metacognitive and cognitive abilities. Students were not only involved in inquiry-based instructional activities but they were also taught intentionally NOS aspects and allowed to reflect on what they experienced. Those three components complemented each other in the science learning process. Thus, the scientific literacy skills were noticeably improved. The well-structured curriculum mapping design based on NGSS standards framework was delivered using a suitable instructional approach allowing students to construct knowledge of scientific inquiries with a variety of activities to reflect about their experiences. This resulted in a holistic authentic learning. Students were proving high capability of resolving innovatively various emerging issues while experimenting and observing to master the learning targets. The acquisition of an adequate NOS understanding was expected to happen based on the established learning environment. The advanced NOS perception empowered students to demonstrate their scientific literacy skills in various situations.

This intervention was fruitful due to the combination of the explicit reflective teaching and the inquiry-based instruction. The review of the literature indicated that even though a variety of pedagogies can be used in explicit reflective approach, inquiry-oriented pedagogy is the most widespread (Akerson, Hanson & Cullen, 2007; Khishfe, 2008; Abd-El-Khalick, 2013; Wilcox & Lake, 2018; Cofré et al., 2018; Yacoubian and Khishfe, 2018; Karisan & Zeidler, 2017). Following the criteria of the explicit reflective model, the planning intentionally focused on NOS aspects in relation to the science concepts. Whereas, the inquiry-based instruction was used as an approach to delivering the intentional NOS planning model. This resulted in a holistic intervention that affected positively students' perceptions of NOS aspects. Many scholars indicated that the explicit-reflective teaching approach is the most promising way to teaching NOS (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2006; Dagher et al., 2004; Lederman, 2006; Smith & Scharmann, 2008; Wolfensberger & Canella, 2015), yet (Abd-El-Khalick, 2013; Nussbaum, 2008; Smith & Scharmann, 2008) insisted to complement it with structured opportunities to allow students to be engaged in collaborative discourse about NOS aspects. This conclusion connects the theoretical framework in chapter two with the empirical evidence presented in the fourth chapter. All the phases of this study were designed based on the Theory of Change model. Thus, the researcher was able to measure accurately the degree of change in students' conceptions of NOS. The two preconditions, the curriculum factor and the approach factor, formed the basis of the intervention which resulted in successful outcomes. The relationship between the outcomes and the preconditions was defined to provide a logical link between the planning of the intervention, the implementation of the intervention, and the evaluation of the impact.

The results of the combined effect of the alignment of the curriculum and the instructional approach in this study confirm what other scholars concluded about the influence of explicit reflective inquiry based instructions (Cil & Cepni, 2016; Vazquez-Alonso et al., 2016; Seckin Kapucu et al., 2015; Karison and Zeidler, 2017). Thus, the study proved that the combination between the two factors contribute to building a better NOS perception. The curriculum has to state explicitly the relationship between the science standards and NOS aspects. The most recent studies (McComas and Nouri, 2016; Wilcox and Lake, 2018) were calling for a thorough review for the NGSS curriculum Framework to dedicate one specific section under every standard for NOS aspects. At the same time, the instructional strategy has to focus on creating various opportunities to allow students to experiment and conclude. Though explicit reflective is identified as the most effective approach (Allichin, 2014; Khishfe, 2008; Bloom et al., 2015; Lederman & Lederman, 2014; Wolfensberger &

Canella, 2015), they recommend additional modifications to increase its effectiveness in developing students' conceptions of NOS. Interestingly enough, Yacoubian & Khishfe (2018) insist that the success of explicit NOS instructional approaches have been limited. On top of that, the alignment between the curriculum and the instructional approach has to be well structured and studied. In addition, conducting studies that focus only on curriculum and approaches is not enough unless there is a clear understanding of the adequacy of students' perceptions of NOS. This conclusion was a common concern for many researchers who were calling for conducting studies focused on understanding students' perceptions of NOS aspects rather than investigating the approaches used to acquire scientific skills (Vazquez-Alonso Manassero-Mas Garcia-Carmona & Montesano De Talavero (2016); Bello and Adedoyin (2017); Griethuijsen Eijick Haste Brok Skinner Mansour Gencer & BouJaoude, 2015; Sarieddine & BouJaoude, 2014; Khishfe Alshaya BouJaoude Mansour & Alrudiyan, 2017).

One of the most striking issues nowadays is developing the scientific literacy skills among the new generation. The intervention allowed students to explore the occurrences in the real world. The collective evidence from the various resources of data confirmed the high metacognitive and cognitive abilities of students to manage real world challenges. The review of the literature confirms that the possession of a thorough understanding of scientific concepts makes an individual scientifically literate (Sarrieddine & BouJaoude, 2014; Lederman, 2006), able to make informed decisions about societal and personal issues (NRC, 2013; NSTA, 2003), and logical in drawing conclusions (Serdar Köksal & Tunç Şahin, 2014; Forawi, 2010). The accessibility of students to the aspects of NOS allowed them to become scientifically literate (Lederman, 1999; Lederman, 2007b). Hence, as a closure, the combined explicit reflective and inquiry-based instruction is a holistic science model that enhance the scientific skills through building an informed NOS conceptions for students.

5.2.3 Communicating Science to Construct Literacy

In spite of diversity in wording, the findings have shown that students become excited about what they are doing once they take part in their own learning. Giving them the opportunity to express themselves whether verbal or in written motivate them to state their opinion about drawing conclusions. In this study, the reflective journal prompts and the collaborative learning opportunities empowered students. Students were engaged in collaborative discourse about NOS aspects using the reflective approach (Abd-El-Khalick, 2013; Nussbaum, 2008; Smith & Scharmann, 2008). Working together allowed students to find answers for themselves by redirecting one another. It also helped them to understand the world together through experimentations and observations. They were debating, collaborating, and criticizing to reach a common understanding together as a team. Students were participating actively in the science lessons with the feeling of the ownership of their own knowledge. Hence, it boosted their self-confidence in science and its aspects and inspired them to excel in their own learning. With such a learning environment, the enhancement of scientific skills was a guaranteed result.

Furthermore, students were excited about using the reflective notes to specify their academic and personal feedback. They were documenting every step during experimentation to share it with their peers and their teacher. It was evident that the reflections were a successful practice which contributed a lot to the success of the planned intervention. Reflective process allowed the researcher to discover the world through the eyes of the participants (Çimer et al., 2013; Maree, 2007). Students witnessed the benefits of the designing learning opportunities when they were discussing in groups the various inputs of their peers based on the reflective journal prompts.

The multiple research methodologies used for this topic of this research study showed that students had been able to apply scientific knowledge in different ways, to evaluate the validity of knowledge in different contexts, to validate the information documented in visual or written texts, and to use the language of science for interpretations. Thus, their scientific literacy skills were proficiently developed. The reflective journal prompts clearly demonstrated their possession of a thorough understanding of scientific concepts to make informed decisions about social and personal issues. Students were able to understand the “how” and “what” of science. Thus, the findings from this study lend a support for the recent studies conducted by educator (Cheung et al., 2017; Khishfe et al., 2017; Sarieddine & BouJaoude, 2014; Vázquez-Alonso et al., 2016) who were calling for examining the impact of explicit reflective and inquiry-based instruction on students’ perceptions about nature of science.

5.3 Implications of the Study

The outcomes of this research study have various theoretical, empirical and practical implications to enhance the perceptions of students of NOS aspects in Lebanon. The theoretical implications of the study are related to the theoretical framework and the review of the relevant bodies of literature. Vygotsky’s Social Cognitive Theory, Lederman’s Conceptualization of NOS Model, and Theory of Change were supportive to reach a clear theoretical mapping. The previous studies reviewed in the literature chapter showed the value of this research study.

The empirical implications of the study are tightly related to the mixed method approach used for the purpose of this research study. In particular the use of the reflective journal prompts throughout the fourteen weeks of the intervention provided a plentiful and an in-depth information about the quality improvement achieved throughout this specific intervention by each individual student. The field notes from class observations aimed to understand the dynamics of the learning environment in the science lessons. Interviewing students on individual basis have been very helpful to confirm the open-ended question responses in the pretest and posttest ERIBINOSQ. The usage of the four various instrumentations aided in the authenticity of the research study.

The practical implications for local and global science educators that are keen on enhancing students' conceptions of NOS are related to looking at the structure of the curriculum outlining the science content. Looking at the NGSS Framework structure it is clear that there is no dedicated section under each standard for NOS aspects. The main framework does not have any clear connection between the standards and nature of science aspects. Instead, there was a dedicated Appendix (NGSS: Appendix H, 2013) dedicated to the eight understandings of NOS in relation to the different phases from K-12. The complete absence of the nature of science from the main framework makes it look as a secondary component of the science curriculum. Science teachers consider the NGSS curriculum Framework as the main reference for their planning process. They use its components to design their lessons. Even though some important features are isolated in different appendices, yet they consider what is in the framework as the primary focus while the other NGSS appendices are secondary sources of information. Specifically, the curriculum is considered the main point of reference for science teachers. It provides all the essential aspects needed to design a comprehensive lesson plan. Having more than one document to complement the main curriculum framework tends to be misleading for teachers. The teaching profession is becoming very demanding with this ever-changing world. Thus, policymakers have to design practical frameworks which include all the needed information in one single document. For instance, NOS aspects have to be clearly stated in relation to each domain in every grade level throughout the science curriculum. Teachers need to see the relationship in a clear manner, rather than guessing how to integrate it with science learning. Based on the positive results of this study, the policymakers have to reconsider how the NOS aspects are integrated within each standard. Teachers need to have those connections visible to be able to plan for their instructional strategies. Thus, it is recommended that educators look at a way to introduce nature of science aspects to become visibly seen in every science reference.

Furthermore, teachers play a major role in the teaching and learning process. Investigating teachers' views of NOS provides an idea about their performance in the science classroom when they will attempt to teach NOS aspects. Teachers who are confident about their knowledge tend to deliver an outstanding science lesson which strengthen the scientific literacy skills and connects the scientific knowledge to the aspects of the nature of science. They become able to tailor the lessons to meet the needs of the individual students. When teachers possess proficient scientific literacy skills, they will train their students to become scientifically literate. On the contrary, if the teachers are not sure about their NOS understanding, then they tend to avoid discussing those aspects in order not to reveal their weaknesses in front of their students. For that, it is recommended to look at the embeddedness of NOS aspects in teachers' training programs and preparatory courses at universities. Such education programs provide teachers with practical ways to embed NOS in science learning. Teachers need such programs to acquire an adequate NOS perception, to read science standards, and to use the appropriate approach to teach science. When teachers feel confident about the process of integrating NOS with science concepts then they start doing that spontaneously with their students. Teachers need to be empowered to become able to show students the links and relationships between NOS aspects and their science learning objectives. Moreover, some teachers have graduated since a long time, thus they are not familiar with the latest trends in education. They did not experience inquiry-based instructional approaches neither when they were high school students nor when they were college students. They need to be continuously educated to stay up-to-date with the latest innovative approaches to engage students and motivate them to become lifelong learners. Organizing professional development sessions that aim to share best global practices is essential for educators. It provides them with a variety of ideas to pilot in their science classrooms. In specific, a lot of studies (Michel & Neuman, 2014; Peters 2012; McComas, 2004; Khisfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004; Khishfe, 2008; Kucuk, 2008; Akerson, Hanson & Cullen, 2007) were conducted to identify the elements that enhance students understanding of the nature of science. Sharing the results of those tried out ideas help teachers to improve science learning. Thus, it is highly recommended to study the professional development programs designed to understand the level of understanding of teachers and analyze how that affect students' perceptions.

5.4 Recommendations of the Study

This research study aimed to investigate the impact of the combined explicit reflective and inquiry-based instruction on middle and high school Lebanese students' conceptions of NOS. The intervention used was designed to embed NOS aspects in the science content and to use inquiry-based instruction to allow students to explore science and to have an in-depth understanding of NOS. The uniqueness of this intervention lies in planning for the curriculum component and the instructional approach component simultaneously. Those two major components complement each other in the learning process. The conceptions of students about NOS cannot be enhanced by either using inquiry-based instruction or explicitly integrating NOS aspects with science content. Students shall acquire an adequate sustainable understanding of NOS aspects when the teacher intentionally talks about NOS aspects as part of science teaching while using an inquiry-based instructional approach.

Scientific literacy skills shall be enhanced as a result of an adequate NOS understanding when the curriculum and the instructional approach are both aligned and well planned. Focusing on one component only shall never give the desired results.

Educators' main interest is to enhance scientific literacy skills. This can only be achievable when students experience science learning as an inseparable part of their lives. Using the implicit teaching approach allows students to become engaged in their own learning and thus feel the ownership of what they have concluded. Students will be scientifically literate when they connect new concepts to prior knowledge as well as their daily life experience (Krajcik and Sutherland, 2010). Designing the appropriate learning opportunities to engage students in an authentic learning environment characterized by communication and collaboration results in developing the desired NOS conceptions and scientific literacy skills in a natural way.

Finally, this research study highlighted on the significance of building teachers' confidence in their knowledge about NOS aspects. The planning process of the intervention allowed teachers to discuss their points of views about NOS aspects in relation to the science content knowledge and to be confident about what they shall discuss in the class. Many studies have strongly recommended to include NOS courses in teachers training programs (Bloomet al. 2015; Sarieddine and BouJoude, 2014). This study comes to stress on this practice and the urgent need to indulge teachers in courses to possess appropriate knowledge of the NOS aspects.

5.5 Limitations of the Study

The limitations have a direct impact on the ability to generalize the attained results of the research study. Creswell (2013) states that the limitations of the conducted research study affect the trustworthiness of the obtained results. The following are some of the limitations which have to be considered as they might have an influence on the findings of the research study.

Firstly, the findings of this study might have been related to some factors such as cultural beliefs, indigenous knowledge, and students' socio-economic status. In Lebanon, all students come from middle-class families who consider education as an essential component to secure their future. They take their studies so seriously by being eager to develop a deep understanding of various concepts. They have a wide range of general knowledge about different topics. They do not rely only on the teacher to learn. Continuously, they challenge one another to show their knowledge about recent inventions, to show their ability to think critically, and to resolve environmental issues. In addition to that, in Lebanon students have to sit for nationwide official exams by end of Grades 9 and 12. This by itself is considered a heavy burden for the students and their parents. Students have to be responsible for their own learning and accountable for the results in front of their parents. Thus, students work hard to improve their competencies either through adopting new ways of thinking or through experiencing new instructional approaches that enable them from understanding in-depth the fundamental basis of the subject. Such status might not be common in all countries especially if the education system is underdeveloped.

Another limitation of this study is the sample size. While significant efforts were made to draw a large sample but teachers at the private Lebanese school were skeptical about participating in this study due to the lack of time. Teachers were under a lot of pressure to cover the curriculum standards and to prepare their students to undertake the official exams. They did not want to be involved in piloting a new idea and test the impact. In general, teachers do not like to try new ideas unless they feel convinced about their value. For them, explicitly embedding the NOS aspects in the science curriculum is an enrichment rather than an essential component to enhance scientific literacy skills. To be specific, the sample was limited in the number of students because their teachers disagreed to participate. A bigger sample size could provide a better picture of Lebanese high and middle school students' perception of NOS.

5.6 Recommendations for Future Research

The outcomes of this research study have important implications to enhance the perceptions of students of NOS aspects in Lebanon. The results collected from mixed method showed a strong evidence that the treatment improve the scientific literacy skills of students. Students were learning science and at the same time build a strong understanding of the NOS aspects. Further investigations could be made to study the relationship between the traditional perceptions of NOS and students attainment in standardized tests. Moreover, it is well known that all the standardized tests focus on the set of skills that a student acquires at a certain age. When looking at science standardized assessments, there is a lot of emphasis on the scientific literacy skills and the acquisition of logical thinking in Lebanon as well as other countries. The United Arab Emirates UAE is nowadays aiming to improve students' results in international assessments which require improving the scientific literacy skills of students by allowing students to acquire an adequate understanding of NOS aspects. To start with, explicit reflective teaching focus on specific planning steps to integrate NOS with science standards. NOS, being tightly related to scientific literacy, becomes a major factor to be looked at by policymakers who are keen on improving students' attainment if the results of this study in UAE show significant changes. Therefore, it is recommended to replicate this study in UAE to study the implications at more than one level.

Based on the limitations of the current study, future studies may explore parental influence on gender gap. Additionally, some future studies could be undertaken at large scale with large sample.

5.7 Summary

The thesis presented an empirical evidence from a quasi-experimental study of how a combined explicit reflective and inquiry-based instructional approach is an effective way of improving students' understanding of NOS. The perceptions of Lebanese middle and high school students were significantly improved based on the using a combined explicit reflective and inquiry-based instruction approach.

Using the mixed method approach to analyze the data collected using a questionnaire, an interview, the reflective journal prompts, and the field notes of class observations. The analysis of the data led to the conclusion that the combined explicit reflective and inquiry-based instruction enhance middle and high school students' perceptions of NOS. The three major concluded themes are: (1) Cultural and Social Development in relation with Implicit Teaching Approach, (2) Combined Curriculum and Instructional Implications , (3) Communicating Science to Construct Literacy. Implications for further studies recommend the replications of this study in UAE, the consideration of teachers' professional development programs, and a review for the science curriculum. Sample size and students' socioeconomic status were the main limitations of this study.

5.8 Concluding Note

This research was conducted in Lebanon were various environmental concerns were arising such as the high pollution rates and the climate change. The results of this research shall significantly assist policy makers and decision makers in setting out a nation-wide strategic views for the near future in education in Lebanon. The results will enable science educators to review the curriculum mapping design to state explicitly the NOS aspects related to every single science concept, to design authentic training programs for science teachers to promote NOS aspects, and to stress on the importance of aligning the intended curriculum with the implemented curriculum. Students need to realize that their well-being is tightly connected to the understanding of the procedural aspects of the science subject. The nation will have a better future when students realize that science is a potent tool for finding solutions to the ever-changing problems as a field of study with no borders.

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APPENDIX A: A LETTER TO THE PRINCIPAL

Date: 18/02/2017

Dear Sir/ Madam:

I am writing to introduce myself to you, inform you of a study I am seeking to conduct in science education, and invite the participation of your school students in it.

My name is Lara Abdallah, a doctoral student at the British University in Dubai for Studies in Education. My study is “Impact of Combined Explicit Reflective Nature of Science and Inquiry Based Instruction on Middle and High School Students Conceptions of Nature of Science”. I wish to invite Grades 6 to 12 students to participate voluntarily in this study.

The following is a short synopsis of the research.

Title of Study: Impact of Combined Explicit Reflective Nature of Science and Inquiry Based Instruction on Middle and High School Students Conceptions of Nature of Science

Purpose: The study aims to investigate middle and high school students’ conceptions of the nature of science, examine the impact of combined explicit reflective NOS and inquiry-based instruction on middle and high school students’ understanding of the nature of science, and investigate middle and high school students’ conceptions of the nature of science regarding demographic variables.

Procedures: The researcher will ask the participants to complete a pre and post survey questionnaire about nature of nature (NOS). To complete the questionnaire students need about 20 minutes. Field notes will be taken from observing science classrooms using explicit reflective inquiry-based instruction where students will be provided with reflective prompts to fill to reflect on their experience in the science activities. Students will be interviewed orally once after they complete the post questionnaire.

Potential risks: This study involves observing the impact of using explicit reflective inquiry-based instructions on students' conceptions of NOS. Students will not be identifiable, and confidentiality will be maintained.

Potential benefits: Participants in this study should benefit from reflecting on their learning activities during science classes. By answering the questions, they will be prompted to think overtly about the characteristics of science and scientific knowledge and their strategies of studying science. This may motivate them to take science more seriously as a possible life pursuit.

Confidentiality: All data generated during this study will remain confidential. Neither the names of school, teachers, nor students will be used in the doctoral thesis. Only the researcher will have access to the primary data. All data will be digitally encrypted, and will be destroyed after the study is concluded.

I do look forward to hearing from you soon. Thank you for your kind consideration of this letter.

Sincerely

Lara Abdallah

Consent Form for the school principal

I understand the procedures and conditions to participate in this research and agree to my school students' participation.

______________________ ___________________________

____

Name of Principal Signature of Principal Date

APPENDIX B: A LETTER TO SCIENCE TEACHERS

Dear Sir/Madam,

I am contacting you asking your voluntary participation in a study in science education. Please let me introduce myself, and my research.

My name is Lara Abdallah and I am a doctoral student in the Science Department at the British University in Dubai in Education working under the supervision of Professor Sufian Forawi. The study forms the basis of my doctoral dissertation on “Impact of Combined Explicit Reflective Nature of Science and Inquiry Based Instruction on Middle and High School Students Conceptions of Nature of Science”. I invite your students to take part in this study. I believe the experience will enrich their understanding of how science works, and help improve their scientific literacy.

The science curriculum encourage enhanced understanding of the concepts of Nature of Science (NOS) in science classes. I am interested in investigating the elements that can influence students’ conceptions of NOS such as the explicit teaching of NOS, usage of inquiry-based instructions and the designed opportunities that allow students to reflect on their experience in the science classes. Comprehensive studies have been conducted about teachers’ conceptions, science textbooks, and the learning experiences in science classes. This study will focus on investigating the impact of using explicit reflective inquiry-based instructions on students’ conceptions of NOS in middle and high school.

The study will collect data from students using reflective prompts, interviews, and pre and post survey questionnaire. The questionnaire will take 20 minutes. The questionnaire consists of Likert scales questions and open-ended questions about NOS aspects. There is neither a correct answer nor a wrong answer.

All data will remain confidential. The names of teachers and students will not be used in the doctoral thesis. Only the researcher will have access to the data. Once all data is digitally encrypted, then it will destroyed two years after the study is concluded. Your students are not under the obligation to participate in this study. Consequently, they have the right to withdraw at any time if they want, to refuse to answer a question, or to skip any questions that seems uncomfortable for them.

The findings of this study will contribute to discovering new approaches that increase students understanding of the Nature of Science. There is a global interest in understanding the mutual relationship between NOS and scientific literacy. Thus, the findings of this study may lead to a new discovery to connect both aspects. At your request, you may receive a copy of the summary of findings from the study once the entire thesis is completed.

Informed consent is required for your participation. In the spaces provided below, please indicate your willingness to participate by placing your signature.

Thank you for your kind consideration. I look forward to working with you.

Sincerely,

Lara Abdallah

Consent Form for the Teacher

I understand the procedures and conditions of my student participations described above and agree to participate in this study

____________________ ____________________ ________________

Name of Participant Signature of Participant Date

APPENDIX C: A LETTER TO PARENTS AND STUDENTS

Date: dd/mm/yyyy

Dear Sir/ Madam:

The depth of the understanding of scientific literacy is tightly connected to their nature of science (NOS) understanding. Our children need to gain scientific knowledge in addition to understand the NOS as a form of human learning. I am seeking your permission to invite your child to participate in a study in science education that shall enhance his/her understanding of scientific literacy and improve classroom practice in this field.

To introduce myself: My name is Lara Abdallah, a doctoral student at the British University in Dubai in Education. The study forms the basis of my doctoral dissertation on "Impact of Combined Explicit Reflective Nature of Science and Inquiry Based Instruction on Middle and High School Students Conceptions of Nature of Science".

With the permission of your child's school principal and science teacher, I ask your permission for your child to take part in this study

The brief summary that follows outlines what we plan on doing, and how:

Title of Study: Impact of Combined Explicit Reflective Nature of Science and Inquiry Based Instruction on Middle and High School Students Conceptions of Nature of Science

Purpose: The study aims to investigate middle and high school students' conceptions of the nature of science, examine the impact of combined explicit reflective NOS and inquiry-based instruction on middle and high school students' understanding of the nature of science, and investigate middle and high school students' conceptions of the nature of science regarding demographic variables.

Procedures: The researcher will ask the participants to complete a pre and post survey questionnaire about nature of nature (NOS). To complete the questionnaire students need about 20 minutes. Field notes will be taken from observing science classrooms using explicit reflective inquiry-based instruction where students will be provided with reflective prompts to fill to reflect on their experience in the science activities. Students will be interviewed orally once after they complete the post questionnaire.

Potential risks: This study involves observing the impact of using explicit reflective inquiry-based instructions on students' conceptions of NOS. Students will not be identifiable, and confidentiality will be maintained.

Potential benefits: Participants in this study should benefit from reflecting on their learning activities during science classes. By answering the questions, they will be prompted to think overtly about the characteristics of science and scientific knowledge and their strategies of studying science. This may motivate them to take science more seriously as a possible life pursuit.

Confidentiality: All data generated during this study will remain confidential. Neither the names of school, teachers, nor students will be used in the doctoral thesis. Only the researcher will have access to the primary data. All data will be digitally encrypted, and will be destroyed after the study is concluded.

Thank you for your support in the conduct of this study.

Sincerely,

Lara Abdallah

Parent Consent Form

Your son or daughter's participation in this study is entirely voluntary. You may refuse to have your child participate at all. You may also withdraw your child from the study at any time without any consequence.

Your signature below indicates that you have received a copy of this consent form for your own records, and that you agree to allow your child to participate.
I consent/do not consent (circle one) to my child's participation,
(name: __________________________), in this study.

____

Signature Date Please print your name here

Student Assent Form

Your participation in this study is entirely voluntary and you may refuse to participate, or withdraw from the study at any time without any consequence to your class standing.

Your signature below indicates that you have received a copy of this assent form for your own records, and that you are willing to participate in this part of the study.

____

Signature Date Please print your name here

APPENDIX D: EXPLICIT REFLECTIVE INQUIRY-BASED INSTRUCTION NATURE OF SCIENCE QUESTIONNAIRE (ERIBINOSQ)

Instruction: This questionnaire is designed to measure your beliefs about science. Your participation is voluntary and anonymous.

Part A: Demographic Information

1. What is your gender? ________Male _______Female

2. What grade are you in? ______________________________

3. What is your birth date? _________ __________ ______________

Day *Month* *Year*

Part B: What do you think about science?

Please read each statement carefully, and then indicate the degree to which you agree or disagree with each statement by putting a circle around the appropriate choice (**SA**=Strongly Agree or **A**=Agree or **U**=Uncertain or **D**=Disagree or **SD** Strongly Disagree).

Scientific investigations use different methods and procedures to obtain data and produce new knowledge	**SA**	**A**	**U**	**D**	**SD**
Technology and advanced tools improve scientific knowledge	**SA**	**A**	**U**	**D**	**SD**
A common set of values characterizing scientific inquiry are: open-mindedness, objectivity, replicability of results, logical thinking, and ethical reporting of findings	**SA**	**A**	**U**	**D**	**SD**
Science knowledge is based on observations and experiments	**SA**	**A**	**U**	**D**	**SD**
In science, there are common rules of evidence used to evaluate explanations about nature	**SA**	**A**	**U**	**D**	**SD**
Science connects the patterns of evidence to current theories	**SA**	**A**	**U**	**D**	**SD**
Science arguments require multiple sources of evidence to support explanation	**SA**	**A**	**U**	**D**	**SD**
Scientific knowledge is subject to change	**SA**	**A**	**U**	**D**	**SD**
Scientific knowledge changes based on new evidence	**SA**	**A**	**U**	**D**	**SD**
Scientific knowledge changes based on reinterpretation of existing evidence	**SA**	**A**	**U**	**D**	**SD**
Scientific discussions are based on logical arguments	**SA**	**A**	**U**	**D**	**SD**
Theories and laws explain natural phenomena scientifically	**SA**	**A**	**U**	**D**	**SD**
Theories do not become laws or facts with time	**SA**	**A**	**U**	**D**	**SD**
Scientific theory is based on a body of facts that has been repeatedly confirmed through experiments and observations	**SA**	**A**	**U**	**D**	**SD**
Science community accepts a scientific theory once it is validated by empirical evidence	**SA**	**A**	**U**	**D**	**SD**
Scientific theory is modified when new evidence is discovered that the theory does not accommodate for	**SA**	**A**	**U**	**D**	**SD**
Scientific theory is dependent on models, mechanisms, and explanations	**SA**	**A**	**U**	**D**	**SD**
Scientists use hypotheses to test and enhance explanations and theories	**SA**	**A**	**U**	**D**	**SD**
Science explains the mechanism of natural systems	**SA**	**A**	**U**	**D**	**SD**
Science provides the process that can be used to refine, elaborate, revise and extend their knowledge	**SA**	**A**	**U**	**D**	**SD**
Science is one of the ways of knowing	**SA**	**A**	**U**	**D**	**SD**

Science uses logical arguments, skeptical reviews, and empirical standards	**SA**	**A**	**U**	**D**	**SD**
Scientific knowledge assumes that natural laws operate consistently the same in the past, present and future	**SA**	**A**	**U**	**D**	**SD**
The universal laws of science form one system of consistent laws	**SA**	**A**	**U**	**D**	**SD**
Scientific knowledge stems from imagination, creativity, and human investigations	**SA**	**A**	**U**	**D**	**SD**
People from different cultures and backgrounds contribute to advances in science	**SA**	**A**	**U**	**D**	**SD**
Cultural, social, and individual values of scientists influence their scientific work	**SA**	**A**	**U**	**D**	**SD**
Science and technology are interrelated and influence each other	**SA**	**A**	**U**	**D**	**SD**
Society influences and is influenced by science	**SA**	**A**	**U**	**D**	**SD**
Science disciplines do not provide answers for all questions	**SA**	**A**	**U**	**D**	**SD**
Science knowledge explains what happen in natural systems rather than what should happen	**SA**	**A**	**U**	**D**	**SD**
As a student, I am unwilling to change my ideas when evidence shows that my ideas are poor	**SA**	**A**	**U**	**D**	**SD**
I prefer to ask the teacher to explain science topics rather than find answers by doing experiments	**SA**	**A**	**U**	**D**	**SD**
I think scientific content knowledge we study in school is boring	**SA**	**A**	**U**	**D**	**SD**
I draw conclusions from experiments, simulations, and modeling in science	**SA**	**A**	**U**	**D**	**SD**
In science experiments, I collaborate with my peers to conduct scientific experiments	**SA**	**A**	**U**	**D**	**SD**
In science experiments, I collaborate with my peers to report expected and unexpected results	**SA**	**A**	**U**	**D**	**SD**
In science experiments, I listen to my peers' opinion, find scientific facts out from experiments, and draw logical conclusions	**SA**	**A**	**U**	**D**	**SD**
In science class, I have the possibility to try my own ideas, to debate or discuss, to work on models, and to explain my ideas	**SA**	**A**	**U**	**D**	**SD**
When I reflect about my learning experience I understand the concepts better	**SA**	**A**	**U**	**D**	**SD**
Collaborating with my peers in group work allows me to discuss all the inquiries	**SA**	**A**	**U**	**D**	**SD**
Science experiments are easy to do	**SA**	**A**	**U**	**D**	**SD**
The projects that I do in science are connected to the real-world	**SA**	**A**	**U**	**D**	**SD**
The instructions in science class are built around real-world problems	**SA**	**A**	**U**	**D**	**SD**
The science tasks resemble the tasks of scientists and real workers	**SA**	**A**	**U**	**D**	**SD**
Science lessons are interesting and engaging due to their relevance to everyday life	**SA**	**A**	**U**	**D**	**SD**

Part C: Answer the following questions

1- What is science?

2- What is the nature of science? Can you specify some of its characteristics?

3-How do you best know and learn about nature of science?

APPENDIX E: INTERVIEW PROTOCOL FOR STUDENTS (HIGH SCHOOL)

Student Code: ________________________ Grade: ________________

Age: _______________________ Gender: ________________

Date: ______________________________

Interviewer:

There are no “right” or “wrong” answers to the following questions. I am only interested in your conceptions on the Nature of Science, on your learning, and on your experiences in science class.

Interview questions
Based on your experiences with science, address the following questions:

1. What is the nature of science? Can you specify some of its characteristics?

2. How is science done? (What is your understanding of the process of science?

3. Which do you think is more important learning of scientific theories/laws/factual knowledge or learning about how science has been developed especially learning about the effects of science on our society or how society or culture has affected science?

APPENDIX F: INTERVIEW PROTOCOL FOR STUDENTS (MIDDLE SCHOOL)

Student Code: ________________________________ Grade: _______________

Age: ______________________ Gender:_______________

Date: ______________________________

Interviewer:

There are no “right” or “wrong” answers to the following questions. I am only interested in your conceptions on the Nature of Science, on your learning, and on your experiences in science class.

Interview questions
Based on your experiences with science, address the following questions:
1. What is the nature of science? Can you specify some of its characteristics?

2. How is science done? (What is your understanding of the process of science?

3. How do humans influence science?

APPENDIX G: NATURE OF SCIENCE CLASS OBSERVATION FORM

Teacher Behaviors and Classroom Discourse

Teacher **(+: Present)** **(-: Lacking)**	**Evidence of NOS** **IBI = Inquiry-Based Instruction** **T =Traditional** **(-) = none** **(+) =Mixed C and T**
Lesson Introduction Emphasis •Provides overview •Relates lesson •Assesses Prior Knowledge	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ____ ____
Modes of Instruction (circle) during Lesson •Whole Class •Recitation •Lecture •Note-taking •Reading •HW/Class Work •Review/Correction •Review •Drill and Practice •Hands-on •Teacher Demonstration •Seat Work •Small Group •Group Presentation •Cooperative Group Work •Open-Ended Inquiry •Data Collection/Manipulation •Note-Book Entry of Log	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ____ ____
Questioning Level •Simple – Knowledge •Comprehension •Procedural •Complex – Application •Synthesis •Analysis •Evaluation •Affective (feeling)	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ____ ____
Teacher Behavior	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence

•Explains and directly guides activity •Circulates and asks questions •Emphasizes relations to real life •Uses ongoing embedded assessment •Manages the materials/resources	3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ____ ____
Instructional Materials Used during Lesson •Printed Reading Materials (books, articles, stories, etc.) •Computer or computer technology Overhead projector, LCD projector, video, films, music •Chalk board, white board, chart tablet Demonstration models •Science Equipment/Manipulatives (hands-on materials) •Worksheets, Data Sheets •Science Notebooks	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ____ ____

APPENDIX H: LETTER FROM BUID TO THE SCHOOL

الجامعة البريطانية في دبي
The British University in Dubai
www.buid.ac.ae

1/29/2018

Marjoyoun National College
South Lebanon, Lebanon

This is to certify that Ms.Lara Nabil Abdallah with Student ID number 2015121012 is a registered full-time student in the PhD in Education offered by The British University in Dubai since September 2015.

Ms. Abdallah is currently collecting data for her research (Impact of Combined Explicit Reflective Nature of Science and Inquiry-based Instruction on Middle and High School Students' Conceptions of the Nature of Science).

She is required to gather data through conducting Class Observation, Document Analysis, Pre and Post tests, Interviews that will help her in writing the final research. Your permission to conduct her research in your organisation is hereby requested. Further support provided to her in this regard will be highly appreciated.

Any information given will be used solely for academic purposes.

This letter is issued on Ms.Abdallah's request.

Yours sincerely,

Dr. Amer Alaya
Head of Academic and Student Administration

PO Box 345015 • Block 11 Dubai International Academic City Dubai U A E • T +971 4 279 1400 • F +971 4 279 1490
FB.com/BUiD.Team BUiD_Team youtube.com/BUiDadmin @BUiD_Team BUiD

APPENDIX I: ETHICAL FORM

الجامعة البريطانية في دبي
The British University in Dubai

Research Research Ethics Form (Low Risk Research)

To be completed by the researcher and submitted to the Dean's nominated faculty representative on the Research Ethics Committee

i. Applicants/Researcher's information:

Name of Researcher /student	Lara Nabil Abdallah
Contact telephone No.	UAE: 00971507198681 Lebanon: 0096171861266
Email address	laraabdallah82@gmail.com
Date	16 January 2018

ii. Summary of Proposed Research:

BRIEF OUTLINE OF PROJECT (100-250 words; this may be attached separately. You may prefer to use the abstract from the original bid):	This research study will investigate the impact of Combined Explicit Reflective Nature of Science and Inquiry-based Instruction on Middle and High School Students' Conceptions of the Nature of Science. Mixed method approach will be used to investigate the depth of students' understanding of the nature of science. Both qualitative and quantitative research methods will be collected separately, maintained separately, and integrated in the final analysis. Explicit Reflective Inquiry-Based Instruction Nature of Science Questionnaire (ERIBINOSQ) based on Lederman's conceptualization of NOS model will provide the quantitative data. Qualitative data will be obtained from open-ended items of ERIBINOSQ, document analysis, class observation forms and reflective journals of students. This study shall be promising since it will shed the light on the complexities of the science education and teaching

	approaches in the unique cultural attributes of the Arab region. On one hand, huge amount of research studies have been conducted in western cultures. On the other hand, few studies have been conducted to investigate the impact of combined explicit reflective and inquiry-based instruction on students' understanding of NOS aspects in Middle Eastern cultures.
MAIN ETHICAL CONSIDERATION(S) OF THE PROJECT (e.g. working with vulnerable adults; children with disabilities; photographs of participants; material that could give offence etc...):	All the work involved in this research study shall gain written consents. Since the research study will take place in a school where the participants are students under 18 years old, sufficient information about the research topic, confidentiality, and participants' rights shall be shared with participants. One of the research priorities is to show ample respect for the school and the participants throughout the study period. An official request form will be submitted to the school authorities to get their informed consent before conducting the research treatment. A student informed consent form will be given to the participants in order to take their beforehand approval.
DURATION OF PROPOSED PROJECT (please provide dates as month/year):	May 2017: conduct the pilot study May 2017-Aug 2017: Analyse pilot study data Sept 2017- Feb 2018: Collect the data for the research study; author chapters 2 and 3 related to literature review and methodology Feb 2018-March 2018: Analyse the data March 2018-July 2018: Author chapters 4 and 5 related to results and discussion
Date you wish to start Data Collection:	September 2017

Date for issue of consent forms:	September 2017

iii. **Declaration by the Researcher:**

I have read the University's policies for Research and the information contained herein, to the best of my knowledge and belief, accurate.

I am satisfied that I have attempted to identify all risks related to the research that may arise in conducting this research and acknowledge my obligations as researcher and the rights of participants. I am satisfied that members of staff (including myself) working on the project have the appropriate qualifications, experience and facilities to conduct the research set out in the attached document and that I, as researcher take full responsibility for the ethical conduct of the research in accordance with subject-specific and University Research Policy (9.3 Policies and Procedures Manual), as well as any other condition laid down by the BUiD Ethics Committee. I am fully aware of the timelines and content for participant's information and consent.

Print name: Lara Nabil Abdallah

Signature: ______________________ Date: Jan 16, 2018

*If the research is confirmed as not medium or high risk, it is endorsed HERE by the Faculty's Research Ethics Committee member (following discussion and clarification of any issues or concerns)** John McKenny ....*and forwarded to the Research Office to be recorded.* JOHN MCKENNY

I confirm that this project fits within the University's Research Policy (9.3 Policies and Procedures Manual) and I approve the proposal on behalf of BUiD's Research Ethics Committee.

Name and signature of nominated Faculty Representative: Professor Ashly H. PInnington

Signature: Approved: Ashly Pinnington Date: 24 Jan 18

iv. If the Faculty's Research Ethics Committee member or the Vice Chancellor considers the research of medium or high risk, it is forwarded to the Research Ethics Officer to follow the higher-level procedures.

* *If the Faculty representative is the DoS, the form needs the approval of the Chair of the Research Ethics Committee.*

APPENDIX J: DESCRIPTIVE STATISTICS OF EXPERIMENTAL GROUP BY CLUSTER

Gender	Descriptive Statistics	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10	Cluster 11	Cluster 12
	Valid	131	131	131	131	131	131	131	131	131	131	131	131
	Missing	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	3.977	3.773	3.504	3.580	3.775	3.559	3.416	3.416	3.158	3.679	3.574	3.746
	Std. Error of mean	0.060	0.065	0.065	0.048	0.067	0.061	0.078	0.078	0.087	0.057	0.063	0.068
	Median	4	4	3.5	3.5714	4	3.4	3.5	3.5	3.3333	3.8	3.5	4
	Variance	0.467	0.553	0.557	0.304	0.585	0.49	0.789	0.789	0.994	0.423	0.52	0.607
	Std. Deviation	0.683	0.744	0.746	0.552	0.765	0.700	0.888	0.888	0.997	0.650	0.721	0.779
	Minimum	1	1	1	1.71	1	1	1	1	1	1	1	1
M	Maximum	5	5	5	5	5	5	5	5	5	5	5	5
	Range	4	4	4	3.29	4	4	4	4	4	4	4	4
	Skewness	-1.429	-1.135	-0.496	-0.088	-1.052	-0.53	-0.486	-0.486	-0.246	-0.665	-0.135	-0.831
	Std. Error of Skewness	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
	Precentiles_25	3.6667	3.25	3	3.1429	3.375	3.2	3	3	2.3333	3.4	3	3.3333
	Precentiles_50	4	4	3.5	3.5714	4	3.4	3.5	3.5	3.3333	3.8	3.5	4
	Precentiles_75	4.3333	4.25	4	4	4.25	4	4	4	4	4	4	4.3333
	Valid	104	104	104	104	104	104	104	104	104	104	104	104
	Missing	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	4.029	3.916	3.450	3.565	3.940	3.487	3.164	3.164	2.756	3.746	3.673	3.901
F	Std. Error of mean	0.062	0.056	0.068	0.057	0.069	0.063	0.091	0.091	0.093	0.065	0.068	0.072
	Median	4	4	3.5	3.5714	4	3.4	3	3	2.6667	3.8	3.75	4

	Variance	0.399	0.331	0.48	0.34	0.499	0.41	0.866	0.866	0.896	0.442	0.475	0.541
	Std. Deviation	0.632	0.575	0.693	0.583	0.707	0.640	0.931	0.931	0.947	0.665	0.689	0.736
	Minimum	1.67	1.75	1.25	1.43	1	1.4	1	1	1	1.6	1.5	1
	Maximum	5	5	5	5	5	5	5	5	5	5	5	5
	Range	3.33	3.25	3.75	3.57	4	3.6	4	4	4	3.4	3.5	4
	Skewness	-0.684	-0.729	-0.239	-0.508	-1.525	-0.064	-0.15	-0.15	0.025	-0.621	-0.575	-1.209
	Std. Error of Skewness	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237	0.237
	Precentiles_25	3.6667	3.5	3	3.1429	3.75	3	2.5	2.5	2	3.4	3.25	3.5
	Precentiles_50	4	4	3.5	3.5714	4	3.4	3	3	2.6667	3.8	3.75	4
	Precentiles_75	4.3333	4.25	4	4	4.5	4	3.5	3.5	3.6667	4.2	4	4.3333

APPENDIX K: DESCRIPTIVE STATISTICS OF EXPERIMENTAL GROUP OF MIDDLE VS HIGH

Grade	Descriptive Statistics	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10	Cluster 11	Cluster 12
6	Valid	63	63	63	63	63	63	63	63	63	63	63	63
	Missing	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	3.7302	3.6667	3.1944	3.3991	3.8532	3.4222	2.9683	2.9683	2.7619	3.6254	3.7222	3.8254
	Std. Error of mean	0.09596	0.10135	0.09094	0.07705	0.09841	0.09397	0.13333	0.13333	0.12031	0.0991	0.11	0.10769
	Median	3.6667	3.75	3.25	3.4286	4	3.4	3	3	3	3.8	4	4
	Variance	0.58	0.647	0.521	0.374	0.61	0.556	1.12	1.12	0.912	0.619	0.762	0.731
	Std. Deviation	0.76166	0.80447	0.72184	0.61158	0.78112	0.74584	1.05827	1.05827	0.95495	0.78657	0.87311	0.85479
	Minimum	1	1	1.25	1.43	1.5	1	1	1	1	1	1	1
	Maximum	5	5	4.75	4.71	5	4.8	5	5	5	5	5	5
	Range	4	4	3.5	3.29	3.5	3.8	4	4	4	4	4	4
	Skewness	-1.038	-1.155	-0.315	-0.739	-1.197	-0.572	0.023	0.023	0.034	-0.982	-0.77	-1.37
	Std. Error of Skewness	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302	0.302
	Precentiles_25	3.3333	3.25	2.75	3.0714	3.5	3	2	2	2	3.4	3.125	3.3333
	Precentiles_50	3.6667	3.75	3.25	3.4286	4	3.4	3	3	3	3.8	4	4
	Precentiles_75	4.1667	4.25	3.75	3.8571	4.5	4	3.5	3.5	3.5	4.1	4.25	4.3333
11 - 12	Valid	67	67	67	67	67	67	67	67	67	67	67	67
	Missing	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	4.1443	3.806	3.6679	3.7228	3.7687	3.6358	3.4776	3.4776	3.3582	3.7045	3.5933	3.9055
	Std. Error of mean	0.06954	0.07169	0.07432	0.06136	0.08627	0.0817	0.10867	0.10867	0.12346	0.07147	0.08487	0.08648

	Median	4	4	3.75	3.7143	4	3.6	3	3	3.3333	3.8	3.75	4
	Variance	0.324	0.344	0.37	0.252	0.499	0.447	0.791	0.791	1.021	0.342	0.483	0.501
	Std. Deviation	0.5692	0.58682	0.60832	0.50224	0.70619	0.66872	0.88947	0.88947	1.01057	0.58502	0.69473	0.70783
	Minimum	2.67	2.25	2	2.86	1	1.8	1	1	1	2	1.75	2.33
	Maximum	5	4.75	5	5	5	5	5	5	5	5	5	5
	Range	2.33	2.5	3	2.14	4	3.2	4	4	4	3	3.25	2.67
	Skewness	-0.352	-0.459	0.09	0.555	-1.072	0.338	-0.18	-0.18	-0.504	-0.184	-0.448	-0.193
	Std. Error of Skewness	0.293	0.293	0.293	0.293	0.293	0.293	0.293	0.293	0.293	0.293	0.293	0.293
	Precentiles_25	4	3.375	3.25	3.4286	3.25	3.2	3	3	3	3.4	3.25	3.3333
	Precentiles_50	4	4	3.75	3.7143	4	3.6	3	3	3.3333	3.8	3.75	4
	Precentiles_75	4.3333	4.25	4	4	4.25	4	4	4	4	4	4	4.3333

APPENDIX L: SAMPLE OF A PROTOCOL FOR CLASS OBSERVATION

Nov 14, 2017
2nd period Tuesday.
B6A

Protocol for Class Observations

Teacher Behaviors and Classroom Discourse

Teacher **(+: Present)** **(-: Lacking)**	**Evidence of NOS** **IBI = Inquiry-Based Instruction** **T =Traditional** **(-) = none** **(+) =Mixed C and T**
Lesson Introduction Emphasis •Provides overview Cyclic path of reproduction •Relates lesson Reproduction was connected to characteristics of mammals. •Assesses Prior Knowledge Teacher did a recap to remind students of fertilization process.	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments:
Modes of Instruction (circle) during Lesson •Whole Class •Recitation •Lecture •Note-taking •Reading •HW/Class Work •Review/Correction •Review •Drill and Practice •Hands-on •Teacher Demonstration •Seat Work •Small Group •Group Presentation •Cooperative Group Work •Open-Ended Inquiry •Data Collection/Manipulation •Note-Book Entry of Log	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: Scientists follow scientific method to discover the knowledge.
Questioning Level •Simple – Knowledge •Comprehension •Procedural •Complex – Application •Synthesis •Analysis •Evaluation •Affective (feeling) wild discussion about	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: Logical arguments about animals who lay large amount of eggs vs small

Teacher Behavior	
•Explains and directly guides activity •Circulates and asks questions •Emphasizes relations to real life •Uses ongoing embedded assessment •Manages the materials/resources	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ________________________________ ________________________________
Instructional Materials Used during Lesson •Printed Reading Materials (books, articles, stories, etc.) •Computer or computer technology Overhead projector, LCD projector, video, films, music •Chalk board, white board, chart tablet Demonstration models •Science Equipment/Manipulatives (hands-on materials) •Worksheets, Data Sheets •Science Notebooks	1.Scientific Investigations Use a Variety of Methods 2.Scientific Knowledge is based on Empirical Evidence 3.Scientific Knowledge is Open to Revision in Light of New Evidence 4.Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena 5.Science is a Way of Knowing 6.Scientific Knowledge Assumes an Order and Consistency in Natural Systems 7.Science is a Human Endeavor 8.Science Addresses Questions about the Natural and Material World. Notes/Comments: ________________________________ ________________________________

APPENDIX M: SAMPLE OF AN INTERVIEW PROTOCOL FOR HIGH SCHOOL STUDENT

ID 0048

Interview Protocol for Students (High School)

Name: [redacted] Grade: 11

Age: 11 / Sept / 2001 Gender: Male

Date: 14/ March / 2018

Interviewer:

There are no "right" or "wrong" answers to the following questions. I am only interested in your conceptions on the Nature of Science, on your learning, and on your experiences in science class. Most of the interview questions explore your responses to the survey in greater detail; a few deal with more general ideas.

Interview questions

Based on your experiences with science, address the following questions:

1. What is the nature of science? Can you specify some of its characteristics?

Nature of science, is the process of finding laws, principles and concepts. It is referred to how scientific knowledge is created and validated.

2. How is science done? (What is your understanding of the process of science?

Science begins with observations then organization of information in an orderly way to look for patterns.

3. Which do your think is more important learning of scientific theories/laws/factual knowledge or learning about how science has been developed, what the effects of science on our society or how society or culture has affected science?

The most important thing for me is using science to invent and have a better life. When we learn science through hands-on activities and we discuss me and my friends the ideas we start coming up with ideas. Sometimes we meet in the afternoon and we go to the forest behind our hospital to try to do some inventions

APPENDIX N: SAMPLE OF AN INTERVIEW PROTOCOL FOR MIDDLE SCHOOL STUDENT

ID0001

Interview Protocol for Students (Middle School)

Name: [redacted] Grade: 6 A

Age: 20/10/2006 Gender: Male

Date: 20/March/2018

Interviewer:

There are no "right" or "wrong" answers to the following questions. I am only interested in your conceptions on the Nature of Science, on your learning, and on your experiences in science class. Most of the interview questions explore your responses to the survey in greater detail; a few deal with more general ideas.

Interview questions

Based on your experiences with science, address the following questions:

1. What is the nature of science? Can you specify some of its characteristics?

Nature of science is all about scientific knowledge. NOS focuses on tentativeness, scientific method, empirical evidence, social values and imagination.

2. How is science done? (What is your understanding of the process of science?

Science to him was all about experiments. Science is the only subject that talks about real things. I used to do experiments in science but this year I understood how science topics were formed.

3. How do humans influence science?

Science allows him to be healthy in choosing the right food. He is able to understand how to take care of the [illegible] environment and reduce pollution.