The Impact of Inquiry based Learning and Explicit Instruction of the Nature of Science on Students' Views of the Nature of Science

أثر التعلم القائم على الاستقصاء والتدريس المُباشر لطبيعة العلوم على فهم الطلاب لطبيعة العلوم

by

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Abstract

Education of science has increasingly attracted new and novel approaches. Recent studies have sought to introduce strategies and methods for teaching science that will significantly enhance learners' capacity to appreciate science. Educators are now at a better position to explore and experiment with new pedagogic approaches. Inquiry-based learning approaches and explicit instruction of the nature of science are contemporary topics in pedagogy. The purpose of this research is to investigate the impact of the inquiry-based and explicit instruction of the Nature of Science on students' views of the nature of science. It provides insights on how inquiry based learning and explicit instruction of the NOS can be applied in the context of the UAE to improve learners' views of NOS. A quantitative research method is used and a quasi-experimental approach is adopted i.e. pre and post tests involving 3 groups apart from the control group. The teachers of the three groups are chosen using the instrument to have adequate views of the nature of science. The 3 groups are taught using science textbooks aligned with the next generation science standards (NGSS). All of the students of the school are Emiratis and the teachers are multinational and they needed to have teaching license of their area of specialty. A pretest was conducted to all groups. Similarly, all groups were taught the same science lesson i.e. same scientific concepts however as the research suggested with different techniques namely inquiry based, explicit instruction, and inquiry and explicit while the control group through direct instruction rote learning. The findings of this study have shown that the combination of both instructional approaches, inquiry based and explicit teaching of the NOS, brings the best of both to the classroom leading to significantly improved views of NOS ($t=-8.004$, $df = 20$, $p = .000$). This study recommends further investigation with and combination of both explicit and inquiry-based instruction approaches in teaching science. Science teachers should aim towards determining the optimal mix of both approaches that will results in the best NOS outcomes for their student.

Keywords: Nature of Science, Inquiry based learning, Explicit instruction

الملخص

لا يزال تدريس العلوم يستدعي طرقًا جديدة يومًا بعد يوم. وقد سعت أبحاث حديثة إلى إدخال إستراتيجيات ومناهج لتدريس العلوم غايتها توسيع مدى استماع المتعلم بالعلوم. فخبراء التربية اليوم أقدر على سَبْر الطرق التربوية الجديدة وتجربتها. وقد برزت مناهج التعلم القائم على الاستقصاء والتعليم المباشر لطبيعة العلوم من بين المواضيع العصرية الشائعة في باب مناهج التعليم. فغرض هذا البحث هو النظر في تأثير التعليم القائم على الاستكشاف والتعليم الصريح لطبيعة العلوم في المتعلمين. فهو يقدم إضاءه حول إمكانية تطبيق التعلم القائم على الاستقصاء والتعليم المباشر لطبيعة العلوم في الإمارات، لتحسين صورة طبيعة العلوم في نظر المتعلمين. فقد تم استخدام منهج بحث كمي وتم الاعتماد على طريقة شبه تجريبية، أي أُجريت اختبارات قبلية وبعدية لثلاث مجموعات مُشاركة باستثناء المجموعة الضابطة. وقد أُخْتِير مدرسون للمجموعات الثلاث وطُلب منهم استخدام أدوات توضح الرؤى حول طبيعة العلوم، واستُخدمت مقررات العلوم المتطابقة مع معايير العلوم للأجيال القادمة في تدريس المجموعات الثلاث. كل طلاب المدرسة إماراتيون، بينما المدرسون من جنسيات متعددة، ويلزمهم الحصول على ترخيص لتدريس مواد تخصصهم. أُجري اختبار قبلي لكل المجموعات، وكذلك تلقت كل المجموعات نفس الدرس، ونفس المفاهيم العلمية. وهكذا خَصَّصَ البحث للمجموعة التجريبية طريقةً خاصةً بها وهي التعليم القائم على الاستقصاء والتدريس ا المباشر ، بينما تم تدريس المجموعة الضابطة بالطريقة التلقينية التقليدية. فقد أظهر نتائج البحث أن الجمع بين المنهجين (الاستقصاء والتعليم المباشر لطبيعة العلوم) أدى إلى تحسين صورة العلوم في نظر المتعلمين بنسبة ($t=-8.004$, $df=20$, $p < .000$)، ولكن هذا البحث يوصي بإجراء مزيد من الدراسات حول الجمع بين منهجي التدريس المباشر والتعلم القائم على الاستقصاء في تدريس العلوم، ذلك أن مدرسي العلوم يجب أن يسعوا إلى الجمع الأمثل بين الطريقتين اللتين من شأنهما أن تحقق أفضل النواتج لطلابهم فيما يتعلق بطبيعة العلوم.

الكلمات والعبارات الرئيسية: التعلم القائم علي الاستقصاء - طبيعة العلوم - التعليم المباشر لطبيعة العلوم

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Chapter 1: Introduction

1.1 Introduction

The role of science education has broadened significantly over the past years. This has created a situation whereby there is a need for the re-evaluation of pedagogic approaches in terms of curriculum development, student assessment and methods of assessment (Duschl and Grandy 2012). According to Duschl and Grandy (2012), the rapid development of scientific knowledge in the past 50 years demands a change in how science is taught; there is a need for science teaching practices to change, adapt and become more relevant. Educators are faced with the same situation that faced educational reformers in the 1960s on how to create techniques for improving learning processes and student outcomes (Duschl and Grandy 2012). According to Sawyer (2006), current educators are better equipped compared to educators of 1960s since there is greater awareness and knowledge on how learning occurs and conditions that favor effective learning. At the same time, educators are more connected and informed on issues concerned with best practice and the growing scientific knowledge. This has put educators in a better position to explore and investigate with new pedagogic approaches. Inquiry-based learning, and explicit instruction of the nature of science are contemporary topics in pedagogy (Bell et al. 2011). This dissertation evaluates the impact of inquiry based learning and explicit instruction of the nature of science on students' views on the nature of science (NOS). It seeks to provide specific insights on how inquiry based learning and explicit instruction of the NOS can be applied in the context of the UAE where inquiry based learning was highlighted as a key element in the unified school inspection framework (Ministry of Education 2016).

1.2 Background of the research

Rapid advancement in science learning coupled with increased understanding of cognitive development amongst children has significantly transformed pedagogy (Sawyer 2006). Science educators in particular have recognized the need to coordinate between epistemic, cognitive and social aspects in teaching science. Previous studies have recommended that the acquisition of conceptual knowledge must not be separated from

the actual process (active engagement in learning science) (National Research Council (NRC) 2007; Sawyer 2006). The established best practice is that science teaching and learning should be premised on epistemology, social practices and social structures.
In the context of science education, change in the understanding of what science is (nature of science) has influenced the perception of how science should be taught and learned and done (Duschl and Grandy 2012). Similarly, change in the understanding of what learning and doing of science entail has also influenced people's understanding of the nature of science (NRC 2007). Consequently, previous studies recommend that science instruction should transition from domain-general principles and structured around knowledge of concepts, practices and frameworks.

Studies in philosophy of mind and cognitive development show that young children have a very high reasoning capability and prior knowledge on certain science domains (Subrahmanyam et al. 2002). Similarly, studies in reasoning and cognitive development in science have also demonstrated that learning content matters when it comes to learning content, environment and goals (Koslowskiand and Thompson 2002; Atran 2002). Essentially, learning needs to be strongly connected with the domain within which learning is occurring. At the same time, effective learning is also dependent on the adoption of certain practices and methods of representation and communication of ideas and critiques in science (Duschl and Grandy 2012).
This dissertation study seeks to investigate how inquiry based learning and explicit instruction of the NOS enhances learners understanding of NOS. Previous studies have shown that children as young as 3 years are capable of complex reasoning when provided with several opportunities to engage with certain scientific practices and processes over time. For instance, scientific practices such as prediction, observation, measuring, recording, counting, collaboration and communication have been shown to promote abstract reasoning. Similarly, concept-linked learning coupled with inquiry practices have also been shown to enhance abstract reasoning (Bell et al. 2011).

1.3 Inquiry-based learning

Inquiry based learning is essentially a scientific process. It incorporates the development of skills for observation, predicting, inferring, classification, measurement, interpretation, questioning, and data analysis (Lederman et al. 2013). Inquiry based learning also incorporates established science learning processes and activities; however, it seeks to combine them with critical thinking, scientific reasoning and scientific knowledge geared towards the development of new scientific knowledge. In the realm of inquiry based learning, learners are expected to develop frame scientifically valid questions followed by structured design for investigating the issue in a manner that yields the right conclusions for the questions (Lederman et al. 2013; Ackerson and Hanuscin 2007). However, as concerns the ability to effectively design an investigation expectation on young learners is usually not very high. Nevertheless, learners are expected to have a proper understanding of the underlying rationale for the investigation. In addition, they are expected to have the ability to critically analyze findings in relation to the data used in the investigation.

In sum, inquiry based learning refers to a systematic process used by learners and scientists in arriving at answers for their research questions. According to Lederman et al. (2013), there is generally a misguided notion on what scientific inquiry really. For the general public and in cases college students, scientific inquiry refers to a fixed set of sequences that must be followed to arrive at research conclusions. In some instances, learners are usually expected to memorize the process and replicate as a recipe. However, this is far from what inquiry based learning refers to. Nevertheless, Lederman (2009) indicated that inquiry based learning is critical path for developing scientific literacy amongst learners. Contemporary perspectives on inquiry based learning argue that research questions should determine the research approach (Lederman et al. 2013). At the same time, research approaches must be flexible and varied across scientific fields. In this regard, inquiry based learning manifests itself in varied forms including experimental, descriptive, and correlation. Learners can adopt one or all of the approaches. Descriptive research is generally used at the beginning of research with the objective of deriving variables and factors.

Overall, scholars argue that inquiry-based learning should be grounded in asking questions and designing approaches to consistently conduct investigation and provide answers to the questions. Research approaches such as correlation are then used to determine causal relationships amongst variables. These are approaches that are not only limited to high level research but can also be intuitively applied to learners at young ages as well. According to Lederman et al. (2013), inquiry based learning (scientific inquiry) does not equate experimental research designs. The dominant perception that experimental research is scientific inquiry is a distortion and definitely not representative of scientific inquiry. Furthermore, Abd-El-Khalick et al. (2008) asserted that inquiry based learning provides an environments that enables students to think about their learning, what is science and how it works, rather than receive information. Therefore, for this study inquiry based learning refers a systemic approach for conducting investigations with the goal of establishing critically reviewed findings.

1.4 Explicit instruction of the nature of science

According to Duschl and Grandy (2012), the concept of explicit instruction when it comes to nature of science is predicated on three aspects. First, the concept of nature of science must be explicitly defined. Second, should science based inquiry be integrated with NOS? Third, how can learners' perception of science be assessed (in terms of observations and measuring with the goal of attaining reliable results)? Explicit instruction refers to the embedding of students' interactive engagement with the practice over long teaching periods whereby inquiry and NOS are coupled.

Explicit instruction prioritizes participation of students in science practices in addition to accessing the knowledge (Duschl and Grandy 2012). In this regard, explicit instruction of NOS in delivered via group activities focusing on material, mechanistic, and cognitive practices. The process of learning and doing is conducted over longer instructional periods where learners are actively engaged with scientific practices. This process is characterized by talking/debating, modeling and critiquing. In addition, learning is aligned with sociology, philosophy, psychology and anthropology.

1.5 Statement of the problem purpose and objectives

Results of previous research studies about implementing inquiry-based learning and explicit instruction of the NOS suggest that student acquire proper conceptions of the NOS leading to improved scientific literacy driven by the ways of knowing (Bell 2008). The hypothesis regarding the use of explicit instruction was proven to be effective in promoting students understanding of the NOS compared with implicit instruction (Abd-El-Khalick 2012).

The aim of combined approach of inquiry-based and explicit instruction is to promote students' achievement, content knowledge, and ways of knowing (Bell 2008). The predominant approach to teaching science in the United Arab Emirates is rote learning and direct application of this knowledge through problem solving. Thus, there is a huge detachment from what science is and how it works. Hence, this would become an obstacle for the United Arab Emirates in its aim to establish a knowledge-based economy. Proper views of the Nature of Science help raise mindfulness regarding the impact of scientific knowledge on society (Lederman 1999).

Purpose and Questions

The purpose of this research is to investigate the impact of the inquiry-based and explicit instruction of the NOS on students' views of the nature of science. The study contributes to research on students' nature of science and improvement of science education, especially pertaining to UAE quest in the development of a knowledge-based economy. This study poses the following research questions

1- What is the impact of inquiry-based learning on students' views of the NOS?
2- What is the impact of explicit instruction of the NOS on student views of the NOS?
3- What is the impact of the combined inquiry-based and explicit instruction of the NOS on student views of the NOS?

1.6 Scope of work

This study adopts a quasi-experimental design using survey tool involving four groups of students: control group, group taught using inquiry-based approach, group taught with explicit instruction of the NOS, and group taught using inquiry-based with explicit instruction of the NOS. The participants of the research were science teachers (N (1) = 4) and tenth grade students (N (2) = 100). One of the main limitations of this approach is that a significantly smaller sample is used. Consequently, controlling variables such as teacher ability, student background, language, age, and innate student ability might not be representative of the whole population. However, the impact of such limitations on the applicability of findings to the general population is relatively low. At the same time, measures have been taken to ensure that the sample is as representative as possible.

1.7 Significance and Relevance of the Study

The United Arab Emirates vision 2021 placed the advancement of the educational system on the top of its priorities in order to achieve a world class rigor. Similarly, Abu Dhabi’s vision 2030 emphasizes enhancing of the level of education as part of building a knowledge-based economy in the Emirate. Both visions focus on promoting science education and students’ enrollment in science related streams throughout secondary and postsecondary education. Moreover, promoting progressive teaching practices exist across the agendas of each vision as an essential path to advancement of the country. Therefore, teaching methods should be adequate to equip Emirati students with the knowledge and skills needed to achieve the country’s visions. This research suggests a change in how science is presented to students in the classroom through the use of instructional approaches which improve inquiry such as inquiry-based instruction and understanding of what is science and how it works. This paper will provide recommendation for both teachers and policy makers.

1.8 Structure of the Study

This dissertation is organized into five chapters. The first chapter introduces the paper providing a brief background to the study, outlining the objectives, scope and structure of the dissertation. Chapter two conducts a detailed literature review detailing theoretical foundations on inquiry based learning and nature of science. Chapter two presents critical review of previous empirical studies. Chapter three explains the adopted methodological approaches and the rationale for choosing them. Chapter four analyses and presents the findings of the study. Chapter five concludes on the findings of the study and offers recommendations for practice and policy. It also suggests areas for future research.

Chapter 2: Literature Review

There have been a wide range of studies on nature of science, inquiry-based learning, and explicit instruction and how they interact with each other. This chapter critically reviews both theoretical and empirical studies on the above aspects. This chapter is divided into two sections. The first section presents the adopted conceptual framework pertinent to inquiry based and explicit instruction of the NOS. The second section reviews previous studies on inquiry-based learning and nature of science (NOS).

2.1 Conceptual Framework

Rubba's model of scientific knowledge describes the characteristics NOS as: amoral, creative, developmental, parsimonious, testable and unified (Forawi 2010). On amoral, NOS provides man with numerous capabilities but does not provide instructions on such capabilities needs to be used. Moral judgement is only passed as a consequence of man's application of knowledge and not because of the knowledge itself. On creative, NOS results from the intellect of man. In this regard, it requires as much imagination as a product of artist, composer or poet. In essence, scientific knowledge exists and emerges from the creative process of scientific inquiry.

Developmental aspect posits that scientific knowledge exists in such a manner that it cannot be absolutely proven. Instead, it behaves like a living organism that change over time. In this regard, the process of justifying scientific knowledge is generally treated as probable. Essentially, perspectives which might be considered as reasonable now might be disproved later with emergence of new evidence. Thus, past beliefs and truths are best assessed from the historical context (Forawi 2010).

Parsimonious Scientific knowledge is such that it seeks to be simple without necessarily undermining the need for complexity. At the same time, it aims be comprehensive and not necessarily specific. On NOS as testable, it should be possible to empirically test scientific knowledge and arrive at consistent results. Consistency of results is necessary; however, it is not a confirmation of the sufficiency of the result in proving the hypothesis being tested. Finally, NOS as unified all scientific knowledge seeks to provide an understanding of the unified nature. Thus knew knowledge often emerges from existing theories, concepts and laws (Forawi 2010).

In educational contexts, the term NOS is used to describe the association between disciplines of science education seeking to inform about how what science is and how it works (Forawi and Liang 2011). According to Forawi and Liang (2011), NOS embodies multiple concepts and ideas incorporating sociology, history and philosophy of science. Towards this end, NOS combines with cognitive sciences to provide a rich understanding of what science is, how it works, and how practitioners are expected to operate as a group of scientists and relationship between society and scientific endeavors (Holbrook and Rannikmae 2007).

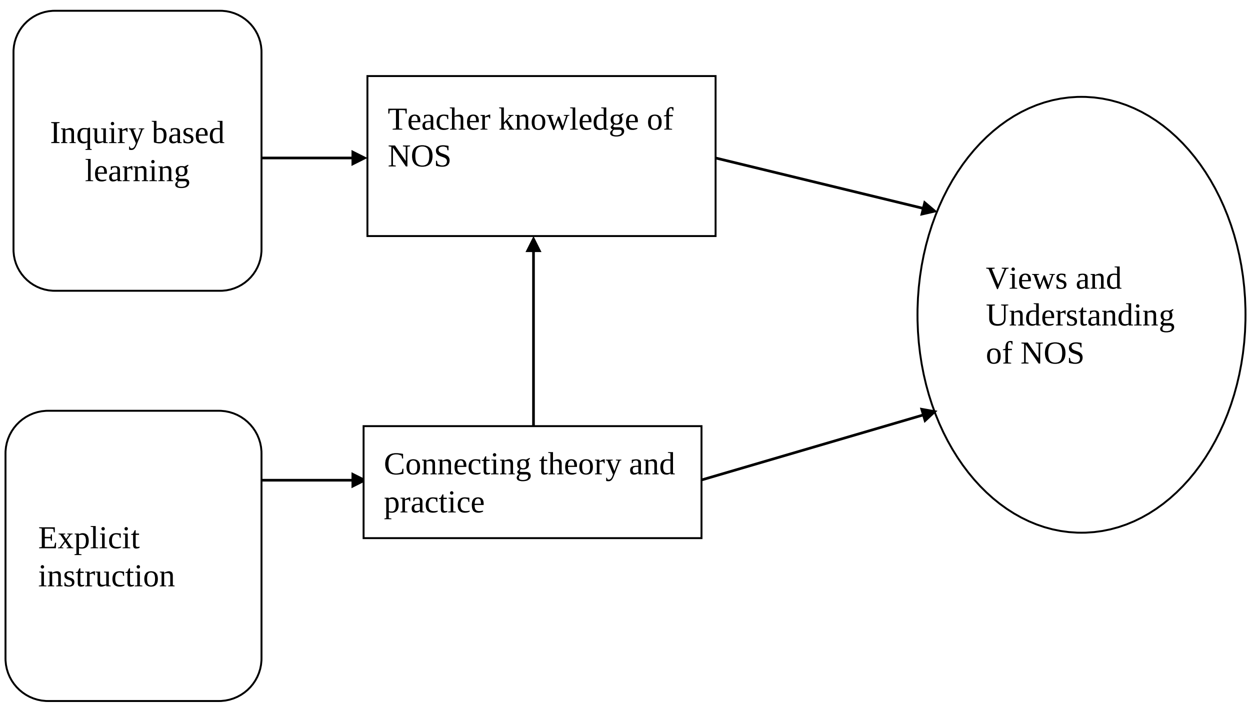

Figure 1: Conceptual Framework

In this regard, this study adopts the following conceptual framework. Inquiry based learning and explicit are independent variables mediated by teacher knowledge of NOS and connection of theory and practice in enhancing views and understanding of NOS (Forawi 2010; Forawi and Liang 2011). In essence, the ability to link theory with practice and proper teacher knowledge of NOS mediate the impact of explicit instruction and inquiry based learning on students' views of NOS. Schwartz et al. (2004) indicated in a study that the model combining both inquiry and explicit instruction enables students not only to develop adequate views of the NOS but also deepen their content knowledge. In fact, inquiry based teaching approaches are more effective in making students acquire better understanding of the NOS when coupled with explicit instruction (Abd-El-Khalick 2013).

2.2 Literature Review

2.2.1 Definition of NOS

Science educators and scientists have emphasized for years that proper understanding of NOS is essential for successful teaching of science (Forawi 2014). For almost a century now, science educators have called for the inclusion of NOS into the educational curriculum. However, acceptance and practice of concepts and principles of NOS are still largely lacking in schools. According to Forawi (2014), some students barely have an understanding of NOS and some teachers are yet to fully appreciate the fundamental elements of NOS.

The concept of NOS does not have a specific definition rather it refers to the epistemology and values of scientific development (Forawi 2014). Most psychologists are of the opinion that teaching should be based on the misconceptions and concepts that students bring to the classroom (Carey 2000). Studies in cognitive development have shown that young learners (from a low as kindergarten) have shown that young learners have the capability to know and reason about science exceptionally well (Forawi 2014, Ackerson et. al 2007). This realization has provided impetus for scholars and practitioners to promote and anchor NOS in teaching and learning.

For many years now, the concept of NOS has increasing emerged as one of the most important pillars of science and development of science literacy (Forawi 2010). The broad role and place of NOS in science education has contributed to how NOS is defined, understood and practiced in scholarly and practitioner contexts. Rubba and Anderson (1977) defines NOS as creative, amoral, parsiomonious, developmental, testable, and unified knowledge.

2.2.2 Empirical Studies

There have been a number of empirical studies which have sought to test some of the theoretical NOS concepts. In a study by Ackerson et al. (2007), it was established that certain teaching strategies such as the use of contextualized NOS instruction methods promote and enhance understanding of NOS. Instruction strategies such as using debriefing of science lesson, use of children's literature, guided inquiries and embedded written NOS assessments are significantly correlated with understanding of NOS. In this study, the researchers conducted interviews of students before and after instructions. The instruction process was videotaped and class notes were also taken and maintained with research logs. The researchers also collected lesson plans and other evidence of student class work. The study conclusively established that for each context, children were able to significantly enhance their understanding of NOS. This led the researchers to conclude that despite differentiated understanding of NOS across varied ages and grades, even young students were sufficiently capable of understanding NOS when it was adequate taught to them.

According to Forawi (2014), learning science in its nature is a critical part of learning science for children. In essence, learning science is all about comprehending the natural world through questioning, observing and investigating what is happening and trying to make sense of it. Forawi (2014) further argues that it is based on this that knew knowledge is created to help have a better understanding of what might happen in future. In this regard, scientific inquiry can be as simple as a kid conducting class experiments or as complex as hundreds of professors seeking to find a cure for an epidemic. In essence, the underlying assumptions, procedures and even goal formulation process for conducting experiments are largely the same for simple or complex researches.

In a study conducted by Forawi (2014), it was established that understanding and appreciation of NOS amongst students and teachers is still below par. In the study, it was established that for early elementary students, science is only taught for 30 to 40 minutes once or utmost twice a week. The study also established that most teachers were highly aware of the concept of guided inquiry as hands-on learning activity for students. However, when it comes to the concepts of NOS and how elementary teachers were planning to introduce them to their students, the study established that few to none of the teachers understood or had a plan for NOS (Forawi, 2014). The above result was not just limited to newly licensed teachers but also to experienced teachers as well. Most of them were at pain to adequately articulate NOS concepts.

Forawi (2014) also conducted a quantitative analysis of student results pre and post testing on students' conceptualization of NOS over a period of instruction. The study established that young learners indeed possess some knowledge of NOS prior to receiving instruction. Use of explicit instruction approaches significantly aided the process of improving young learners' conceptualization of NOS during the instruction period. This led Forawi (2014) to conclude that the exceptional prior capability of young learners to understand can be leveraged by teachers to enhance the teaching of young learners. Young learners already have an understanding of NOS providing the basis for sparking their interest and enhancing their performance in promoting the learning of science.

Previously, most teachers have perceived NOS as unsuited for early childhood and only appropriate for high school students. The study by Forawi (2014) debunks this myth by showing that understanding of NOS is possible from a very young age. Forawi (2014) further argues that as the world becomes increasingly more driven by technology and innovation, it also becomes more knowledge intensive. As such, there is need for young learners to start acquiring scientific knowledge early on in their educational journey (Forawi, 2014). It is only through engagement in authentic science experiences early on that learners will be able to fully harness their potential for their career aspirations.

Abdel Khalik and Lederman (2000) and Forawi (2011) studied how implicit NOS approaches relate to NOS. They established that planning of NOS is best achieved through guided-inquiry instruction. Both studies concluded that guided-inquiry method is significantly correlated to development of better understanding of NOS amongst students. Forawi (2011) also established that teachers who were adequately aware of NOS were more capable of availing even better opportunities for student to experience and various scientific ways of knowing.

Forawi and Liang (2011) argue that both explicit and implicit instructional approaches of NOS are equally useful in enhancing student understanding of NOS. Thus, they formulated a model that combines both explicit and implicit notions of NOS building on SWKM (Scientific Ways of Knowing Model) model. In their study, they also established that teachers who adopted the new SWKM model achieved greater understanding of NOS amongst their students.

2.2.4 Inquiry-based learning and Nature of science

Forawi and Liang (2011) defines inquiry-based learning as a multi-faceted activity involving making of observations, asking questions and examining books and other sources in order to determine available information. Inquiry-based learning is premise on identification of assumptions, adoption of critical and logical approaches, and consideration of alternative views and alternatives. Thus, Forawi and Liang (2011) encourage teachers to adopt inquiry instruction methods with their students in order to develop proper understanding of scientific methods and science in general.

Llewelyn (2013) considers scientific inquiry as comprising of seven segments: investigating a phenomenon, identifying the key question, setting the investigating, running the investigation, collecting evidences and analyzing data, creating knew knowledge, and transferring new knowledge. At the outset, Llewelyn (2013) argues that scientific investigation comprises of three main areas namely, the question, the procedure and the results. The above three areas can be further divided into seven distinct segments. On the question, there is the exploration of the phenomenon and focusing on the question. On the procedure, there is the planning of the investigation and conduction of the investigation. On the results, there is analysis of data and evidence, construction of new knowledge, and the communication of the new knowledge. Thus, inquiry based learning ought to encompass all of the above.

Kubicek (2005) describes the inquiry-based approach as one whereby the development of scientific knowledge and literacy is premised on instructional techniques and environment where students engage in an active process of inquiry, problem solving and decision making. In this regard, inquiry based learning seeks to establish rich and meaningful contexts for learning science. It is within such contexts that students are able to discover the importance of science in their daily life. Rich contexts also serve to promote appreciation of the interconnected nature of science, environment, technology and the society at large (Kubicek 2005).

Use of inquiry-based learning has gained considerable support in the teaching of science. An increasing number of science educators have adopted or interested in utilising teaching methods that involve the use of inquiry (Lederman 2009). Lederman (2009) argues that inquiry-based learning is a type of learning approach which seeks to engage students in activities which are in line with the ways of scientific investigation, with learning content being addressed in the context of inquiry. In order to be effective, inquiry-based learning includes the basic features of conducting a scientific investigation as well as the understanding of the way scientists conduct their activities. Inquiry-based learning also seeks to stress the importance of learning and understanding the 'process' of science, such as the formulation empirically testable questions and being able to support claims made with sufficient evidence (Lederman 1999).

Previous studies have shown that the effectiveness of inquiry-based learning is that it enables students to engage in self-directed inquiry, in being able to learn and think scientifically, and in being to understand the relationships between theory and evidence (Byers and Fitzgerald 2002). In essence, the focus is not so much about the outcome of an inquiry as the most valuable aspect but the process used. As such, it is important to provide time for discussion and also to provide encouragement to students to make their ideas and concepts very explicit (Watson 2000). In the context of traditional understanding of science inquiry, a number of studies support the use of inquiry as an ideal teaching model (Byers & Fitzgerald 2002).

Inquiry based learning can be very effective particularly when class activities are open-ended and centered towards the learner (Bell 2008). It is critical that pupils can choose their own investigations in terms of questions and problems, and have the ability to direct their inquiry the way they wanted to be. Such environment makes inquiry more realistic, increases enthusiasm, and thus helps develop adequate views of the nature of science. When inquiry is conducted in the context of traditional methods such direct instruction using textbooks or worksheets, pupils cannot for proper understanding of the NOS: "the presentation of science as a process of following step-by-step instructions and filling in blanks on worksheets promotes erroneous and impoverished concepts regarding the nature of science" (Huber and Moore 2001, p.33).

In a study by Capps and Crawford (2013), it was found that teachers' beliefs and knowledge constitute a complex system which drives their instructional decisions and curriculum design. Overall, this complex system influence (a) knowledge attainment and understanding, (b) development and selection of tasks, (c) interpretation of curriculum contents, and (d) selection and adoption of assessment strategies and tools (Gormally et. al 2009). Kirschner et al. (2006) suggested that reforms in science education are mismatched and hindered when findings represent the proposed curriculum for researchers and not the indorsed curricula of teachers. The literature has repeatedly revealed that the complex system of teacher's beliefs and knowledge have shaped and altered reforms in curriculum over the years (Capps and Crawford 2013). It is generally expected that the use of inquiry approaches by teachers suggest that they should have deep and solid understandings of content knowledge in science, the way students learn, and the nature of science (Savery 2015). Insights related to how beliefs and knowledge shape teaching practices was provided by a recent study by Crawford (2000). The study described that six pedagogical approaches reflected the teaching of Jake, an ecology high school teacher, comprising of the contextualization of instruction, data collection and analysis, student-teacher collaboration, linking science to society, modeling the science community, and the pathways to novelty. The way Jake approached and demonstrated these characteristics in teaching was presented in several significant occasions. For instance, Jake dedicated a considerable time of the lesson debating irregularities (anomalies) in the data related to bacterial counts and took advantage of the opportunity to teach about the nature of science in the context of what science is and how it works. As such, inquiry based teaching approaches mandates extensive knowledge of pedagogy, deep understanding of science content, adequate views of the nature of science, and skillfulness in engaging and mentioning students during collaboration (Crawford 2000). Additional studies are certainly required to build a knowledge base needed to adequately present inquiry based teaching and learning approached in teacher education and training programs.

In a school where the majority of students from Hispanic and Haitian origins, Fradd and Lee (1999) examined teachers' perceptions of inquiry based science learning in classrooms where English is a second language. The study reported the reluctance of teacher to shift away from the structured teaching approaches which in their opinion are most suitable for diverse cultures. Nevertheless, Fradd and Lee indicated that such resistance to change hinders students from maximizing their scientific thinking potentials. They also emphasized on the argument that teachers needed to be the sources transmitting knowledge to students rather than facilitating their learning. This arguments can be tackled if the needs of students in local context are derived and integrated within the teacher roles. Fradd and Lee reached a conclusion, ``In addressing the needs of diverse learners, a research agenda that includes the perspectives of teachers as contributors can provide an important focus. Teachers provide important insights unavailable from any other sources" (1999, p. 19).

A study by Crawford (2000) also linked teacher use of inquiry to teacher beliefs. One of the most important highlights of this study is that the extensive use of inquiry based teaching approaches in response to students' genuine questions. Their inquiry approaches included detailed explanations of activities that teachers used to help students come up with questions or engage in discussions which constituted the foundation for investigations. Peters (2012) stimulated curiosity with observations of scientific phenomenon and diverted back students' questions to them to answer themselves. Peters (2012) dedicated a space on a board where students could note down whatever queries they had at any time. He also used questioning techniques and observations activities, ``Question Search," and ``More Testable Questions," to train his pupils on conducting investigations based on questions.

In essence, in-service teachers provide insights on teaching and learning practices which are difficult to obtain from extensive observations and researches. Teachers develop overtime informed knowledge of their own pupils; and since they are responsible for the learning of their students and safety in the classroom, only they can determine what works and what does not work in the classroom. Studies on pedagogies and teacher curriculum knowledge including that of the nature of science and how can this be transferred to the learner will be crucial in embedding inquiry in pre-service and in-service teacher education programs.

2.2.5 Role of explicit instruction of the nature of science

Over the past four decades, three main strategies have reported of teaching the nature of science, including the historic, implicit, and explicit approaches (Lederman 2004). The historic approach suggests the use of the history of science to shed the light on several components of the nature of science. The implicit approach assumes that doing science and involvement in scientific investigations such as inquiry help develop accurate understanding of the nature of science. The explicit approach dictates that teaching goals ‘‘allowing teachers to experience science through inquiry that is connected to an explicit–reflective NOS approach’’ (Akerson et. al 2007, p. 19). This approach, not be confused with didactic instruction, aims to purposely shed the light and draw the learner’s attention on selected aspects of the nature of science through activities, including investigations, formulation of hypothesis and question, discussions, reflections, and historical examples.

Abd-El-Khalick and Lederman (2000) asserted in a review of studies on instruction of the nature of science that the historical and implicit approaches are found consistently less effective than the explicit approach. They indicated that there is a significant amount of research pointing that reforms in science education can achieve the desired development of adequate understanding of the nature of science through explicit instruction approaches. Much of the subsequent studies has supported such findings (Abd-El-Khalick & Akerson 2004; Akerson & Hanuscin 2007). On the other hand, a number of studies have reported limited or no effect upon adopting explicit instruction of the nature of science (Morrison, Raab, & Ingram 2009). Moreover, most of the studies illustrating the effectiveness of explicit instruction have adopted single treatment approach with no comparison group. Implicit versus explicit instruction of the nature of science was reported in only one study (Khishfe and Abd-El-Khalick 2002). Although the results of the study conducted in a private school in Lebanon favored explicit instruction, however, there was no significant high gain of the participating sixth graders.

A number of researchers have expressed concerns over the absence of genuine context that can be used to teach the nature of science away from considerable science content (Johnston & Southerland 2002). These authors have voiced concerns over non-contextualized instruction that can doubtfully produce the adequate perceptions of the nature of science that would help teachers address the nature of science as part of their instruction. According to Clough (2003), much of the failure of recent efforts to teach the nature of science is attributed to such instruction. For the reason that the emphasis of science courses is on teaching practices and not on science content, it is expected that non-contextualized instruction is the norm of the nature of science. When the science instruction is far from what students consider as “real” science content, they are likely able to interconnect science and it nature as integral parts of each other (Peter 2012).

A number of studies have also shown that reflective explicit instruction is far better in constructing learners’ perceptions of the NOS compared to implicit instruction (Akerson et al. 2007). Reflective approach in teaching about the NOS allows enables the learners to think about their practices in the classroom including inquires and investigation to the work of scientists in terms of similarities and differences. On the hand, explicit instruction focuses the attention of the learners on key aspects of the NOS through classroom activities and discussions mimicking scientific practices.

A number of studies have also reported the success of explicit instruction of NOS instructional approaches in developing adequate understanding of the NOS among learner (Hanuscin et al. 2006). As mentioned earlier, the explicit instruction of the NOS intentionally draws the attention of the learners to various key aspects of what is science and how it works. Hence, this type of instructional approach requires teachers to embed various aspects of the NOS in their planning and classroom practices as central element of learning, not a supplementary learning outcome. Findings reported in a number of studies (Hanuscin et al. 2006; Abd-El-Khalick and Akerson 2004) indicate the effectiveness of explicit instruction of the NOS.

Implicit approaches in teaching about the NOS assume that engaging students in inquiry based learning activities develops an understanding of the NOS without the need to deliberately focus on aspects of the NOS. The findings of several studies (Sandoval and Morrison 2003) indicate that implicit approaches are mostly neither effective nor successful in developing learners' adequate understanding of NOS. Furthermore, studies continue to indicate that implicit instruction does not result in improved understanding for all learner (e.g., Abd-El-Khalick and Akerson 2004). Evidences from emerging research in the field of argumentation have indicated the importance of argumentation in helping learners to develop more informed view of NOS (Bell & Linn 2000; Ogunniyi 2006; Yerrick 2000).

Research on argumentation in explicit instruction (i.e., embedding rigorous aspects of discussion and reflection including definitions, structure, and function to assess the validity of argumentation) has provided valuable evidences that attempt to improve argumentation skills among learners. The skills and / or qualify of argumentation have improved among learners when explicit argumentation instruction is adopted as reported studies conducted in science contexts (Bell and Linn 2000; Zohar and Nemet 2002). According to McDonald (2010), argumentation in scientific contexts with the application of reasoning enables learners to discuss and understand justification, validity, limitation, and evaluations related to hypotheses, scientific evidence, competing models, and theories.

Nevertheless, improvements in learners' skills and / or quality of argumentation were reported without adopting explicit argumentation instruction in studies conducted in socio-scientific contexts (Jimenez-Aleixandre 2007). These contexts for explicit argumentation instruction are applied in the classroom on issues involving scientific ideas and reasoning with the consideration of moral, ethical, and social perspectives (Erduran, Osborne, and Simon 2004).

In the study by McDonald (2010) the following five premises were established: (1) learners’ views of the NOS influence their discussion (argumentation) in scientific contexts; (2) development of learner’s skills and /or quality of argumentation, view of NOS, and engagement in argumentation require the adoption of both explicit NOS and explicit argumentation instruction; (3) guidance is crucial to ensure the application and relevancy of the aspects of NOS in the teaching strategies and arguments; (4) engagement of learners in scientific argumentation may enhance their NOS understanding without the use of explicit instruction of NOS; and (5) implementation of explicit instruction of NOS and argumentation results in improvements in the learner view of NOS.

Chapter 3: Methodology

3.1. Introduction

The development of a methodology that suits the research objectives and answers the research questions is one of the important steps in conducting a successful research. In the process of choosing the desired research methodology, it is important to determine the right research paradigm. Guba and Lincoln (1994, p. 107) defines research paradigm as "world view that defines, for its holder, the nature of the 'world', the individual's place in it and the range of possible relationships to that world". Once the research paradigm has been selected, a clear path towards the achievement of research objectives and answering of research questions is outlined. According to Crotty (1998), research paradigm is the justification of methodological choice to be used is a study or the process of creating new knowledge. The aim of this study is to determine the impact of inquiry based learning and explicit instruction on students' view of NOS. In this regard, this study adopts a quantitative approach. This chapter outlines research philosophy, study design, data collection process, sampling strategies, data analysis techniques, and the ethical measures taken to preserve the integrity of the study.

3.2. Research Philosophy

The development of research philosophy is a critical step in for purposes of informing research design and also for explaining the rational for approaches taken in relation to the establishment of research credibility (Bazeley and Jackson 2013). Similarly, identification of an appropriate research philosophy is essential in the establishment of the legitimacy of research findings given that research philosophy is the cornerstone of any study (Shenton 2004).Morgan (2007) states that there are four important features that needs to be considered in the development of any research methodology: the epistemology informing the research, the philosophical foundation or the research paradigm (such as post-positivism, interpretivism, pragmatism, and advocacy/participatory), the procedures and approaches used in collecting the data. A number of authoritative studies in research methods (Creswell 2011; Denzin et al. 2006; Merriam 2009; Tashakkori and Teddlie 2003), have established three main research approaches: qualitative, quantitative and mixed methods. Each of the above research approach emanates from a different philosophical perspective.

Qualitative research has been described as an activity that places the observer in the actual real world where the subject of study is experiences or lived (Denzin and Lincoln 2005). Through qualitative research, the world becomes visible via interpretive practices which essentially seek to establish representations of the world through field notes, logged data, interviews, portrayals, and recordings amongst other methods. Denzin and Lincoln (2005) further describe qualitative research approach as involving interpretive and naturalistic way of conceptualizing the world. It seeks to make attempt of understanding phenomena as shaped by how people understand and perceive them. It takes the position that it is possible for different people to perceive differently depending on context and other individualized factors. In a sharp contrast to interpretivism, positivism is grounded on quantitative research approach. Quantitative research approach is premised on objectivity and existence of a single 'truth' that is devoid of human perceptions (Lincoln and Guba 1985). As such, positivism is founded on the idea that the only way to explore the truth is through quantification and measurement of factors that influence human perception. The underlying rationale in positivist research approaches is to remove the inherent bias in human perceptions.

This study follows a positivistic research philosophy. Positivism is typically associated with quantitative research, often-emphasizing purely objective research and minimal interaction with research participants (Wilson 2010). In the context of this study, quantitative method is appropriate for one main reason. An objective evaluation of the differentiated impacts of inquiry based learning and explicit instruction on NOS can only be effectively conducted using quantitative technique. Quantitative analysis will clearly show performance at baseline (pre-test) and the impact of each instructional approach on students' views and endpoint (post-test).

3.3. Research Approach

Research approach is underpinned by the research philosophy. According to Fowler (2013), the philosophical underpinning of a research provides the rationale for supporting the credibility of a research. At the same time, research design widely influences the legitimacy and validity of research findings. Towards this end, Fowler (2013) recommends careful consideration of epistemology, the chosen philosophical paradigm, and the methodology and procedures for collecting the data.

A quantitative design utilizing a survey (see Appendix 1) as the primary data collection instrument has been selected. This strategy enabled the researcher to systematically investigate the relationships between key variables in order to lay the groundwork for further study into this important topic. Perhaps the most significant advantages associated with using a quantitative, survey-based approach are logistical: by using survey, the researcher was able to create a survey which could be filled out by a relatively large number of respondents at their convenience. A quasi experimental approach was adopted i.e. pre and post tests using the survey instrument. Such method was required to evaluate the impact of the intervention model on different groups. Thus, this study only utilized deductive research approach for data analysis. According to Saunders (2011), deductive research approach is suited for quantitative studies where a researcher seeks to prove hypotheses or theories. For this study, the aim was to establish how inquiry based learning and explicit instruction approaches impact students' understanding of NOS. Deductive analytical approaches are used to interpret the findings and conclude on the research objectives.

3.4. Methods

The quasi experimental approach involved 3 groups apart from the control group. The teachers of the 3 groups are chosen using the instrument to have adequate views of the nature of science. The 3 groups are taught using science textbooks aligned with the next generation science standards (NGSS). All of the students of the school are Emiratis and teachers are multinational and they needed to have teaching license of their area of specialty. A pre test was conducted to all groups. Similarly, all groups were taught the same lesson i.e. same scientific concepts however as the research suggested with different techniques namely inquiry based, explicit instruction, and inquiry and explicit while the control group through direct instruction rote learning. The lesson (see Appendix 2) tackled Galileo and Newtonian mechanics related to free falling objects and terminal velocity.

The 1st group was taught through inquiry based experimentation using data loggers and sensors investigating gravitational acceleration and terminal velocity of various objects. Students used data loggers and sensors to describe and interpret the motion, calculate the acceleration, and identify terminal velocities of the different objects when dropped freely. The 2nd group was taught using explicit instruction of the nature of science tacking Galileo's experiments and findings versus Newtonian experiments and findings. The teacher of the 2nd group provided a historical background on the work of Galileo and Newton related to free falling objects. Then, students were asked to interpret the motion of free falling objects in the light of the findings of the two scientists. The 3rd group was taught using a combination of both inquiry-based and explicit instruction of the NOS.

This study used a structured 5-point Likert scale survey to collect data measuring students' views of the NOS during the pre-test and post-test stages. The survey was designed after extensive literature review and consultation with research supervisor. The design, formulation, and administration of the survey in this thesis study followed the conventions of Brinkman (2009). Once the sample size is huge, it is not preferable to use open-end questions while developing the questions in the survey (Brinkman 2009). At the same time, there should be an agreement between the type of questions in collecting data and the sample size. Brinkman (2009) emphasizes the use of rationalized 'questions' however "instead of aiming for in-depth understanding, with closed-questions the focus is on systematically summarizing the data and if possible trying to generalize it to the population at large" (p.4). Therefore, the survey's constructs were designed in a structured manner to facilitate the respondents' choices. At the same time, this also allowed for generalizability of findings to the general populace.

As mentioned above, according to Brinkman's (2009) conventions, the survey started with an introductory section in which the researcher outlined the aim of the study and informed the participants that their participation is voluntary. At the same time, participants were also informed that there will be no repercussion if any participant decided to withdraw from the study at any stage. As concerns demographic factors, this study did not collect any. As such, they are not utilized in the analysis in this study. The survey is divided into several main parts. The first section comprised of questions on observations and inferences. The second section contained questions on change of scientific theories. The third section comprised of questions on scientific laws and theories. The fourth section presented questions on social and cultural influence on science. The fifth section presented questions on Imagination and creativity in scientific investigations. The final section comprised of questions on methodology of scientific investigations. The survey used comprised of a 5 point scale with items positively or negatively coded (from -2 to +2) depending on the type of question (see Appendix 3).

The survey used in this study is a tried and test tool that has also been used in a number of previous studies. Student Understanding of Science and Scientific Inquiry (SUSSI) instrument is premised on international science education research (Chen et al. 2006). SUSSI has been developed as a formative assessment tool for both large and small scale studies. SUSSI as a scientific instrument particularly focuses on evaluation of: tentativeness of scientific knowledge, science as observation and inferences, subjectivity and objectivity that is inherent and expected in science, rationality and creativity in science, socio-cultural embeddedness of science, scientific laws and theories of science, and existence of scientific methods (Chen et al. 2006). By using a standardized tool, the findings of this study will be easily comparable and generalizable to the general population.

Piloting the Study

The above survey was first piloted and subsequently revised. Piloting of a study seek to achieve a number of purposes such as examining the validity of instruments, identifying the selection criteria and sample size, and establishing and checking the procedures and mechanism of conducting the study. Hence, it was very critical to conduct this piloting before conducting the study of this thesis. Arnold et al. (2009) defined piloting as “small study for helping to design a further confirmatory study”. In addition, Creswell (2011) asserted that piloting or pre-administration of an instrument with a sample of the population, and taking in consideration feedback for improvements are essential for the validity of the instrument.

The pilot research was conducted using quantitative approach in investigating the impacts of inquiry based learning and explicit instruction on students' views of NOS using survey to collect the data. Although the survey is adapted and modified from previous studies, the researcher sent the adapted survey to experts in science education and teaching English as a second language to ensure the suitability and the validity of the survey instrument for this particular study. The reliability test Cronbach's alpha of all 24 items of the survey was good (.772) for teachers and (0.765) for students who participated in the pilot study. The feedback and the recommended adjustments were considered and incorporated then the final version of the survey was sent to the selected sample for the piloting process. The piloting process yielded a number of feedbacks which informed further adaptation of the survey.

3.5. Samples and Sampling Strategy

There are a number of sampling methods that can be used depending on the nature of study and available budget. For this study, purposeful sampling method was used. This is whereby a researcher pragmatically chooses the most appropriate participants that will enable him or her achieve the objectives of the study. Creswell (2011) describes purposeful sampling strategy as "the intentional selection of the samples and the sites "to learn or understand the central phenomenon" (p.207). Patton (1990) considers purposeful sampling as being information and able to empower a researcher to have an in-depth understanding of phenomena. There are several types of purposeful sampling which can be used. The two most widely used are maximal variation sampling and minimal variation sampling. Maximal variation is whereby the research defines the nature and type of individuals needed in the sample beforehand while minimal variation is whereby the researcher defines individual characteristic during the data collection process Creswell (2011). The sampling technique chosen was critical to the success of the quasi experimental approach. Where there is no background homogeneity amongst the members as well as each participant is the bearer of the required characteristics, the discussion might move away from the intended data or lose its representativeness (Cohen, Manion and Morrison 2011).

The most effective sample size for quasi-experimental groups or focus group participants is between 6 and 15 participants (Morgan 2007). The reason for this sample size as outlined by Morgan (2007) is that when the sample size is too large the observers will lose control. On the other hand some members might not participate effectively. In contrast, if the sample size is small, it might not represent the actual behaviors of the intended population of the study. Therefore, the sample for this study was in-line with the defined criteria.

3.6 Data Collection

A total of 87 students and 4 teachers participated in the study. The control group comprised of 24 students in the pre and post test. The rest of the groups (inquiry-based learning, explicit instruction group, inquiry and explicit learning groups) had a total of 21 students each participating in pre and post instruction survey.

After obtaining the formal approval to start the study, the targeted group of students received the survey to collect the data needed. The researcher explained to the participants in the introduction of the survey the purpose of the study along with any potential benefits and risks. It was made clear from the beginning that participation is voluntary, and participants have the right not to be involved or withdraw at any stages of the study. Participants were also assures that all information is kept confidential and will not be disclosed with anyone at all times. Signing the letter and consent form is considered a formal agreement between the researcher and participants.

Data was collected electronically over the duration of two weeks using an online web service which recorded single submission from each participant without asking for personal information. The targeted students received guidance from the participating teachers to assure that the surveys were completed properly, and to avoid any counterfeit or biasing. The researcher shared the following procedures to insure consistency in conducting the surveys for all groups: 1) students must fill the survey by themselves, 2) copying fraudulently from each other is strictly forbidden, and 3) no pressure whether positive or negative should be exercised on students during the survey. The research with the help of teachers dedicated specific timing for these surveys in order not to affect the instructional time and curriculum delivery. All the surveys were completed and submitted online.

3.7 Data Analysis

Analysis of the data obtained through the survey instrument followed a relatively standard process involving checking for completeness and discarding any incomplete surveys as appropriate, editing, coding, and organization; because of the online mode of administration, however, these steps will not need to be performed manually as with analogue, pen-and-paper surveys, but can be automated through the survey platform. Once this was accomplished, the data was cross-tabulated and inputted into SPSS for descriptive and inferential analyses. The results were briefly summarized using descriptive statistics, such as measures of central tendency and variability. Next, the properties of the response distributions were analyzed by statistical inference through the use of a statistical model aimed at providing a basis for generalizing the results of this study to a larger population of interest (Gacula 2013).

3.8 Validity and Reliability

This study utilized a number of measures to ensure its reliability and validity. The research instrument used is a standardized tool that has been used in a number of studies. Secondly, the data analysis techniques adopted are also devoid of individualized perspectives. SPSS is a standardized tool that objectively analyses and presents data inputted into it. This effectively removed researcher subjectivity in data analysis. The data collection process was also automated where survey was administered online for both the pre and post tests. This ensured that participants had adequate time to fill the survey objectively and effectively.

For the validity, clarity, and the reliability, the designed survey is adapted from the literature. The research instrument was piloted on science teachers, and a certified ESL (English as a Second Language) teacher whose role was crucial to make sure that the way the statements are written would be clear and suitable for students who are studying English as a second language. This help avoid any jeopardy in the research findings.

Piloting of an instrument is necessary for its reliability and validity as it helps improve the content and suitability of items for the targeted sample or population of a research (Cohen, Manion and Morrison 2007). After the piloting process, the survey was modified and refined to become a well-established instrument suitable for the intended study. Furthermore, three domains governed the adapted survey instrument namely: readiness, perception, and implementation. Such categorization was essential to the researcher for constructing a solid platform for the study. As a matter of fact, the overall reliability test Cronbach's alpha of all 24 items of the survey improved significantly (.852) after implementation compared to (0.772) when it was piloted.

3.9. Research Ethics

Rules of research ethics insist on the importance of conducting research in the most ethical manner during the entire study process (Creswell 2011). During the entire research process and in-line with established research ethical guidelines, the researcher sought prior approval for the study from the department. The confidentiality and anonymity of all participants were maintained throughout the whole stages of the study. As the intended thesis involved human participants, a consent form (see Appendix 4) was provided to all the participants. The consent form outlined the potential risks, benefits and rights of participants to ask questions or even withdraw from the study completely. Concerning teachers, the invitation email for conducting the focus group was enclosed with a statement to indicate that by replaying to the invitation email, involved teachers accept willingly to participate in the study and they were informed that their participation is for research purposes. The purpose of the study was explained to them from the very beginning of the study as well as their confidentiality will be maintained. As for the students, a letter (see Appendix 5) was sent to their parents/guardians along with the consent form in which the researcher explained and assured the parents/guardians that their children will not be at risk by participating in the intended study.

In addition, this study also adhered to Belmont Protocol (1978) which requires that the burden of research is fairly shared between the researcher and participants. In this regard, the entire process had to have explicit approval from the participants. The participants had every right to refuse to answer any question without providing an explanation for the same. Ultimately, the researcher committed to protecting privacy, confidentiality and anonymity of the participants (Heffetz and Ligett 2014). As part of the consent form, the researcher agreed to limit the use of the data collected to just this study. In order to mitigate the ethical issues, the following are some of the measures that were used as recommended by the Belmont Report (1978):

Respect for Persons: this incorporates two or more ethical convictions: individuals should be treated as autonomous agents. In situation where participants had low levels of autonomy, such participants are entitled to protection. For this study, the participants had full autonomy and every measure was taken to protect their privacy and autonomy.

Beneficence: participants must be treated in an ethical manner; respecting their decisions and putting in places measures that protect them from any harm arising directly or indirectly from the study. In addition, a researcher is also expected to make every effort to secure the well-being of each and every participant. In this study, the identity of the participants was never disclosed to anyone. This also encompasses ensuring that the performance of each student was not disclosed at any point. All of the data was anonymized with the help of a serial number. During the collection of data, the web application used to conduct the survey was not designed to collect or retain any personalized information. Nonetheless, for purposes of ensuring the validity of this study, measures were taken to ensure that the right participants were actually filling the questionnaires. This necessitated the need to restrict IP addresses.

Informed Consent: Belmont Protocol mandates that researchers how respect to participant. In this regard, researchers are required to ensure that to the degree that they are able should give participants the opportunity to choose what shall or shall not occur to them during the course of the study. In this study, a signed consent form was used to obtain the consent of participants at the onset of the study.

Assessment of Risks and Benefits: The onus is the researcher to conduct careful evaluation of the context of research, relevant data and wherever possible identify other alternative ways of achieving the desired benefits sought from the research. The collection of data from participants should be adopted as the last resort. For this study, the data collection was necessary and every measure was taken to ensure that no personally identifiable information is leaked into the final data before or after the analysis.

Chapter 4: Findings and Analysis

4.1 Introduction

This chapter presents the analyses and findings of the study. This chapter is organized into six main sections. The first section introduces the chapter. The second section presents data on participants and participation at pre and post instruction. The third section presents means score at pre and post for all variables. The fourth section presents t-test results providing a comparative analysis between pre and post instruction. The fifth section presents ANCOVA findings comparing significance across the groups.

4.2 Participants

A total of 87 male Emirati students and four science teachers participated in the study. The four teachers who participated in the study had adequate understanding of the Nature of Science measure using the survey (M = 32). The table below shows participation across all of the groups.

Group	Number of participants & responses
Teachers	4
Control (not taught in specific way)	24
Inquiry (taught using inquiry-based learning approach)	21
Explicit (taught with explicit presentation of the NoS)	21
Inquiry & Explicit (taught with explicit presentation of the NoS & using inquiry-based learning approach)	21
Total	4 teachers and 87 students

Table 4.2: Participants of the Study

All students who participated in the study are Emirati nationals. The school where the study was conducted focuses on science and technology. All students in the school are

Emiratis. The teachers in the school are multinational from various countries in Europe and America. The science books used in the school are aligned with the Next Generation Science Standards (NGSS). Teachers were selected based on their understanding of the NOS i.e. they took the survey and based on the results the choice was made on which teachers will participate in the study. On the control group, there were a total of 24 students at both pre and post instruction. For all of the other groups (inquiry, explicit and explicit-inquiry), the total number of participant for each group was 21 both at pre and post instruction.

4.3 Pre-Instruction and Post-Instruction Mean Score

As outlined in the methodology section, data was collected pre and post instruction across all groups (control, inquiry, explicit, and inquiry explicit). This section presents results on the difference in means pre and post instruction. This section will also delve deeper into the individual questions and analyze how participants responded to them.

4.3.1 Overall

The maximum score that can be achieved is 48 while is the minimum is -48. The research instrument has positive and negative components to ensure its internal reliability. Figure 4.3.1 below shows total mean score across the board.

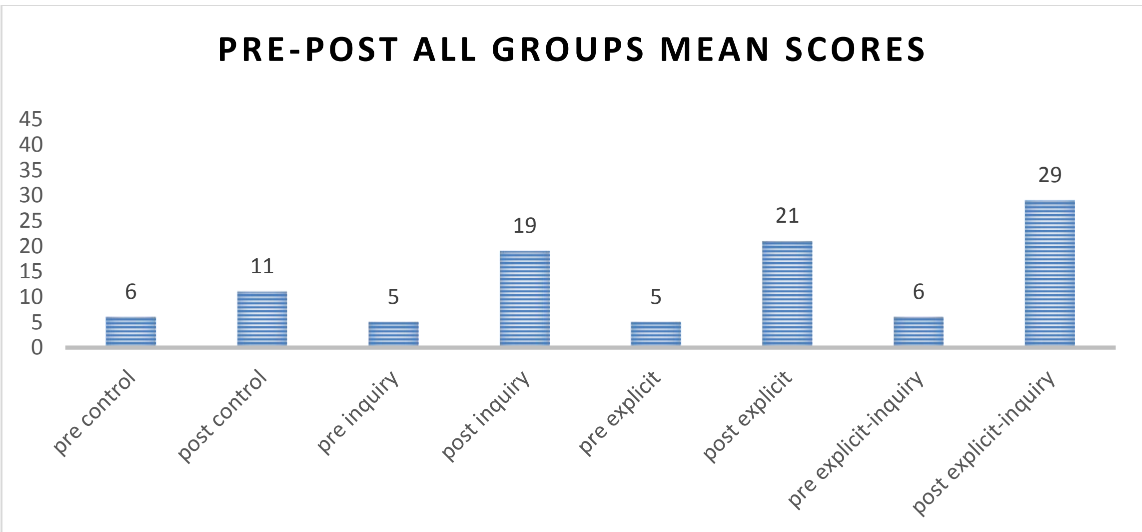

Figure 4.3.1a: Pre and Post Instruction mean scores

Figure 4.3.1 above shows that for the control group, the pre-instruction score (M=6) was significantly lower than the post instruction score (11) with 83% increase. On inquiry-based method of instruction, the pre-instruction score (M=5) increased by 280% (M=19). Explicit instruction method resulted in an even higher change in students' perception of NOS from (M=5) to (M=21) making for a 320% change in students' perception of NOS. Explicit instruction combined with inquiry-based learning methods resulted in an even higher change in NOS perception from (M=6) to (M=29) accounting for 383% change in students' perception of NOS. Explicit instruction method performed better compared to inquiry-based learning methods with the combined instruction methods performing even better. On the performance between explicit instruction and inquiry-based learning, further statistical analysis is conducted in subsequent sections to determine whether difference in performance is any significant.

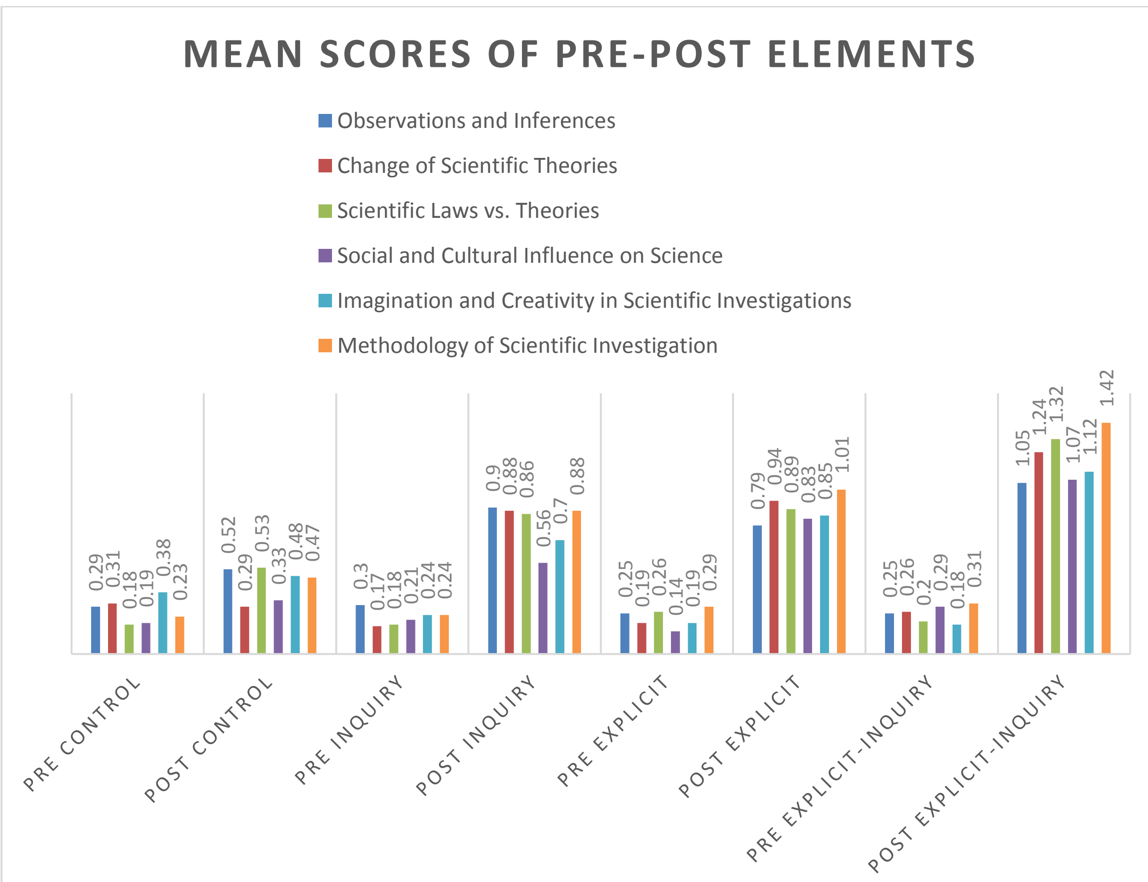

Figure 4.3.1b: Mean scores of elements

Figure 4.3.1b shows the performance of each element pre and post instruction. There was marked improvement in each of the element post instruction across control, inquiry-based learning, explicit instruction, and combined explicit-inquiry instruction methods. The only exception was on change of scientific theories where post-instruction score (M=.29) was actually lower than pre-instruction score (M=0.31) for the control. It is also worth noting that change in students' views of NOS remained largely flat for the control group for majority of the elements compared to the other groups.

On the control group, scientific laws and theories emerged as the best performer increasing from .18 to .53. The second most improved element was methodology of scientific investigation which improved from .23 to .47. On the inquiry-based learning group, change of scientific theories was the most improved from .17 to .88. It was closely followed by scientific laws vs. theories which improved from .18 to .86. Observation and inferences which was highest at pre-test registered the lowest improvement for the inquiry-based learning group. In the case of the implicit instruction group, the element of 'social and cultural influence on science' registered the most improvement from .14 to .83. The element of 'scientific laws vs. theories' improved the least for this group from .26 to .89. In the group using a combination of explicit instruction and inquiry-based learning the element of 'methodology of scientific investigation' emerged as the most improved from .31 to 1.42 with the element of 'social and cultural influence on science' registering the least improvement from .29 to 1.07. The subsequent sections will conduct further analyses to establish the significance of the differences in mean at pre and post instruction for all variables.

4.3.2 Control Group

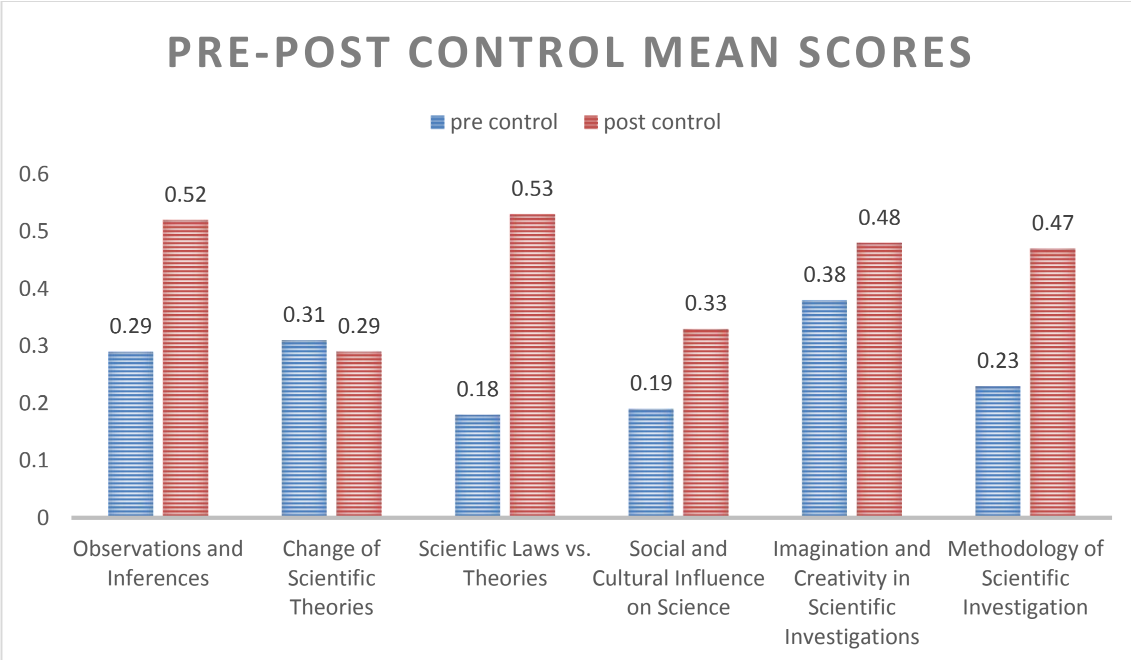

Figure 4.3.2: Pre and Post Control group mean scores

Figure 4.3.2 above shows element performance for pre and post instruction performance for the control group. Positive change in students' views was registered across all elements with the exception in 'change of scientific theories' which registered a decline. Students' views on scientific laws and theories registered the highest change from (M=0.18) to (M=0.53). Other elements that registered significant improvement for the control group included 'methodology of scientific investigation' (from M=.23 to M=.47) and 'observations and inferences' (from M=.29 to M=.52). This serves to show that students' perception of NOS improves over time as they learn regardless of the method of instruction adopted. There is bound to be some improvement in students' perception of NOS whether a specific method of instruction has been adopted or not. The above finding serves to show that young learners already have an understanding of NOS which should provide the basis for sparking their interest and enhancing their performance in promoting the learning of science. However, the significance and the comparative aspect of the improvement in students' views of NOS for the control group will be evaluated further. Further insight will be provided on this in the subsequent analysis.

4.3.3 Inquiry based learning group

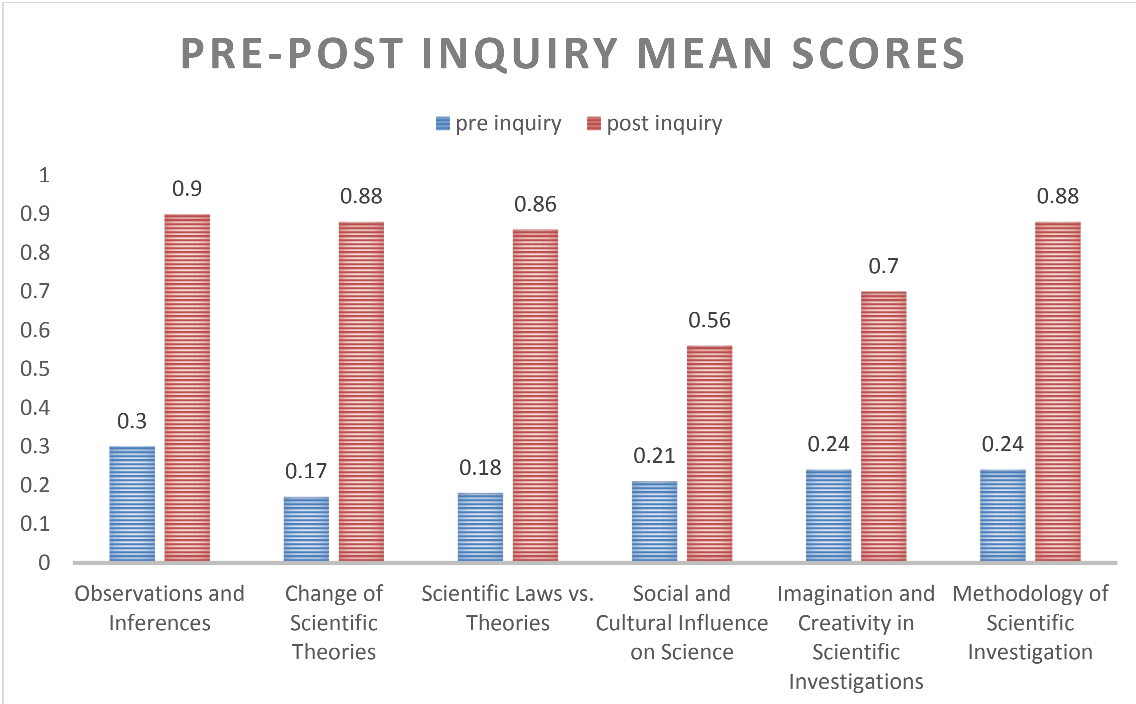

Figure 4.3.3: Pre and Post Inquiry based learning mean scores

Figure 4.3.3 above shows the performance of the inquiry-based learning group. Overall, each element registered significant change of views amongst the participants. The element 'change of scientific theories' recorded the highest change (from M=.17 to M= 0.88). The element of 'social and cultural influence' on science registered the lowest change in views (from M=.21 to M=.56). On the other hand, observations and interferences increased (from M=.3 to M=.9), change of scientific theories (from M=0.17 to M=0.88), scientific laws vs. theories (from M=.18 to M=0.86), imagination and creativity in scientific investigations (from M=.24 to M=.7), and methodology of scientific investigation (from M=.24 to M=.88).

4.3.4 Explicit instruction group

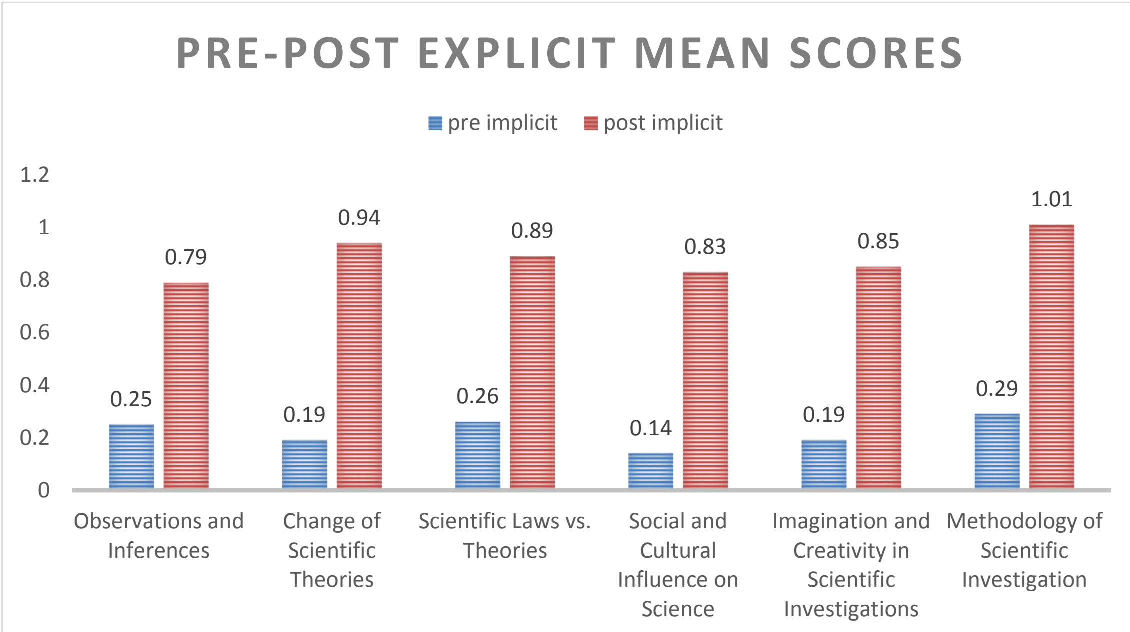

Figure 4.3.4: Pre and Post Explicit instruction group mean scores

Figure 4.3.4 above shows the performance of explicit-instruction method group. There is significant change of views across all of the elements. The element of ‘change of scientific theories’ registered the highest change in students’ views (from M=.19 to M=.94). The rest recorded 300 per cent or more change in student views: observations and interferences increased (from M=.25 to M=.79), scientific laws vs. theories (from M=.26 to M=0.89), social and cultural influence on science (from M=.14 to M=.83), imagination and creativity in scientific investigations (from M=.19 to M=.85), and methodology of scientific investigation (from M=.29 to M=1.1).

4.3.5 Combined Explicit inquiry group

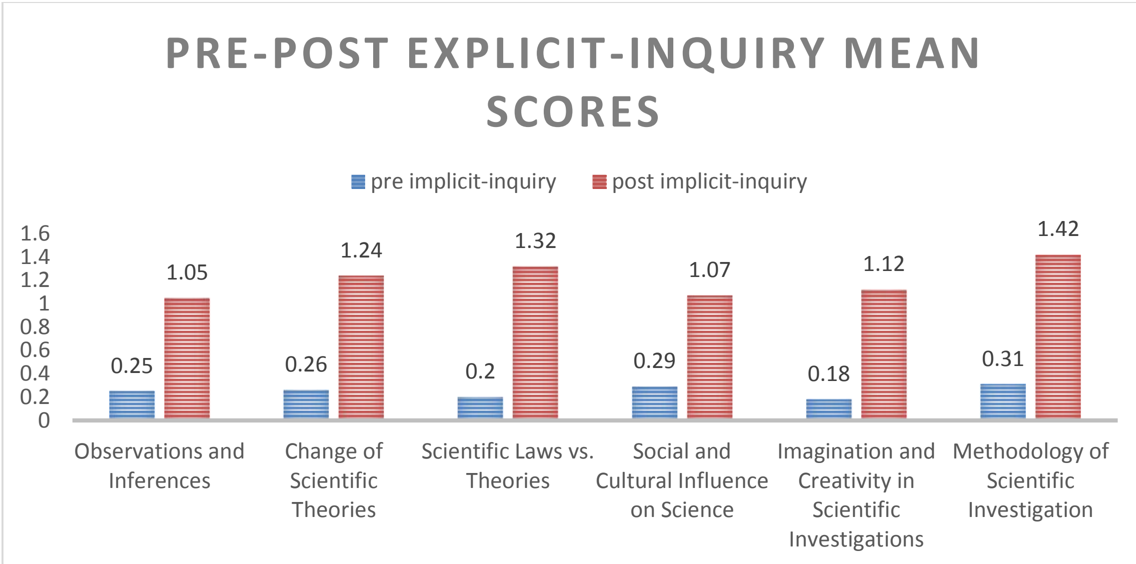

Figure 4.3.5: Pre and Post Combined Explicit inquiry mean scores

The combined explicit-inquiry learning group emerged as the best performing group across all categories. Across each element, the combined instructional methods delivered significantly better performance relative to the control group, inquiry based learning group, and explicit instruction group operating independently. Figure 4.3.5 above shows student change in views pre and post combined explicit-inquiry instruction method group. As expected, there was significant change in students' views with scientific laws vs. theories recording the most change. Interestingly, observations and inferences registered the lowest improvement. Nevertheless, the registered improvement was higher than either instruction method or instruction group independently as per the following: observations and interferences increased (from M=.25 to M=1.05), change of scientific theories (from M=.26 to M=1.24), scientific laws vs. theories (from M=.2 to M=1.32), social and cultural influence on science (from M=.29 to M=1.07), imagination and creativity in scientific investigations (from M=.18 to M=1.12), and methodology of scientific investigation (from M=.29 to M=1.1).

4.4 T-tests

The study also conducted T-tests to determine if there was any significance in the pre and post instruction surveys. T-test is one of the most widely used SPSS test for comparing performances across different groups. It essentially compares and contrasts the means of two variables with the factor variable having a maximum of 2 sub groups. The difference in group means is also used to show the extent of the difference across the groups.

4.4.1 Control Group

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-control	6.2917	24	8.49798	1.73464
	Post-control	10.5000	24	7.16877	1.46332

Table 4.4.1a: Paired Samples Statistics of the control group

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-control – post-control	-4.20833	11.22876	2.29206	-8.94982	.53316	-1.836	23	.079

Table 4.4.1b: Paired Samples Test of the control group

The tables above shows t-test results conducted on the control group. There is no statistically significant difference between pre and post instruction for the control group regarding their views on NOS (t = -1.836, df = 23, p = 0.79).

4.4.2 Inquiry based learning group

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-inquiry	5.3333	21	6.34298	1.38415
	Post-inquiry	19.1429	21	5.59719	1.22141

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-inquiry – post-inquiry	-13.80952	7.42711	1.62073	-17.19030	-10.42875	-8.521	20	.000

Table 4.4.2a: Paired Samples Statistics of Inquiry based learning group

Table 4.4.3b: Paired Samples Test of Inquiry based learning group

The tables above shows t-test results conducted on the inquiry-based learning group. There is a statistically significant difference between pre and post instruction for the inquiry-based learning group regarding their views on NOS (-8.521, df = 20, p = .000). The post instruction mean (M=19.14) was significantly higher than pre instruction mean (M=5.33) for the group.

4.4.3 Explicit Group

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-explicit	5.2857	21	7.41716	1.61856
	Post-explicit	21.2381	21	5.51276	1.20298

Table 4.4.3a: Paired Samples Statistics of Explicit group

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-explicit – post-explicit	-15.95238	8.44083	1.84194	-19.79460	-12.11016	-8.661	20	.000

Table 4.4.3b: Paired Samples Test

The tables above shows t-test results conducted on the explicit instruction group. There is a statistically significant difference between pre and post instruction for the group regarding on their views on NOS (t=-8.6611, df = 20, p = .000). The post instruction mean (M=21.23) was significantly higher than the pre instruction mean (M=5.28) for the group.

4.4.4 Explicit-Inquiry Group

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-explicit-inquiry	5.9524	21	8.07760	1.76268
	Post-explicit-inquiry	28.8571	21	8.85599	1.93254

Table 4.4.4a: Paired Samples Statistics

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-explicit-inquiry – post-explicit-inquiry	-22.90476	13.11451	2.86182	-28.87442	-16.93511	-8.004	20	.000

Table 4.4.4b: Paired Samples Test

The tables above shows t-test results conducted on the combined explicit-inquiry instruction group. There is a statistically significant difference between pre and post instruction for the group regarding their views on NOS (t=-8.004, df = 20, p = .000). The post instruction mean (M=28.85) was significantly higher than the pre instruction mean (M=5.95) for the group. The above result serve to show that there is a significant difference in students' views of NOS post instruction using a combination of both explicit instruction and inquiry-based learning methods. The percentage change in difference is significantly higher than for either inquiry based learning or explicit instruction used in isolation.

4.5 Inter-Group Difference

One way ANCOVA analysis was also conducted to determine statistical difference across the groups between pre and post instruction. The preliminary test on the pre-test and post- test results (see Appendix 6) indicated that there is homogeneity in regression of data (Miller and Chapman 2001). Thus, the test of covariance was conducted.

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Control	Explicit	-10.737*	2.085	.000	-16.375	-5.098
	Inquiry	-8.642*	2.085	.000	-14.280	-3.004
	Explicit & inquiry	-18.357*	2.083	.000	-23.989	-12.724
Explicit	Control	10.737*	2.085	.000	5.098	16.375
	Inquiry	2.095	2.151	1.000	-3.722	7.912
	Explicit & inquiry	-7.620*	2.152	.004	-13.439	-1.800
Inquiry	Control	8.642*	2.085	.000	3.004	14.280
	Explicit	-2.095	2.151	1.000	-7.912	3.722
	Explicit & inquiry	-9.715*	2.152	.000	-15.534	-3.896
Explicit & inquiry	Control	18.357*	2.083	.000	12.724	23.989
	Explicit	7.620*	2.152	.004	1.800	13.439
	Inquiry	9.715*	2.152	.000	3.896	15.534

Table 4.5: Pairwise Comparisons

Table 4.5 above presents ANCOVA results which shows significant difference between all the groups with the exception of between explicit and inquiry. There is a significant effect of instruction method on students' views of NOS across all groups. There is a significant difference between the control group and explicit instruction, inquiry and explicit-inquiry groups ($p < .000$). Explicit instruction group also registered significant difference with control ($p < .000$) and explicit-inquiry ($p < .000$); however, there was no significant difference between explicit instruction and inquiry-based learning method group ($p = 1.000$). Explicit-instruction group registered significant difference with control group ($p = .000$), explicit group ($p = .004$) and inquiry-based learning group ($p < .000$).

Chapter 5 Conclusions and Recommendations

The previous chapter presented and analyzed the results of the study. This chapter presents a discussion, concludes on the results, offers recommendations and suggests areas for future research. This chapter is organized into three sections. The first section provides a discussion related to the findings in the context of previous studies. The second section reflects on the research questions and offers conclusions in the context of previous studies. The third section offers recommendations for practice and policy makers. The fourth section outlines the limitations of the study and outlines areas for future studies.

5.1 Discussion

The aim of this study was to investigate the impact of instruction methods; explicit instruction, inquiry based learning, and a combination of both on students' views on the nature of science. Overall, the results presented in the previous chapter showed remarkable improvement in students' views of NOS across the board explicit instruction group, inquiry learning group, and inquiry-explicit group registering the highest improvement in students' views of NOS ($p <.000$). Similar results were reported in a study conducted by Forawi in 2014 involving young learners. The study indicated the significant impact of the explicit teaching of NOS on students' conceptions ($t = 5.217$ $p < .000$). Improvement in students' views of NOS was also reported across all elements of NOS across all groups with exception of 'change of scientific theories' in the control group. This serves to show that students' perception of NOS improves over time as they learn regardless of the method of instruction adopted. The results also echo a previous study by Forawi (2014) which established that learners indeed possess conceptualization of NOS prior to receiving any instruction. However, the level of improvement varies significantly across the groups. Nevertheless, the exceptional prior capability of young learners to understand can be leveraged by teachers to enhance the teaching of young learners. Young learners already have an understanding of NOS providing the basis for sparking their interest and enhancing their performance in promoting the learning of science (Forawi 2014).

Inquiry-based learning, explicit instruction and explicit-inquiry groups registered significant changes post instruction. This highlights the importance of adopting more proactive approaches in teaching science. This results echo previous findings by Abdel-Khalik and Lederman (2000), and Forawi (2011). These studies concluded that it is only through engagement in authentic science experiences early on that learners will be able to fully harness their potential for their career aspirations. Abdel Khalik and Lederman (2000) and Forawi (2011) studied how implicit NOS approaches relate to NOS. They established that planning of NOS is best achieved through guided-inquiry instruction. Both studies concluded that guided-inquiry method is significantly correlated to development of better understanding of NOS amongst students. Forawi (2011) also established that teachers who were adequately aware of NOS were more capable of availing even better opportunities for student to experience and various scientific ways of knowing

Interestingly, the findings of the study also show that explicit instruction and inquiry based learning methods have the same impact on students' view of NOS when used independently. There is no significant difference in their impact on NOS. Previous studies have shown that the effectiveness of inquiry-based learning is that it enables students to engage in self-directed inquiry, in being able to learn and think scientifically, and in being to understand the relationships between theory and evidence (Byers and Fitzgerald, 2002). The findings of this study affirm the conclusions by Byers and Fitzgerald (2002); however, it reports no difference in the efficacy of inquiry-based learning compared to explicit learning. Explicit instruction approach is reported consistently in numerous studies to be more effective compared to historical or implicit instruction (Abd-El-Khalick and Lederman 2000). They have also indicated that explicit instruction can help develop adequate view of the NOS as prescribed in documents pertinent to reform in science education. Much of the subsequent studies has affirmed the same findings (Abd-El-Khalick & Akerson 2004; Akerson & Hanuscin 2007). In this regard, this study contrasts some of the above studies which have deemed explicit instruction methods to be more effective in science education.

The above results have also shown that there is a significant difference in students' views of NOS post instruction using a combination of both explicit instruction and inquiry-based learning methods. The percentage change in difference is significantly higher than for either explicit or inquiry learning methods. Cross-group analysis also shows significant change in students' perception of NOS between combined inquiry-explicit and explicit (alone) and inquiry based learning (alone). This underlies the importance of combining both learning methods in order to significantly enhance learning of science. The findings of this study also contrast a number of investigations utilizing an explicit approach to nature of science instruction which have with reported limited or no success (Morrison, Raab, & Ingram 2009). However, it echoes a number of studies which have also shown that reflective explicit instruction is more effective in enhancing learners' understandings of the NOS compared to implicit instruction (Akerson et al. 2007). A number of studies have also emphasized on the effectiveness of explicit instruction of NOS in improving learners' understanding of NOS (Hanuscin et. al 2006). This study also supports findings reported in a number of studies (Hanuscin et al. 2006); Abd-El-Khalick and Akerson 2004) which have provided evidence of the effectiveness of explicit approaches to NOS instruction.

5.2 Conclusions

The aim of this study was determine how varied instruction methods influence students' views of NOS. Towards this end, the results presented in the previous chapter show how explicit instruction and inquiry-based learning methods influenced students' views of NOS.

Overall, students' views of NOS post-test improved. There was marked improvement in each of the element post instruction across control, inquiry-based learning, explicit instruction, and combined explicit-inquiry. The only exception was on change of scientific theories where post-instruction score was actually lower than pre-instruction score for the control. It is also important to note that while there was change in students' views of NOS for the control group, the change in students' views of NOS remained insignificant for the control group for majority of the elements compared to the other groups. There is no statistically significant difference between pre and post instruction for the control group regarding their views of NOS.

The lack of significant change in students' views of NOS for the control underlies the need for utilizing innovative pedagogical approaches. The findings of this study have shown that traditional instructional approaches are largely inadequate and ineffective in teaching science. It highlights the need for adoption of more proactive approaches in teaching science. These results reflect findings by Abdel Khalik and Lederman (2000) and Forawi (2011) which have also shown that traditional teaching methods are not properly aligned with proper teaching of science. These studies concluded that it is only through engagement in authentic science experiences early on that learners will be able to fully harness their potential for their career aspirations

Nevertheless, the findings of this study also show that while the difference in post-instruction and pre-instruction performance was not significant for the control, there was marked improvement in post instruction performance. Improvement in students' views of NOS was also reported across all elements of NOS with exception of 'change of scientific theories' for the control group. This serves to show that students' perception of NOS improves over time as they learn regardless of the method of instruction adopted. The same result was reported in a previous study by Forawi (2014) which established that learners indeed posses conceptualization of NOS prior to receiving any instruction. Thus, the most important role for teachers is to devise instructional methods that work to improve and enhance learners' views of NOS effectively.

One of the research questions that this study sought to answer was; what is the impact of inquiry-based learning on students' views of the NOS? The findings of this study have clearly shown that there is a statistically significant difference between pre and post instruction for the inquiry-based learning group regarding their views of NOS. The researcher expected this result given that inquiry-based learning methods have been shown by a number of studies to more effective in science instruction (Forawi 2014; Kubicek 2005; Polman 1998). Inquiry based learning is associated with rich and meaningful learning contexts that enable effective science learning. It is within such contexts that students are able to discover the importance of science in their daily life. Rich contexts also serve to promote appreciation of the interconnected nature of science, environment, technology and the society at large (Kubicek 2005). The findings of this study have served to affirm the above views; inquiry-based learning methods are very in enhancing learners' views of science.

The second research question that this study sought to answer was; what is the impact of explicit instruction of the NOS on student views of the NOS? In this regard, the findings of this study have shown that there is a statistically significant difference between pre and post instruction for the group regarding their views on NOS. The researcher expected this result as a number of studies have shown explicit instruction technique to be very effective in the teaching of science (Bell 2008; Akerson and Hanuscin 2007). A study by Akerson et al. (2007) showed that reflective explicit instruction is more effective in enhancing learners' understanding of the NOS than implicit instruction. Explicit instruction effectively draws the learner's attention to key aspects of the NOS through discussions and written work following engagement in hands-on activities.

Comparatively, explicit instruction registered marginally higher score compared inquiry-based learning methods. However, the difference between the two is insignificant. In essence, the findings of the study have shown that explicit instruction and inquiry based learning methods have the same impact on students' view of NOS when used independently. There is no significant difference in their impact on NOS. However, when both instruction methods are combined the change in students' views of NOS is significantly different. The later was confirmed in a study conducted by Lederman (2004) indicating the advantages and improvements in the learners' view of the NOS.

The third research question that this study sought to answer was; what is the impact of combined inquiry and explicit instruction of the NOS on Student views of the NOS? The findings of this study have comprehensively shown that there is a significant difference in students' views of NOS post instruction using a combination of both explicit instruction and inquiry-based learning methods. The percentage change in difference is significantly higher than for either explicit or inquiry learning methods. Cross-group analysis also shows significant change in students' perception of NOS between combined inquiry-explicit and explicit (alone) and inquiry based learning (alone). This underlies the importance of combining both learning methods in order to significantly enhance learning of science.

The findings of this study have shown that the combination of both instructional approaches brings the best of both to the classroom. Explicit instruction of the NOS directs the learner's attention on various NOS aspects during classroom activities such as discussion and questioning. This type of instructional approach is constructed based on the idea of having NOS embedded as an integral component of learning in the science classroom and not a supplementary one. Similarly, inquiry-based instruction approaches emphasizes inquisitiveness, interaction and engagement with the learning content. Findings reported in a number of studies (Hanuscin et al. 2006; Abd-El-Khalick and Akerson 2004) provide evidence of the effectiveness of explicit approaches to NOS instruction. However, none of the previous studies evaluated by this researcher found any studies where both approaches were combined and compared with each approach independently. This is one area that this study offers news insights and also identifies a new are for further researcher. In the study by McDonald (2010) five premises were established: (1) learners' views of the NOS influence their discussion (argumentation) in scientific contexts; (2) development of learner's skills and /or quality of argumentation, view of NOS, and engagement in argumentation require the adoption of both explicit NOS and explicit argumentation instruction; (3) guidance is crucial to ensure the application and relevancy of the aspects of NOS in the teaching strategies and arguments; (4) engagement of learners in scientific argumentation may enhance their NOS understanding without the use of explicit instruction of NOS; and (5) implementation of explicit instruction of NOS and argumentation results in improvements in the learner view of NOS.

5.3 Recommendations

One of the issues that this study has identified is the fact that science education can benefit from proactive changes in policy reform, curriculum and pedagogy. Science educators have to recognize the need to coordinate between epistemic, cognitive and social aspects in teaching science. Previous studies have recommended that the acquisition of conceptual knowledge must not be separated from the actual process (active engagement in learning science) (National Research Council (NRC) 2007; Sawyer 2006). In this regard, this study recommends further investigation using combination of reflective-explicit approach, implicit instruction, and open-inquiry learning. Science teachers should aim towards determining the optimal mix of both approaches that will results in the best NOS outcomes for their student.

This study also recommends that science instruction should transition from traditional domain-general principles and be more structured around knowledge of concepts, practices and frameworks. At the same time, learning needs to be strongly connected with the domain within which learning is occurring. This is because effective science learning is largely dependent on the adoption of certain practices and methods of representation and communication of ideas and critiques in science in a manner that enhances immersion and promotes engagement with learning materials.

This study also recommends that inquiry based learning incorporates established science learning processes and activities. In addition, it must also combine them with critical thinking, scientific reasoning and scientific knowledge geared towards the development of new scientific knowledge. In the context of inquiry based learning, learners are expected to be able to develop and frame scientifically valid questions followed by structured design for investigating the issue in a manner that yields the right conclusions for the questions. This should be embedded in the learning process and integrated with explicit instruction approaches. Explicit instruction prioritizes participation of students in science practices in addition to accessing the knowledge). In this regard, explicit instruction of NOS in delivered via group activities focusing on material, mechanistic, and cognitive practices. The process of learning and doing is conducted over longer instructional periods where learners are actively engaged with scientific practices. This process is characterized by talking/debating, modeling and critiquing learning science in its nature is a critical part of learning science for children. In combination with inquiry-based learning approaches, both become a very powerful tool in the learning of science. The onus is on the teachers to have a proper understanding of their learners and adopt an appropriate mix of both techniques. As outlined by Forawi and Liang (2011) both explicit and implicit instructional approaches of NOS are equally useful in enhancing student understanding of NOS.

Ultimately, combination of inquiry based learning and explicit instruction techniques should seek to establish rich and meaningful contexts for learning science. It is only within such contexts that students are able to discover the importance of science and also be able to apply it in their daily life. Rich contexts also serve to promote appreciation of the interconnected nature of science, environment, technology and the society at large (Kubicek, 2005).

This also recommends the need to train and equip teachers with the rights skills for delivering science lesson through inquiry-based learning and explicit instruction. Teachers should have the right understanding of both approaches. Previous studies have shown that teachers are active curriculum creators who make instructional decisions based on a complex system of beliefs and knowledge. In general, teachers' beliefs and understanding influence (a) knowledge acquisition and interpretation, (b) developing and selecting the task at hand, (c) interpretation of course content, and (d) choice of assessment. It is important that teachers have the right interpretation in order to be able to effectively execute both or either techniques in teaching science. Consequently, this study recommends that teachers who use an inquiry approach or explicit instruction approaches should have established in depth rich understandings of science content, nature of science, inquiry-based learning, argumentation in the science classroom, and students' learning.

5.4 Study Limitations and Suggestions for Future research

One of the main limitations of this study is the relatively small sample of less than 25 students per group and just 4 teachers. Consequently, it becomes a huge challenge to control for aspects such as varied teacher and student ability. In addition, the research was conducted over a relatively shorter period of time from base line to post instruction tests. This also makes it relatively challenging to effectively vouch for the efficacy of either explicit or inquiry-based learning methods in science instruction. There is a possibility that over longer periods one method could prove to be more effective over the other in transforming students' views and learning of science.

The above limitations provide the basis upon which this study suggests areas for future research. First, subsequent studies should seek to have significantly larger samples comprising of students from diverse backgrounds and types of schools. The use of a larger sample should make it possible determine the efficacy of either methods in across learners and teachers with varied abilities. This will provide more accurate and highly generalizable results from the study. Second, this paper suggests that future studies should be conducted over a longer period of time ranging from a whole school term to an entire academic year. Third, including open-ended questions in the survey will allow for more in depth analysis of students understandings of the nature of science. This will make it possible for teachers to establish any difference in instruction method efficacy over long time.

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Appendix 1: Survey

	Strongly Disagree (SD)	Disagree More Than Agree (D)	Uncertain or Not Sure (U)	Agree More Than Disagree (A)	Strongly Agree (SA)
1. Observations and Inferences					
A. Scientists observations of the same event may be different due to their previous knowledge affecting their observations					
B. Scientists' observations of the same event will be the same because scientists are objective.					
C. Scientists' observations of the same event will be the same because observations are facts.					
D. While observing the same event, scientists may make different observations.					
2. Change of Scientific Theories					
A. Scientific theories are exposed on continuous testing and revision.					
B. Scientific theories may be completely replaced by new theories when there is new evidence					
C. Scientific theories may change when scientists view existing					

observations in a different perspective.					
D. Scientific theories that are based on accurate experiments will not be changed					
3. Scientific Laws vs. Theories					
A. Scientific theories exist in the natural world and are revealed through scientific investigations					
B. Unlike theories, scientific laws are not able to be changed.					
C. Scientific laws are theories that have been proven.					
D. Scientific theories explain scientific laws.					
4. Social and Cultural Influence on Science					
A. Society and culture do not influence scientific research because scientists are trained to provide studies that are pure and uninfluenced by anything.					
B. Cultural values and expectations determine what science is conducted and accepted.					
C. Cultural values and expectations determine how science is conducted and accepted.					
D. Science is global, regardless of					

society and culture.					
5. Imagination and Creativity in Scientific Investigations					
A. Scientists use their imagination and creativity when they collect data.					
B. Scientists use their imagination and creativity when they analyze and interpret data.					
C. Scientists do **not** use their imagination and creativity because these conflict with their logical reasoning.					
D. Scientists do **not** use their imagination and creativity because these can get in the way of objectivity					
6. Methodology of Scientific Investigation					
A. Scientists use a variety of methods to produce fruitful results. [Suggested revision: Scientists use different types of methods to conduct scientific investigations.]					
B. Scientists follow the same step-by-step scientific method.					
C. When scientists use the scientific method correctly, their results are true and accurate.					
D. Experiments are not the only means used in the development of scientific knowledge.					

Appendix 2: sample lesson sheets

SECTION 3

Free Fall

PHYSICS 4 YOU Before their parachutes open, skydivers sometimes join hands to form a ring as they fall toward Earth. What happens if the skydivers have different masses? Do they fall at the same rate or different rates?

MAIN IDEA
The acceleration of an object in free fall is due to gravity alone.

Essential Questions
- What is free-fall acceleration?
- How do objects in free fall move?

Review Vocabulary
origin the point at which both variables in a coordinate system have the value zero

New Vocabulary
free fall
free-fall acceleration

Digital Vision/Getty Images

Galileo's Discovery

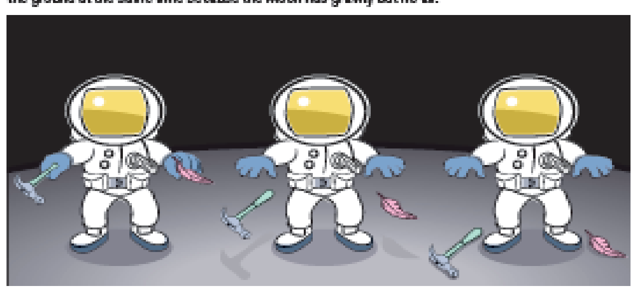
Which falls with more acceleration, a piece of paper or your physics book? If you hold one in each hand and release them, the book hits the ground first. Do heavier objects accelerate more as they fall? Try dropping them again, but first place the paper flat on the book. Without air pushing against it, the paper falls as fast as the book. For a lightweight object such as paper, collisions with particles of air have a greater effect than they do on a heavy book.

To understand falling objects, first consider the case in which air does not have an appreciable effect on motion. Recall that gravity is an attraction between objects. **Free fall** is the motion of an object when gravity is the only significant force acting on it.

About 400 years ago, Galileo Galilei discovered that, neglecting the effect of the air, all objects in free fall have the same acceleration. It doesn't matter what they are made of or how much they weigh. The acceleration of an object due only to the effect of gravity is known as **free-fall acceleration.** Figure 19 depicts the results of a 1971 free-fall experiment on the Moon in which astronauts verified Galileo's results.

Near Earth's surface, free-fall acceleration is about 9.8 m/s^2 downward (which is equal to about 22 mph/s downward). Think about the skydivers above. Each second the skydivers fall, their downward velocity increases by 9.8 m/s. When analyzing free fall, whether you treat the acceleration as positive or negative depends on the coordinate system you use. If you define upward as the positive direction, then the free-fall acceleration is negative. If you decide that downward is the positive direction, then free-fall acceleration is positive.

Figure 19 In 1971 astronaut David Scott dropped a hammer and a feather at the same time from the same height above the Moon's surface. The hammer's mass was greater, but both objects hit the ground at the same time because the Moon has gravity but no air.



Section 3 • Free Fall 75

Computer
13

Air Resistance

When you solve physics problems involving free fall, often you are told to ignore air resistance and to assume the acceleration is constant and unending. In the real world, because of air resistance, objects do not fall indefinitely with constant acceleration. One way to see this is by comparing the fall of a baseball and a sheet of paper when dropped from the same height. The baseball is still accelerating when it hits the floor. Air has a much greater effect on the motion of the paper than it does on the motion of the baseball. The paper does not accelerate very long before air resistance reduces the acceleration so that it moves at an almost constant velocity. When an object is falling with a constant velocity, we prefer to use the term *terminal velocity*, or v_T. The paper reaches terminal velocity very quickly, but on a short drop to the floor, the baseball does not.

Air resistance is sometimes referred to as a *drag force*. Experiments have been done with a variety of objects falling in air. These sometimes show that the drag force is proportional to the velocity and sometimes that the drag force is proportional to the square of the velocity. In either case, the direction of the drag force is opposite to the direction of motion. Mathematically, the drag force can be described using $F_{drag} = -bv$ or $F_{drag} = -cv^2$. The constants b and c are called the *drag coefficients* that depend on the size and shape of the object.

When falling, there are two forces acting on an object: the weight, mg, and air resistance, $-bv$ or $-cv^2$. At terminal velocity, the downward force is equal to the upward force, so $mg = -bv$ or $mg = -cv^2$, depending on whether the drag force follows the first or second relationship. In either case, since g and b or c are constants, the terminal velocity is affected by the mass of the object. Taking out the constants, this yields either

$$v_T \propto m \text{ or } v_T^2 \propto m$$

If we plot mass versus v_T or v_T^2, we can determine which relationship is more appropriate.

In this experiment, you will measure terminal velocity as a function of mass for falling coffee filters and use the data to choose between the two models for the drag force. Coffee filters were chosen because they are light enough to reach terminal velocity in a short distance.

OBJECTIVES

- Observe the effect of air resistance on falling coffee filters.
- Determine how the terminal velocity of a falling object is affected by air resistance and mass.
- Choose between two competing force models for the air resistance on falling coffee filters.

MATERIALS

computer
Vernier computer interface
Logger *Pro*
Vernier Motion Detector
5 basket-style coffee filters

PRELIMINARY QUESTIONS

1. Hold a single coffee filter in your hand. Release it and watch it fall to the ground. Next, nest two filters and release them. Did two filters fall faster, slower, or at the same rate as one filter? What kind of mathematical relationship do you predict will exist between the velocity of fall and the number of filters?
2. If there was no air resistance, how would the rate of fall of a coffee filter compare to the rate of fall of a baseball?
3. Sketch a graph of the velocity *vs.* time for one falling coffee filter.
4. When the filter reaches terminal velocity, what is the net force acting upon it?

PROCEDURE

1. Connect the Motion Detector to the DIG/SONIC 1 channel of the interface.
2. Support the Motion Detector about 2 m above the floor, pointing down, as shown in Figure 1.
3. Open the file "13 Air Resistance" from the *Physics with Vernier* folder.
4. Place a coffee filter in the palm of your hand and hold it about 0.5 m under the Motion Detector. Do not hold the filter closer than 0.15 m.
5. Click [Collect] to begin data collection. When the Motion Detector begins to click, release the coffee filter directly below the Motion Detector so that it falls toward the floor. Move your hand out of the beam of the Motion Detector as quickly as possible so that only the motion of the filter is recorded on the graph.

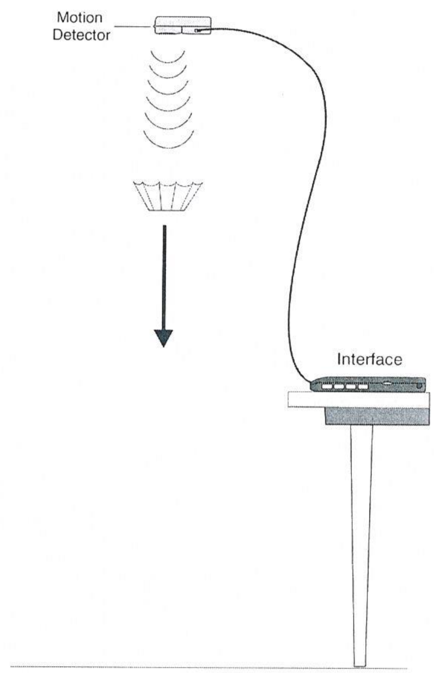


Figure 1

6. If the motion of the filter was too erratic to get a smooth graph, repeat the measurement. With practice, the filter will fall almost straight down with little sideways motion.
7. The velocity of the coffee filter can be determined from the slope of the position *vs.* time graph. At the start of the graph, there should be a region of increasing slope (increasing velocity), and then it should become linear. Since the slope of this line is velocity, the linear portion indicates that the filter was falling with a constant or terminal velocity (v_T) during that time. Drag your mouse pointer to select the portion of the graph that appears the most linear. Determine the slope by clicking the Linear Fit button.

8. Record the slope in the data table (a velocity in m/s).
9. Repeat Steps 4–8 for two, three, four, and five coffee filters.

DATA TABLE

Number of filters	Terminal Velocity v_T (m/s)	(Terminal Velocity)^2 v_T^2 (m^2/s^2)
1		
2		
3		
4		
5		

ANALYSIS

1. To help choose between the two models for the drag force, plot terminal velocity v_T *vs.* number of filters (mass). On a separate graph, plot v_T^2 *vs.* number of filters. Use either Logger *Pro* or graph paper. Scale each axis from the origin (0,0). Page 2 of the experiment file is already prepared for you.
2. During terminal velocity the drag force is equal to the weight (mg) of the filter. If the drag force is proportional to velocity, then $v_T \propto m$. Or, if the drag force is proportional to the square of velocity, then $v_T^2 \propto m$. From your graphs, which proportionality is consistent with your data; that is, which graph is closer to a straight line that goes through the origin?
3. From the choice of proportionalities in the previous step, which of the drag force relationships ($-bv$ or $-cv^2$) appears to model the real data better? Notice that you are choosing between two different descriptions of air resistance—one or both may not correspond to what you observed.
4. How does the time of fall relate to the weight (mg) of the coffee filters (drag force)? If one filter falls in time, t, how long would it take four filters to fall, assuming the filters are always moving at terminal velocity?

EXTENSIONS

1. Make a small parachute and use the Motion Detector to analyze the air resistance and terminal velocity as the weight suspended from the chute increases.
2. Draw a free body diagram of a falling coffee filter. There are only two forces acting on the filter. Once the terminal velocity v_T has been reached, the acceleration is zero, so the net force, $\sum F = ma = 0$, must also be zero

$$\sum F = -mg + bv_T = 0 \qquad \text{or} \qquad \sum F = -mg + cv_T{}^2 = 0$$

depending on which drag force model you use. Given this, sketch plots for the terminal velocity (y-axis) as a function of filter weight for each model (x-axis). (Hint: Solve for v_T first.)

Appendix 3: Scoring table

	Strongly Disagree (SD)	Disagree More Than Agree (D)	Uncertain or Not Sure (U)	Agree More Than Disagree (A)	Strongly Agree (SA)
1. Observations and Inferences					
E. Scientists observations of the same event may be different due to their previous knowledge affecting their observations	-2	-1	0	+1	+2
F. Scientists' observations of the same event will be the same because scientists are objective.	+2	+1	0	-1	-2
G. Scientists' observations of the same event will be the same because observations are facts.	+2	+1	0	-1	-2
H. While observing the same event, scientists may make different observations.	-2	-1	0	+1	+2
2. Change of Scientific Theories					
E. Scientific theories are exposed on continuous testing and revision.	-2	-1	0	+1	+2
F. Scientific theories may be completely replaced by new theories when there is new evidence	-2	-1	0	+1	+2
G. Scientific theories may change when scientists view existing observations in a	-2	-1	0	+1	+2

different perspective.					
H. Scientific theories that are based on accurate experiments will not be changed	+2	+1	0	-1	-2
3. Scientific Laws vs. Theories					
E. Scientific theories exist in the natural world and are revealed through scientific investigations	+2	+1	0	-1	-2
F. Unlike theories, scientific laws are not able to be changed.	+2	+1	0	-1	-2
G. Scientific laws are theories that have been proven.	+2	+1	0	-1	-2
H. Scientific theories explain scientific laws.	-2	-1	0	+1	+2
4. Social and Cultural Influence on Science					
E. Society and culture do not influence scientific research because scientists are trained to provide studies that are pure and uninfluenced by anything.	+2	+1	0	-1	-2
F. Cultural values and expectations determine what science is conducted and accepted.	-2	-1	0	+1	+2
G. Cultural values and expectations determine how science is conducted and accepted.	-2	-1	0	+1	+2
H. Science is global, regardless of	+2	+1	0	-1	-2

society and culture.					
5. Imagination and Creativity in Scientific Investigations					
E. Scientists use their imagination and creativity when they collect data.	-2	-1	0	+1	+2
F. Scientists use their imagination and creativity when they analyze and interpret data.	-2	-1	0	+1	+2
G. Scientists do **not** use their imagination and creativity because these conflict with their logical reasoning.	+2	+1	0	-1	-2
H. Scientists do **not** use their imagination and creativity because these can get in the way of objectivity	+2	+1	0	-1	-2
6. Methodology of Scientific Investigation					
E. Scientists use a variety of methods to produce fruitful results. [Suggested revision: Scientists use different types of methods to conduct scientific investigations.]	-2	-1	0	+1	+2
F. Scientists follow the same step-by-step scientific method.	+2	+1	0	-1	-2
G. When scientists use the scientific method correctly, their results are true and accurate.	+2	+1	0	-1	-2
H. Experiments are not the only means used in the development of scientific knowledge.	-2	-1	0	+1	+2

Appendix 4: Consent form

You are invited to take part in a research study titled "The Impact of Inquiry based Learning and Explicit Instruction of the Nature of Science on Students' Views of the Nature of Science". The study aims at investigating the impact of particular teaching approaches on your child's view of the nature of science.

You will be asked to take survey that will not take more than 20 minutes. The survey will be administered on two particular occasions. Participation in this study is voluntary. You can stop participating at any time. If you stop, you will not lose any benefits. There are no anticipated risk involved with this study. On the other hand, it is expected that you may benefit from the study by developing better view of the nature of science.

Your name along with any affiliated personal data will not be used in any part of the study. All records and other personal information will be kept confidential.

Terms	Please Initial Box
1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.	☐
3. I agree to take part in the above study.	☐

________________________ ______________ ____________________

Name of Participant Date Signature

Appendix 5: letter to parents

Your child has been invited to take part in a study titled "The Impact of Inquiry based Learning and Explicit Instruction of the Nature of Science on Students' Views of the Nature of Science". The study aims at investigating the impact of particular teaching approaches on your child's view of the nature of science.

Your child will be asked to take a survey that will not take more than 20 minutes. The survey will be administered on two particular occasions. Participation in this study is voluntary. Your child can stop participating at any time. If your child stops he will not lose any benefits. There are no anticipated risk involved with this study. On the other hand, it is expected that you child benefit from the study by developing better view of the nature of science.

Your child's name along with any affiliated personal data will not be used in any part of the study. All records and other personal information will be kept confidential.

.

As parent or legal guardian, I authorize ________________________________ (child's name) to participant in the study indicated in this form.

Parent or Legal Guardian's Signature   Date

____________________________   ____________________________

Appendix 6: Data test for covariance

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	preimplicitinquiry	5.9524	21	8.07760	1.76268
	postimplicitinquiry	28.8571	21	8.85599	1.93254

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	preimplicitinquiry & postimplicitinquiry	21	-.198	.390

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
preimplicitinquiry	21	-16.00	19.00	5.9524	8.07760
postimplicitinquiry	21	4.00	48.00	28.8571	8.85599
Valid N (listwise)	21