The Effects of Guided Inquiry Instruction on Students' Achievement and Understanding of the Nature of Science in Environmental Biology Course

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ABSTRACT

Science textbooks coupled with appropriate instructional strategies play a pivotal role in conveying the educational reform documents vision through students' teaching and learning of the three domains of science: the body of content knowledge, scientific process skills and the nature of the scientific knowledge. The purpose of this study is two folds: 1) to investigate students' views of the nature of science (NOS) based on the newly implemented science curriculum, the Hartcourt International, in United Arab Emirates' (UAE) public schools and 2) to investigate the impact of guided-inquiry of instruction in teaching the environmental biology subject and the NOS aspects with students. Seventy six tenth-grade students distributed amongst 4 mutual exclusive classes participated in this study. The respective classes are randomly divided into two intact groups: experimental and control groups. The experimental group is taught using the guided inquiry instruction during theoretical classes and laboratory activities, which based on grappling with guided-inquiry questions and practicing science as process skills. The control group is taught using the traditional strategies, without incorporating the guided inquiry instruction and the science process-skills. A modified NOS scale adopted from Wenning (2006), Iqbal et al. (2009) and the doctorate thesis of Larson-Miller (2011), and an environmental biology achievement test from the Hurtcourt International biology assessment guide book are used as pre and post-tests for measuring the effect of guided inquiry instruction on both students' NOS conceptions and biology achievements respectively. Results reveal that the students' NOS conceptions in the pre-case are still wanting. Moreover, implementing the guided inquiry instruction in teaching the environmental biology subject has significant effect in improving the students' academic achievement. However, this kind of instruction alone seems to be insufficient in developing NOS conceptions in the students. Differences in the total average scores between pre- and post-NOS scale are not statically significant for both the experimental and control groups. It is possible that more explicit instructional approaches are needed to be investigated for their effectiveness in achieving NOS understandings in students' minds.

Keywords: Guided inquiry, Nature of Science, Students, Academic Achievement, Reform Education.

الملخص

تلعب كتب مناهج العلوم مقرونةً مع طرق التدريس المناسبة، دوراً مهما في تحقيق رؤية وثائق تصحيح التعليم لدى الطلاب من خلال تعليمهم عن المجالات الثلاث للعلم وهي: محتوى المادة العلمية، عمليات ومهارات العلم ومعرفة طبيعة العلم.

تتفرع أهداف هذه الدراسة إلى قسمين. الأول: استكشاف وجهات النظر التي يحملها الطلاب عن طبيعة العلم، وخاصة بعد تطبيق مناهج العلوم الجديدة Hartcourt International في مدارس التعليم العام منذ العام الدراسي 2005-2006، في دولة الامارات العربية المتحدة. الثاني: دراسة تأثير طريقة التعلم بالإستقصاء الموجه في تدريس علم البيئة في مادة الأحياء للصف العاشر على التحصيل العلمي للطلاب وعلى إدراكات الطلاب عن طبيعة العلم. لقد كان مجموع الطلاب الذين خضعوا للتجربة في هذه الدراسة هو 76 طالب، وهم موزعون على أربع غرف صفية في مرحلة العاشر. لقد تم تقسيم الفصول إلى مجموعتين وبشكل عشوائي، مجموعة ضابطة ومجموعة تجريبية. المجموعة التجريبية، تم تدريسها المحتوى العلمي بطريقة الإستقصاء الموجه في كلاً من الحصص النظرية و الدروس العملية. تعتمد هذه الطريقة في التدريس على جعل الطلاب يتفاعلون بجدية وعمق مع الأسئلة المصاغة سلفاً بناءاعلى أهداف المادة العلمية وممارسة طرق البحث العلمي ومهاراته للبحث عن المعلومات العلمية، وبالتالي للبحث عن الإجابات الصحيحة لتلك الأسئلة بمفردهم قدر الإمكان، ومن ثم مناقشتها وتوثيقها. أما المجموعة الضابطة، تم تطبيق طرق التدريس التقليدية عليها أثناء الحصص الدراسية والدروس العملية، وهذه الطرق لا تشتمل على الإستقصاء الموجه أو ممارسة طرق ومهارات البحث العلمي.

ولقياس تأثير معاملة التجربة على طلاب المجموعتين قبل وبعد تطبيق التجربة، استخدم الباحث أداتين للقياس. الأولى: تتعلق بطبيعة العلم، حيث تم اقتباس هذا الاختبار وتعديله ليتناسب مع الطلاب من ثلاث مصادر وهي:Wenning (2006) و Iqbal et al. (2009) و Larson-Miller (2011) . أما أداة القياس الثانية وهي اختبار الأحياء لعلم البيئة والذي تم نقله من كتاب دليل التقويم لمادة الأحياء للصف العاشر، حيث يوفر هذا الدليل نماذج الإمتحانات المختلفة للمادة العلمية في منهج الأحياء.

لقد كشفت النتائج أن إدراكات الطلاب عن طبيعة العلم مازالت تتراوح في مكانها الغير مرضي بعد هذه الفترة الطويلة من تطبيق هذه المناهج الجديدة. وإضافة على ذلك، وجد أن لتطبيق مثل هذه الطريقة في تدريس مادة علم البيئة في الأحياء أثراً معنويا في تحسين التحصيل الأكاديمي للطلاب، إلا أنه يبدو أن هذا النوع من التدريس، بشكل منفرد، غير كافي لتطوير إدراكات صحيحة وسليمة عن طبيعة العلم لدى الطلاب. إن الإختلافات بين متوسط النتائج الكلية لاختبار طبيعة العلم، قبل وبعد تطبيق التجربة، لم تظهر أي فروقات احصائية معنوية في كلا المجموعتين، التجريبية والضابطة. يبدو أنه من الضروري استخدام طرق تدريس تعالج قضايا طبيعة العلم بشكل واضح ومباشر وليس بشكل ضمني، من أجل تحقيق مثل هذه المخرجات التعليمية الفكرية لدى الطلاب.

DEDICATION

I would like to dedicate this work to the spirit that inhabits my soul, my father, to the unknown soldier who always silently sacrifices for me, my mother, to my eldest brother who cares me like a father, Doctor Ashraf Hassan, and finally, to the one who has coped with all the details of my study journey, my wife.

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Chapter I: Introduction

Nature of Science and Guided Inquiry as Science Education Standards

It is widely agreed by educational reform documents that science education aims to fostering students' intellectual competencies such as problem solving, critical-thinking, independent learning and decision making (American Association for the Advancement of Science (AAAS) 1994; National Research Council (NRC) 1996; Schraw, Crippen & Hartlely 2006). In order to achieve this vision, calls for science education reform have shifted from 'teacher-centered' as in conventional schooling, to 'student-centered' as in constructivist oriented instruction. These scientific approaches should in turn produce students that are scientifically literate and with required skills.

The recent science education reform efforts support nurturing the two domains at the same time: the body of knowledge and the instructional strategies. The first domain is concerning with 'what' students should learn in the context of the current reformed science. The other domain refers to the way of instruction and 'how' instructional strategies should be in order to deliver the content knowledge purposefully.

Out of concern for the first domain, many researches transcend only acquiring body of scientific knowledge to further cultivating Nature of Science (NOS) views in students, while practicing scientific processes and methods. In other words, students should be taught both about and through the three main domains of science: "body of knowledge, the NOS and a set of methods and processes" (Bell 2009, p. 2 of 6). This attitude is thoroughly elaborated in many studies through conducting science lessons as 'reform-oriented science teaching' (Schwaiz & Gwekwere 2007). Khishfe and Abd-El-Khalick (2002) emphasize the role of explicitly integrating NOS aspects in science activities to be taught in order to meet science education benchmarks and standards. Barak and Shakman (2008) conclude that teachers should be professional in both the body of knowledge and the pedagogical content knowledge (PCK) and skills alike, in order to prompt reform-based instruction. Accordingly, this type of instruction enhances higher-order thinking skills as one of the main goals of NOS and science education reform.

For the second domain, Schraw, Crippen and Hartley (2006) list many strategic areas that come in line with the overhauling efforts of science education such as: the use of technology-based learning, collaborative support learning, problem solving and critical thinking and, most importantly, inquiry-based learning. In essence, the focus of all these strategies is to instill lifelong learning, student's meta-cognition, self-regulation, deep understanding and science as a process and habits of mind in students (AAAS 1993; NRC 1996; NRC 2005). Crawford (2000) considers that adopting inquiry-based instruction environment in science education is the pivot of the NRC recommendations that focus on supporting scientific inquiries while interacting with and teaching students. The author continues describing the inquiry-based learning environment as an expiation of the past-erroneous view 'teacher-proof curriculum', that is a curriculum designed in a cookbook fashion so that everyone who uses the product will have the same results.

Inquiry and Its Levels

Teaching and learning theories, in particular constructivism, highlight the student-centered orientations as a general trend in education. The constructivist learning approach encourages the use of open-ended, participative teaching strategies where inquiry in science is the catalyst in such learning environments. The definition of 'inquiry' fluctuates between practices and processes that scientists use to do while they are studying a phenomenon, and as "an active learning process engaged in by students and modeled after the inquiry processes of professional scientists" (Asay & Orgill 2009, p. 58). The United States' national science education standards (NSES) explains the 'inquiry' concept in science education as both a vehicle and a content knowledge "that leads to knowledge acquisition and understanding of scientific ideas" (Asay & Orgill 2009, p. 58). The latter is accomplished through investigations and activities under a range of degrees of instruction (NRC 1996). This active learning environment provokes both acquiring the content knowledge and the skills in how students can construct their own concepts and understandings.

Obviously, the NRC document (NRC 1996, p. 105) articulates the term 'inquiry' and elaborates on the skills that embody its practices as follows:

> Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.

According to Fradd et al. (2001), inquiry activities are classified in a matrix with 6 levels, depending on the skills that are entrusted to both the teacher and students. More details about the Science Inquiry Matrix are reported in Appendix A. While the vertical dimension represents the hierarchical levels of inquiries in regard of the student centeredness, the horizontal dimension distributes the respective tasks that are vested in both the teacher and students during these activities. Student centeredness may vary according to the amount of directions provided by the teacher and/or materials during inquiry activities.

Guided inquiry, which is the focus of this research study, has a prominent feature, which is that "the teacher provides only the materials and problem to investigate, while students devise their own procedure to solve the problem" (Colburn 2000, p. 42). Students at this level should be skillful enough to be able to design their own investigations. However, the teacher is still considered the corner stone, since he provides the inquiry-driven questions. Very well-articulated questions that pave the way to the inquiry objectives and prepare students to be entirely involved are the essence of the guided-inquiry (Martin-Hauser 2002).

Convergence of Science, Science Literacy and NOS

Based on the above, scientific inquiry is deemed as a main part of science that leads to the body of scientific knowledge which exists in regular science textbooks. NOS, the third dimension of science, is a multifaceted concept that defies direct and simple definition. However, NOS "seeks to describe the nature of the scientific enterprise and the characteristics of the knowledge it generates" (Bell 2009, p. 1 of 6). Bill (2009) continues that NOS "includes aspects of history, sociology, and philosophy of science, and has variously been defined as science epistemology, the characteristics of scientific knowledge, and science as a way of knowing". Because of the multifaceted-NOS definition, science educational researchers delineate a key set of ideas underlying the NOS concept which includes: tentativeness, observation and inference, empirical evidence, scientific methods, scientific laws and theories, creativity, objectivity and subjectivity of the scientific knowledge (Lederman et al. 2002).

Holbrook and Rannikmae (2009, p. 281-282) limit the main three ideas about NOS as follows:

* Philosophical and historical views towards scientific theories as the ‘big ideas’.

* Processes that represent scientists’ work in producing science such as; inquiry learning, problem solving skills or simply through experimentation.

* Social framework of science knowledge and socio-scientific decision making with regard to other areas such as economics, politics, society, environment and attitudes.

The third main concept in this research study, the science literacy is seen as a minimum desired goal of k-12 science teaching by AAA (1993) in its report:

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

Forawi (2011, p. 15) defines science literacy as: “providing students with a broad foundation of scientific knowledge and skills to be able to live in an increasingly scientific and technological world”. Holbrook and Rannikmae (2009) add another dimension to the previous definition, which is the scientific ways of knowing. Wenning (2006, p. 10) elaborates on the milestones of the growing scientific literacy content, and concentrates on the common elements of the term as follows:

* Knowledge of science content,

* Understanding science as a way of knowing, and

* Understanding and conducting scientific inquiry.

To sum up, the nature and processes of science, such as scientific inquiry, are key elements of the science literacy and science itself. More closely, scientific inquiry is a convergent point of all science, science literacy and NOS. Thus, many researchers advocate the implicit and explicit of teaching students the processes and NOS concepts to meet the contemporary goal of producing 'scientifically literate citizens' (AAAS 1993; NRC 1996; Larson-Miller 2011; Rudolph 2000; Dogan 2011; Hipkins, Barker & Bolstad 2005; Khishfe & Abd-El-Khalick 2002). Duncan and Arthurs (2009, p. 11) emphasize this view when they quote the National Science Standards' vision: "…in order to participate effectively in a democracy, citizens must understand the nature of scientific claims that increasingly influence or even become matters of public debate".

1.1 Statement of the Problem and Significance of the Research Study

In the light of the low achievement of United Arab Emirates (UAE) students in Trends in International Mathematics and Science Study (TIMSS) 2003 and 2007 in science for the grades 4 and 8, calls for reforming education have been raised. These low scores, which are less than the average scale (500) of TIMSS, reflect unacceptable positions of science literacy and academic achievement for a wide range of students that hold hopes for the future. Moreover, results of the former TIMSS tests show that the national curriculum in the UAE public schools is lagging behind other curricula such as UK, USA and CBSE that are taught in different schools in UAE (Thomson 2008). Thus, the Ministry of Education in UAE has started inclusive efforts to change all science curricula in the governmental school sector since the year 2005, and new science curricula, known as Harcourt International, has replaced the old ones in all science subjects. The Table of Contents and a brief description of the 10th grade Biology textbook is provided in Appendix B as an example of the new science curricula. It is also worth mentioning that, in the academic year of 2011-2012 10^{th} grade students, at the researched school, have achieved 52 out of 100 as an average score in the final Fujairah Educational Zone (FEZ) exam in biology for the first semester. This score, compared with that of 2003's and 2007's TIMSS average scores, is deemed at the same unsatisfactory rank for 10 years. On the other hand, views of secondary school students' of NOS were investigated in 1999 by Haidar and Balfakih. Results revealed that UAE students as well as their teachers hold significantly uninformed and mixed views about NOS. The result regarding the teachers is found in Haidar (1999) where Haidar investigated NOS conceptions of a sample of pre and in-service teachers in UAE. In addition to the above, the researcher in a previous study scanned a wide sample of 11th and 12th scientific track students on the east coast of the UAE about their NOS conceptions and results were in consistent with those of Haidar and Balfakih. Together, these former studies and the recent scores in FEZ biology exam emphasize the presence of a problem in the conceptions of NOS in students and thus consequently in their scientific literacy positions as well as their academic achievements. Based on that, the researcher wishes to apply a reformed based educational strategy in order to tackle this problem.

Investigating students' views of the NOS, which portrays students' positions of science literacy, is considered a persistent endeavor in all educational structures. Moreover, this kind of investigations provides a picture about the current trends in the prescribed science textbooks. This research study also considers evident guidelines for future reform considerations to be consistent with the contemporary vision of science education. Thus, science curricula designers, science educators and science teachers should benefit from the results.

On a wider scale, applying inquiry, as instructional strategy, in teaching biology is considered a new horizon for improving science teaching practices and accordingly students' academic achievements as well as science literacy. This study may be of interest to science educators and researchers, since it directly examines the effectiveness of the implicit way of teaching NOS concepts. This study could contribute to the growing literature in NOS and teaching methodologies in science education.

1.2 Aim and Questions of the Study

This research study intends to seek alternative ways to teach biology so as to improve achievements of students and their science literacy positions in a manner consistent with the recommendations of the contemporary science reform documents. The motivations for this work include the following three items. Firstly, because of the assumption that practicing inquiry, as instructional strategy, in science education is strongly interconnected with developing both content knowledge and NOS views in students, secondly, this study may be considered as an attempt to reform science education in the target school and thirdly, to cover for the shortage of studies in this realm. Accordingly, this research study specifically aims to:

1- Investigate the 10th grade students' conceptions of NOS.

2- Examine the effect of using guided-inquiry, as an instructional strategy, on students' conceptions of the NOS, and

3- Study the effects of using guided-inquiry, as an instructional strategy, on students' achievement of environmental biology.

Aforementioned aims in this research study will be investigated through the following research questions:

1- What prior NOS conceptions do 10th grade students hold in the target school after nearly five years of the new science curricula (International Harcourt) implementation?

2- How does the use of guided-inquiry instructional strategy affect students' conceptions of the NOS?

3- How does the use of guided-inquiry instructional strategy affect students' achievement in environmental biology?

1.3 A Brief Context and Organization of the Study

This study is divided into two phases. The first stage seeks to depict NOS conceptions of students who have experienced the new science curricula for the past five years. The second stage is aimed at studying the effect of guided inquiry as instructional strategy on both academic achievement of students in environmental biology and on NOS conceptions. For this purpose, the researcher utilizes the 10th grade boy students at the researched remote school on the east coast of the UAE as a sample of the study. In a previous study, conducted at the same school, this particular grade was found suffering the most intractable educational and schooling problems. The corresponding sample size is 78 students while the full time framework for both planning and implementing the experiment is nine weeks. Finally, this research study follows the quantitative approach.

Chapter one highlights the main concepts that are used in this study and definitions, and the characteristics of the guided inquiry as instructional strategy. Chapter two sheds light on the literatures that argue the effectiveness of the guided inquiry in teaching science, starting with the theoretical foundation of the guided inquiry strategy in teaching both concepts and skills. One of the most crucial points currently on the forum of science education research is the guided inquiry and its interconnection to the NOS concepts, which is also tackled in this chapter. Factors that affect students' NOS views are discussed in this chapter also, especially the dominant biology textbooks. Chapter three provides the methodology for approaching the research questions. Chapter four shows the data analysis and results, and finally, discussion and conclusion are presented in the last two chapters.

Chapter II: Literature Review

This chapter highlights the theoretical foundation of the guided inquiry as a constructivist instructional strategy through the scope of the cognitive psychology. The chapter also argues the effectiveness of the guided inquiry in teaching science and the factors that may hamper guided inquiry practice. The foci of the interconnection between NOS, as a target of the NSES, and guided inquiry, as a NRC recommended instructional strategy, are under investigation in this chapter. Finally, many factors that affect students' NOS views are discussed in the last section of the chapter. However, the impact of the textbook, as a priority in this research study, is highlighted and discussed at the beginning of the last section.

2.1 Theoretical Foundation of Guided Inquiry Pedagogy

The Dynamic Skill Theory (DST) is considered a foundation for scaffold inquiry. It, as a neo-Piagetian theory, holds that in order to integrate a new knowledge into an existing schema, learners normally cycle through levels of cognition. Moreover, in regard of acquiring a particular skill, new mental elements should be properly and accurately interconnected to form a mental model of such a skill. This complex process of learning both scientific concepts and skills requires time and practice under instructor scaffold in an emotional stimulating environment (Schwartz 2009). Based on this theory, a student's performance varies corresponding to the support or scaffolding provided. The more supportive the learning environment is to the learners, the more proper connecting of the mental elements and thus robust constructing of new mental models is settled. (Matyas 2000; Fisher & Rose 2001).

During learning a new skill and/or a concept, two of the upper limits of skill or ability may observed, a functional level and an optimal level. A student normally shows a functional level while he is listening to a lecture or reading a text. This functional level is clearly related to the individual and conventional instructional environments. Conversely, establishing a social-constructivist learning environment, which can be a highly supportive environment, such as a group guided inquiry work, provokes the highest skill level in students' cognitions (Fisher & Rose 2001; Schwartz 2009; Schwartz & Fisher

2003, 2004). Inquiry activities under veteran assistance "prompts to the key mental elements required for learning a concept or performing a specific task and, therefore, support individual student growth at the optimal level" (Barthlow 2011, p. 23) more than at the functional level.

2.2 Guided Inquiry as an Instructional Strategy

Guided inquiry, as an instructional strategy in teaching sciences, embraces students' deep understanding of the scientific knowledge and scientific process alike. This trend is not only for memorizing information for the sake of the exams, but also to be as habits of mind beyond the scope of the schools. Accordingly, these scientific habits of mind are expected to be readily reflected in students' achievements and scientific decision making and further to make students able to apply scientific inquiries in novel situations.

In one meta-analysis study, Minner, Levy and Century (2010) compare between guided inquiry and conventional schooling, in terms of students' academic achievements. The results reveal the superiority of the guided inquiry as an instructional strategy. Opara (2011) adds new evidence to the aforementioned superiority when she examined the positive effect of the guided inquiry in teaching biology. Remarkably, Ketpichainarong, Panijpan and Ruenwongsa (2010) investigate the effectiveness of different levels of inquiries on different students' outcomes. Students' achievements, as a priority, are gauged by using two instruments, conceptual achievement test and formation of a concept map. The authors also recognize an improvement in students' scientific process skills, critical thinking and ability to apply the new knowledge in real situations when they analyze what students have reported at the end of the inquiries. The students reported many industrial applications of cellulase enzyme. At the final stage of this study, the researchers collect students' self-reflections, questionnaire's results and interviews transcripts in order to understand students' attitudes towards this kind of instructional strategies which were positively affected. The study applies inquiries ranging from guided inquiry to open inquiry and promotes range of skills listed as: "asking good questions, predicting, problem solving, drawing conclusion and communication" (Ketpichainarong, Panijpan and Ruenwongsa 2010, p. 169). This inclusive research emphasizes the effectiveness of inquiry method and provides a “framework for implementing a dynamic instruction with a range of inquiry level for the undergraduates” (Ketpichainarong, Panijpan and Ruenwongsa 2010, p. 169). Norris, Phillips and Korpan (2003) highlight the prominent role of inquiry-based instruction on two levels of science literacy, gaining body of knowledge and showing scientific approach while addressing either societal or personal affairs. Authors refer the first level to the functional level of scientific literacy while the other level is called derived level. In their study, Brickman et al. (2009) emphasize the effect of such instructional environments on students’ self-efficacy, in addition to the two mentioned levels of scientific literacy.

In order to integrate the effect of inquiry teaching and learning, many studies advocate the cooperative group learning while holding inquiry sessions (Lee et al. 2010). Decreasing students’ competitiveness while increasing the social constructivist learning environment during inquiries will allow students to learn from each other, prompt higher order thinking skills, answer questions, solve problems and refine and verify concepts (Brown, P. 2010; Brown, S. 2010). Bilgin’s (2009) study results reinforce the former claim when he found that the integrated cooperative learning with guided inquiry was favorable compared to the individual guided inquiry approach in teaching particular concepts in chemistry. Moreover, students’ attitudes also improved.

Barthlow (2011, p. 53-54) presents five reasons of why guided inquiry classrooms are preferable over the traditional ones:-

> * Understanding of fundamental facts, concepts, principles, laws, and theories;
>
> * Development of skills that enhance the acquisition of knowledge and understanding of natural phenomena;
>
> * Cultivation of the disposition to find answers to questions and to question the truthfulness of statements about the natural world;
>
> * Formation of positive attitudes toward science; and
>
> * Acquisition of understanding about the nature of science.

To mull over these five points, one can read the components of science domains and science literacy at the same time. Upon that, guided inquiry approach in teaching and learning sciences is more than a way of delivering concepts or body of knowledge, it is a way of long-life learning that concepts, process skills and the nature of the scientific knowledge overlap with one's daily life like the scientists' day-to-day works.

2.3 Limitations of Inquiry Implementation

Although the pre-eminence of inquiry approach through its manifest and positive outcomes which are documented in massive and prominent research papers, the arena of education is not devoid of favor to the opposite camp that minifies the presumed superiority of the approach.

Berg et al. (2003) found that students' willingness is a key challenge to grapple with posed problems during open-inquiry projects. Students with poor attitudes towards the former approach could not finish their tasks unless the teacher supports them. Klahr and Nigam (2004) call for revising traditional instruction inability when students in direct instruction group outperformed their discovery group counterparts in learning experimental design aspects. Findings are attributed to the specific student characteristics and the extent of the appropriateness between lesson's objectives and instructional strategy. They conclude that a judicious mix should take into account students' competences, topic and type of pedagogy in order to achieve the most effective knowledge delivering and outcomes.

Bilgin (2009, p. 1039) cites Chung (2007) when he tried to compile constraints that hinder the best implementation of inquiry as follows:

> Insufficient time, teachers' believes, scarcity of effective research materials, pedagogical problems, management problems, crowded classes, security issues, fear of encouraging students to misunderstandings, students' complaints, fear of assessment, lack of methodological knowledge as well as scientific content.

To sum up, success of an instructional strategy in one situation is limited to the students' competences and attitudes as well as needs. Since students are diverse in all former factors, no one particular method is recommended for teaching science classes. Each study is considered relative and has its own merits in terms of its discrepancies: student populations and assessment tools of the learning outcomes, aim, level, definition and scope of the inquiry activities (Brickman et al. 2009). Martin-Hauser (2002, p. 37) comes to terms with the debate between supporters and opponents of the inquiry-based learning when she said: “Different types of lessons, and therefore different types of inquiry, are used for specific needs in the science classroom”. Relying on that, increasing student-centeredness during inquiry activities can be executed as students’ competences become more honed. Otherwise, it may be a source of distortion of the knowledge or misconceptions, at best, or “at worst, a set up for failure” (Matyas 2000, p. 5).

2.4 Interconnection between Inquiry and NOS

Taking the three dimensions of the science literacy into consideration, science education becomes more than merely delivering a body of scientific knowledge. Rather, education that is based on meaningful guided inquiry methods in teaching science as a way of knowing has been and still a persistent endeavor for this century. This was when Dewey (1904) called for infusing inquiry approaches and experiential learning in science teaching strategies (cited in Steinkuehler & Duncan 2008; Wenning 2006).

Reform documents, such as AAAS (1993) and NRC (1996), recommend that students should not only be taught both through and about scientific inquiries, but also achieved understandings of NOS. National Science Education Standards (NSES) state that “science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students’ activities” (NRC 1996 p.105). Moreover, “engaging students in inquiry helps students develop … an appreciation of ‘how we know’ what we know in science, understanding of the nature of science [and] skills necessary to become independent inquirers about the natural word” (NRC 1996 p.105). As a scientific inquiry at school classrooms and/or laboratories implies students practice science and process of science as scientists do, yet researchers in science education are still debating the effectiveness of inquiry in constructing NOS views in students and teachers alike. At this point, it is important to discriminate between NOS and process of science. Many researchers use the NOS and the process of science interchangeably.

Carpi and Egger (2009) ascribe the process of science to the practices utilized by scientists to uncover the knowledge behind their observations. Abd-El-Khalick, Bell and Lederman (1998, p. 418) stress not to conflate between NOS and process of science. For this purpose, they provide an explanation to clarify the difference between NOS and process of science when they state:

> …scientific processes to be activities related to the collection and interpretation of data, and the derivation of conclusions. For example, observing and inferring are scientific processes. On the other hand, the NOS refers to the epistemological commitments underlying the activities of science. Consequently, an individual's understanding that observations are constrained by our perceptual apparatus and are inherently theory-laden is part of that individual's understanding of the NOS.

Upon that, many researchers consider NOS as cognitive instructional outcome that entails explicit attention, while doing inquiries (Abd-El-Khalich, Bell & Lederman 1998; Khishfe & Abd-El-Khalick 2002; Akerson, Hanson & Cullen 2007). However, Metz (2004) asserts that engaging 2^{nd}, 4^{th} and 5^{th} graders in scaffold independent inquiries will lead them to develop epistemological perspective about the uncertainty of the scientific knowledge. He further claims that students were able to detect the uncertainty in their inquiries and to suggest strategies "for how to modify their study to address the uncertainty" (p. 219). He attributes the results to the nature and form of inquiry activities that are implemented. In a recent study, Forawi (2011) obviously examines the relationship between practicing inquiry skills and developing NOS perceptions in pre-service teachers. A positive moderate correlation result ($r = 0.52$) was calculated between teachers' perceptions of NOS and inquiry teaching skills. However, he explicitly mentions that participants were exposed to an explicit instruction of NOS concepts, and this treatment distorts the effect of practicing the inquiry skills individually on their views of NOS.

To settle the matter, Bell et al. (2004) consider this interchange between the two concepts for the favor of effective teaching and learning science. Bell (2009), in different study, refer this conflation to some science classroom practices and deemed this interconnection as an advantage to science teaching. He summarizes the relationship between many process skills and their relevance to NOS concepts in Table 1.

Process Skill	Relevant Nature of Science Concepts
Observing	Scientific Knowledge is based upon evidence. Scientific Knowledge changes as new evidence becomes available. Scientific laws are generalizations based that summarize vast amounts of observational data.
Inferring	Scientific Knowledge involves observation and inference (not just observation alone). Scientific theories are based partly on entities and effects that cannot be observed directly and hence are inferential.
Classifying	There is often no signal "right" answer in science.
Predicting/ Hypothesizing	Scientific theories provide the foundation on which predictions and hypotheses are built.
Investigating	There are many ways to do science. There is no signal scientific method that all scientists follow.
Concluding	Scientific conclusions can be influenced by scientists' background knowledge. Theories provide frameworks for data interpretation.

Table1. The relationship between sample process skills and the nature of the scientific knowledge (Bell 2009, p. 4 of 6).

It is clear from the table that scientific process skills underlying the guided inquiry activities, in their nature, are different from the related NOS concepts. Practicing those skills through hands-on activities or for searching and analyzing data is probably the appropriate method for mastering such skills. On the other hand, it seems that NOS concepts are theoretical cognitive concepts that probably need another explicit teaching strategy.

2.5 Factors Impact on Students' NOS Views

Science textbooks are considered as the main source for scientific knowledge for both teachers and students alike. This central role of scientific textbooks concretely impact students' science literacy and NOS views. Moreover, teachers hold them reliable for defining both what and how they teach. Thus, well-written textbooks are seen as a 'power catalyst' for enhancing knowledge acquisition (Roseman, Stern & Koppal 2010). The authority of these textbooks at schools, according to Wei and Thomas (2005) from Asia and Mumba, Chabalengula & Hunter (2006) from Africa, is well recognized when state that "science courses are taught and learned through the national science curriculum materials which comprise national science textbooks, syllabi, laboratory manuals and past science examination papers" (cited in Chabalengula et al. 2008, p. 208). They describe these materials as a reference for both instructional and assessment students' learning outcomes. These materials are not without defects. Describing the scientific method as linear and imperative turning of the scientific theories into laws are examples of the misconceptions of NOS aspects in science curricula. Generally, several studies consider NOS is poorly addressed in science textbooks. (Abd-El-Khalick, Waters & An-Phong 2008; Bell 2004).

Rodulph (2000) argues that traditional science curriculum, in spite of the continuous pleas of integrating NOS with it, has often met with poor success in satisfying the NOS standards in science textbooks. He attributes former deadlock status to the "various competing, often conflicting, views of the essence of scientific inquiry" (p. 403). Accordingly, Rodulph also advocates indigenous authentic approaches, rather than universe or diverse, that relates to the students' daily life practices. In this sense, Haidar and Balfakih (1999) investigate the UAE secondary students' perceptions about science epistemology, and most of the students hold science epistemological views that are strongly related to religion and tradition. In this respect, the authors recommend that the UAE national science curriculum should be connected purposefully to the students' local and cultural environments in order to bridge their NOS views consistently and meaningfully with their beliefs. And thus, former epistemological authorities should be taken into account during "developing and presenting science curriculum materials" (Haidar and Balfakih 1999, p. 24). Dogan (2011) wonders what went wrong to make literature-math branch students achieve better than science-math branch students in NOS scale questionnaire. The author emphasizes the importance of including social science courses such as: philosophy, history and literature courses in the high school science curricula for the scientific stream students. Duncan and Arthurs (2009) applied a transformed astronomy course with explicit teaching aspects of NOS on an experimental group compared with a traditional course for control group. Results came better to the favor of the experimental group, since they showed higher level of sense to the value of science and expressed clearly that science is not inherent to a specific group of people and any one can do science.

Forawi (2010) pinpoints the lack of the NOS reflections in the biology textbooks and teacher's perceptions of NOS. Based on the former, unless teachers have a sound understanding of what science is and how it is done, as NOS conceptions, they will not be able to properly effect their students' NOS views. Thus many researches elaborate extensively on preparing both pre and in-service teachers' NOS views. Moreover, in order to prevent the inverse impact of teachers with distorted conceptions of NOS on classroom practices and students' NOS conceptions, Tairab (2001) asserts the importance of developing both pre-service and in-service teachers alike, in regard of their NOS views. Accordingly, he recommends that teacher preparation programs should adopt the NOS and characteristics of technology as core subjects in these programs.

In spite of the former massive and successive calls for reform education to foster both the nature and process skills of science as a core, several studies are considering students and teachers' understandings of these topics are still wanting (Abd-El-Khalick & Lederman 2000; Cochran 2003; Ozdemir 2010; Koksal & Cakiroglu 2010). At the local level, teachers' positions are not far from the former shortcomings when Haidar (1999, p. 807) describes the views of the NOS of his sample study with "neither clearly traditional nor clearly constructivist, they held mixed views about the nature of science". Thus, calls for reform are continued either by explicit teaching of history and philosophy of science or implicit instruction through implementing scientific inquiries and highlighting the science process skills (Forawi 2000; Forawi 2011; Akerson, Hanson & Cullen 2007). Tasi (2006) emphasizes the type of instructional content knowledge offered to the students, since exposing a group to two courses about students' misconception and conceptual change provokes participants to better develop constructivist views about NOS than a group exposed to philosophy of science course.

It is clear that previous trend of seeing nature and process of science as core as the content knowledge has been a persistent to make NOS as a standard that needs processing throughout school years. Tao (2003) describes students' NOS views as conservative and barely to be affected by short intervention. In addition to that, Sutherland and Dennick (2002) support this realist view of students' NOS perceptions, which considers the scientific knowledge as static and final. Authors pinpoint the role of culture and language on these perceptions. However, Forawi (2011, p. 15) shows the opposite instrumentalist view that “tends to explain the scientific knowledge as a developmental process of human imagination”. This was when the experimental sample, at the beginning of his study, classified its views about NOS as changeless, while the calculations, at the end of the experiment, revealed that the same group achieved developmental views about NOS (Forawi 2011).

From the standpoint of the constructivism, Iqbal, Azam and Rana (2009) claim that practices such as; inquiry, active engagement, collaboration with others and problem solving are deemed effective constructivist strategies for establishing NOS views in students, pre-service and in-service teachers alike. However, it is worth to mention that conducting only simple inquiry activities seems insufficient in affecting students’ perceptions of NOS as it is the situation in the explicit reflective instruction. Former strategy is considered an explicit strategy in teaching NOS that is the most efficient in this realm (Akerson & Abd-El-Khalick 2003; Khishfe & Abd-El-Khalick 2002; Akerson & Donnelly 2010).

Akerson, Cullen & Hanson (2010) count on explicit reflecting, as an instructional practice, in drawing the students’ attentions to the topics related to the nature and processes of science after the action of teaching and learning. This explicit reflective could be in: writing works, questioning, asking and discussing about students’ acquisition of the nature of science and scientific process skills they have learned. Informed and veteran teachers are eligible to sustain students’ NOS understandings by developing well-structured instructional and assessment tools that help purposefully support students’ NOS acquisition. Moreover, many considerations must be taken into account such as: students’ disabilities, abilities, and psychological and developmental cognitive levels so that teachers are able to meaningfully practice reformed based teaching strategies and appropriately asses student acquisitions of NOS (Akerson, Cullen & Hanson 2010). Tools for assessing, following up and diagnosing weak points in students are pivotal in achieving the targeted NOS objectives. Thus, researchers mention many of these instruments such as: “responsive, formative and/or summative” work sheets that should be directed to reflect students’ NOS acquisitions. Pursuing results from such tools acts as indicative signs for teachers that help them revise the teachers' PCK, classroom activities and the curriculum itself in order to meet the students' competences and cognitive levels as well as the international science literacy standard. (Lederman et al. 2002; Wenning 2006).

In brief, many intertwined factors impact on students' NOS views. Science textbooks, syllabi, laboratory manuals and assessment tools, as curriculum representatives, play a substantial role in forming and reshaping students' NOS conceptions. This is especially true when the curriculum has the highest authoritative power beyond the teacher. This is because of the teachers' commitment to the science textbooks' contents for the final exams. Informed teachers have the greatest chance to help students get sound understanding of the NOS conceptions. Accordingly, improving teachers' understandings and beliefs of what is science and how science is done should be under teachers' development programs agendas. Assessment tools should also be consistent with these trends of reformed-based instruction orientations. Thus NOS conceptions, as cognitive outcomes, should be measured through regular exams. Results gained by such assessment tools will help teachers follow up, develop and reform students' NOS conceptions. Preferably, connecting these conceptions with students' daily life will increase the opportunity to help students get competent in science education.

Chapter III: Methodology

3.1 Research Hypotheses

Taking in to account the aforementioned educational problems in teaching biology in the researched school, as well as based on the findings from the literature reviewed above, this research study hypothesizes that:

Ho1: There would be no significant difference in the mean NOS scores of students taught using guided inquiry teaching method and those taught using the traditional method.

Ho2: There would be no significant difference in the mean achievement scores of students taught using guided inquiry teaching method and those taught using the traditional method.

A quantitative methodology approach is used in this cross-sectional study. A quasi-experimental setup with controlled before-after design is implemented for answering the research questions. This research study is based on the educational psychology that examines instructional strategies in order to tackle students' literacy positions through students' academic achievements and NOS conceptions.

3.3 Research Ethics

As a preamble, the researcher encouraged both the principal and the students in the target school to participate in this research study, and explained to them first, the benefits of such studies on the scope of education and second, the purpose of this research study. Showing due respect throughout the study to both the participants and the school is on the research priorities. All of the participants and administrators as well as lab technicians showed full positive cooperation. An official request was submitted to the school authorities by the researcher in order to get their informed consent before conducting the research treatment. A student informed consent form was also given to the participants in order to take their beforehand consent (both forms are included in Appendix C). The researcher explicitly confirmed, at the top of the questionnaire, that the anonymity and confidentiality of all participants are respected and maintained. All participants were informed that they are free to be a part of this research.

3.4 Participants

Four 10th grade classes with a total of 78 students were the subject of this study. Classes are randomly divided into two groups: 40 students as a control group while the remaining 38 students form the experimental group. All students are boys at the same interval of age ranging between 16 to 17 years old. In general, all students share the same cultural and socio-economic background. The participants of this study have experienced the new science curricula since the academic year 2006-2007, when it was officially introduced in the public education.

The average academic achievement scores in biology for the first semester and success rates in FEZ exam are shown in table 2.

Class	Number of students	Class average in FEZ final biology exam	Success rate in FEZ final biology exam	Students achieved	
				90-99	100
1	21	48.2	47.8	-	-
2	17	60.4	73.7	1	-
3	19	44	45.0	-	-
4	21	55.4	71.4	1	-
Sum/average	78	52	59.48		

Table 2. Students' academic achievement in FEZ final biology exam for the first semester in academic year 2011-2012 (Target school files).

It is clear that grades of the classes and success rates, to some extent, reflect an equitable distribution of the classes on both control and experimental groups. Moreover, numbers in table 2 show a poor academic achievement in FEZ examinations, since the overall average score for the four classes, (52), is around the average scale of the final exam (50), and 40 % of the students could not pass the biology exam for the first semester.

All classes have experienced the same traditional biology teaching approach and had already finished 6 chapters from the prescribed biology textbook. Chapter 7, community ecology, is the target of this research. This chapter contains 3 sections: community interactions (symbiosis), properties of the community and the succession. One main lab is allocated for this chapter in addition to 5 quick activities. This main single lab in this chapter deals with the symbiotic relationship between Rhizobium and Leguminous plants. Students should grow two types of plants, one that is able to associate with the nitrogen fixating bacteria in a symbiotic relationship called mutualism, and another plant that is not capable of this mutualism. Students should identify differences in the root shape of the two plants and then differentiate between red and green nodules on the Leguminous root structurally and functionally. The other 5 quick activities are embedded in the lesson sessions.

3.5 Instruments

3.5.1 Nature of Science Scale (NOSS)

Students' prior NOS views are investigated by using a NOS scale (NOSS) questionnaire. The two articles; Wenning (2006) and Iqbal et al. (2009), and the doctorate thesis for Larson-Miller (2011) are considered the sources of the questionnaire items. Thirty-five questions are collected and modified, in a bipolar strongly agree-strongly disagree and agree, neutral and disagree statements in-between as a five-Likert scale, to construct the NOSS. Items in NOSS are grouped into six sections each corresponding to one of the six key concepts of the NOS. These sections, in the order they appear in the questionnaire, are: scientific method, scientific knowledge, scientific theory, role of scientific community, theory laden, and value of science. A team of four veteran teachers from English, Arabic, Physics, and Chemistry along with the researcher, who teaches biology, participated in translating the questionnaire's questions and reviewing the items for accuracy, clarity, difficulty, reading and redundancy. Each one of these teachers had spent at least more than 15 years at the researched school and have extensive experience in students' academic and literacy situations as well as students' socio-economic structure. Subsequently, the questionnaire is administered to 23 science teachers in 3 public secondary schools located on the east coast of the UAE. Former initial pilot test was held, first: for collecting teachers' comments on the items of the questionnaire in order to seek a reasonable certainty of the content validity, second: for gauging the cronbach's alpha coefficient for reliability of the test. As a result, five items of the questionnaire have been excluded because of the ambiguity in sentence formulation as well as the redundancy. The value for the cronbach's alpha coefficient calculated by using the Statistical Package for Social Sciences (SPSS) version 19 is found equal to (0.725) which is accepted. The remaining 30 items were verified by the supervisor of this research study, who is a specialist in science education especially NOS and inquiry research line, and additional five items were removed because of redundancy. The remaining 25 forced-choice items are spread over the 6 subclasses of the NOS as follow: items 1-3 refer to the scientific method, items 4-8 refer to the scientific knowledge, items 9-12 refer to the scientific theory, items 13-16 refer to the role of scientific community, items 17-19 refer to the theory laden and items 20 -25 refer to the value of science. The final form of the NOSS questionnaire, included in Appendix D, is administered as a pilot test for the reliability, to 74 10^{th} grade students and the corresponding cronbach's alpha coefficient is found equal to (0.726). After the test, students' comments and notes on the questionnaire items are collected and analyzed. Finally, the questionnaire items are revised and rewritten again, based on the feedback, to enhance both validity and reliability.

3.5.2 Environmental Biology Achievement Test (EBAT)

The environmental biology achievement test (EBAT), is taken from the assessment guide book provided by Hartcourt International Company. The test contains 26 multiple choice items, each with 4 possible answers. Their model answers for the items are provided by the same source. Biology questions are designed in accordance to a framework which derived from the objectives of the three sections that encompass the community ecology chapter. Each question is signed with the relevant section number in the chapter. The EBAT items cover most of the outlined sections. A group of four biology teachers, one from the researched school with the researcher and another two from Hamad Bin Abd Allah Al-Sharqi secondary school in Dibba, have revised the 26 items of the EBAT for its appropriateness and content validity. The teachers rewrote some questions in order to be clear and indicative. The 26 items test is included in Appendix X. The questions are already written in Arabic in the assessment guide book. Two groups of 10th graders are subjected to the final version of the EBAT to measure the internal consistency. The first group, from the school under investigation, includes 74 students. The split half technique is followed for the reliability test. Questions in each student's test paper are divided into two groups: odd and even questions, and marked separately. The "spearman brown" factor is calculated by using the correlation factor between the odd and even groups of students' marks as follow: Spearman Brown= (2* the correlation factor)/ (1+ the correlation factor) (Creswell 2008). The reliability value for the EBAT is found equal to (0.712). The same treatment is implemented for the second group of fifty 10th grade students from the other school. The value for the spearman brown factor based on students' split-half results is found equal to (0.878). Taking the whole students as a sample for internal consistency, the value of the spearman brown factor is found to be (0.729). By noticing the students' comments on the EBAT, all EBAT questions were clear to the majority of the students.

3.6 Planning for Guided Inquiry Classes and Activities

To insure the application of guided-inquiry instruction to the experimental group, a lengthy and full detailed dichotomous planning process is established for this purpose. The planning includes first planning for both classroom and activities instruction, and second planning for implementing the guided inquiry instruction on the experimental group. The lesson planning activity is based on the five E learning cycle strategy which is consisted of: engagement, exploration, explanation, elaboration, and evaluation.

The researcher a long with a veteran biology teacher, with 22 years of experience in secondary public schools in UAE, cooperated together in analyzing and specifying each lesson in regard of its main concept(s), sub-concepts and related activities. The analyzing process was established to lead the teachers to introductory questions that are able to gear the students towards the guided inquiry question(s). Although the book presents the objectives of each section, objectives of one section are distributed into two periods in regard of time convenience. Moreover, new sub-objectives are derived in terms of simplifying and pinpointing the concept behind the objectives. As a result 2 periods are allocated for each section. Each lesson has its own three sheets, one for guiding the instructor and two for each student: formative and summative worksheets. Each of the guided inquiry question(s) in student's formative worksheets could address one objective or more. The question is formulated by the teachers after a deep insight in the lesson objectives. It is a question that needs many actions to be tackled such as; dealing with related sub-concepts, serious searching in many resources such as the internet, the school library and, as in sometimes, out-class activities as well as conducting a quick activity. Students are held accountable to grapple with data to answer the guided inquiry question(s). A few several guiding critical thinking questions are stated around the pointed concept, so that students can grope for the right target while dealing with the sub-concepts. This trend in designing the formative worksheets is repeated for each objective. Preparing a summative worksheet always comes after finishing the respective formative worksheet, in order to assess the students' understandings of the target knowledge.

The second part of the planning process is concerned with the quick activities and the lab work. Six quick activities are allocated and usually embedded in the relevant lesson plans, while the main allocated lab for this chapter is independently planned. Each fast activity, carried out during the class, addresses one small idea or a sub-concept. Planning for these activities in the formative worksheets is been by posing 2 to 3 questions around the purpose of the activity. The students then are asked to conduct the activity fast, in order to sensitize and infer the knowledge behind the activity. Usually very simple instruments are needed for quick activities and students are free to use any appropriate lab materials. Some of these activities are modified in terms of time constraints. For example, the first activity for demonstrating the concept of camouflage was changed from using different colored tooth sticks or ear swaps to showing a picture of different butterflies stand on a particular background that shows the camouflage as a defensive mechanism. In general, all relevant questions to these activities are included in the formative worksheets. A separate formative worksheet is prepared for the lab experiment. The two teachers determined the main purpose of the lab in order to form guided inquiry questions. Two main guided inquiry questions are stated to drive the students' lab work, which are: what are the main differences between the roots of bean plants and the roots of radish plants? And how structurally and functionally do the green nodules differ from the red nodules? The same trend in designing the guided inquiry classes was followed for the lab experiment instruction. The main concept of the chapter and the one of the experiments as well as the lab objectives are stated clearly at the top of the sheet. The guided inquiry questions and sub-critical thinking questions form the body of the sheet. After introducing the problem, the students are in the face of the lab work in order to answer their formative sheets under the instructor's supervision. Science as a process was pinpointed through focusing on the way that students follow to answer the questions, and on investigating the different ways of experimentations and the correspondence outcomes. The relevant questions for this purpose were stated in the sheet. Different plants were provided with all possible materials for doing the lab, in order to expose the students to diverse science processes.

Since internet service is considered a key source of information for the most of the classes, it is arranged to be accessible from many places at the school such as; lab computers, school library, educational technology and resources room, and regular classes via wireless connections. This allowed the students to use the internet any time it is needed. For example, students should watch videos about Rattlesnake and Todd's feeding adaptations to study the characteristics of predators and in contrast various defensive adaptations in different prey species. The main obstacle was the limited number of access points at the classrooms. However, this problem was compromised by asking the computer officials at the school computer labs to provide with 5 laptops for each of the experimental classes and make them available for this purpose. The internet is deemed a main source of many videos, essays and different examples of biological interconnections. Moreover, the researcher provided the school library with 3 editions of general biology books, two editions of the Biology of Campbell and one of the Biology of Solomon as biology references.

Finally, each period has its own three planned sheets for guided inquiry instruction and the potential sources of data and materials. All lesson plans, formative worksheets, summative worksheets and lab experiment plan are available in the appendices F, G, H and I, respectively.

3.7 Guided Inquiry Instruction

Prior to starting the course, both control and experimental groups are administered to the EBAT and NOSS questionnaire as pre-tests before the one-month scheduled treatment.

Students in experimental classes are divided into heterogeneous groups according to their grades in the first semester biology final exam. Each group contains 4 students, one high level student who achieved above 80 in the exam, one intermediate above 70 and two low level students below 70 (see photos in Appendix J). Teaching the experimental classes usually starts with a preamble of reading and discussing the lesson objectives. The teacher manages the preamble tactically to lead the students to the guided-inquiry question(s) through discussing the introductory questions. Subsequently, the students are given the allocated formative worksheets and they are free to use any of the provided materials as well as the internet in their search for information, photos and videos in order to answer the critical thinking questions. While students are engaged in both intra discussions within a group and inter discussions among groups, the teacher plays a pivotal role in scaffolding the students in mastering the lesson's concepts, using materials and in managing the panel discussion either by posing questions or by providing allusions and collecting every students' answer by using a checklist for this purpose. Each group should explain, justify, and elaborate on their answers. Right answers are declared by each group announcer with a positive feedback from the teacher. The role of group announcer is rotated amongst the students within the group with each new question in order to engage all students in dealing with lesson's objectives. On the other hand, wrong and/or unclear answers call for teacher's interventions to drive students toward the right path. If students are not able to reach to a consensus on the target answer, the teacher presents it with justifications. In general, the teacher provides students with ample time to grapple with the problem, search for its solutions, build their hypotheses and examine them, and draw conclusions. However, the teacher never offers a blueprint for right answers to be put into action without making students put efforts on their tasks. The former learning cycles is continue until the students finish answering the assigned formative work sheet and then sheets are submitted to the teacher for assessment. The teacher did his best to make the learning environment fair enough for all students. At the end of each period a summative worksheet is assigned for each student as homework. The former worksheets are also turned in for final evaluation. In regard of the lab work, a worksheet is built for assessing the students' knowledge acquisitions. In coordination with the researcher, the lab supervisor had already planted bean and radish seedlings 6 to 8 weeks prior to the lab date in order for the plants to be ready for examination at the proper stage of growing. However, students were asked to grow the seeds four weeks before the lab in order to practice planting and nurturing plants. Each plant was grown in two types of soils, sterile soil and Rhizobium infected one, in order to compare the effect of Rhizobium bacteria on leguminous plants. Students are exposed to the materials, and given a chance to use them independently and appropriately as much as possible. How they can get advantage of these materials to tackle the guided-inquiry questions is a basic desired competency to be mastered by the students as inquiry process skills. The teacher wanders among the groups either for sparking an objective-based point for discussion or guiding the groups' works, while they are preparing for their experiments in order to answer the critical thinking questions on the sheet. The teacher insisted that each group should justify their choices to the plants, and verify the relationship between the nitrogen fixing bacteria and Leguminous in the soil. After finishing the external examination of the roots, students started the microscopic investigation to the nodules with a free choice of using either a dissecting microscope or a light microscope. The most important concern of their choices is that they provide right justifications and practice different ways of the scientific process. At the same time, the students were geared to compare results in light of the different trends in the scientific processes. At the end of the lab, students should compare the microscopic slides that they prepared to the pre-prepared ones. Students' microscopic views to the slides should be reported by both sketching pictures and commenting it. Also, students' formative worksheets are collected after finishing them for evaluation, and summative worksheets, instead were given to the students as a final assessment.

Generally, students in the experimental group are mainly intended to device their own procedure by themselves. Conversely, students in the control group would not have received more than the conventional learning that depends on the teacher as a dispenser of knowledge and the lecture that based on the textbook as a source of information. Additionally, the lab experiment in control group is done by following the cook-book, step-by-step lab manual. At the end of these massive efforts, students in both control and experimental groups are administered again to the EBAT and NOSS questionnaire, in two separate days, as a post-test to measure effects of change on students. Each test consumed a maximum of 30 minutes. Two students from the experimental group have left the school before applying the post tests, and thus their pre-test results were excluded also.

Chapter IV: Analysis of Data and Results

According to the sequence of the aforementioned research questions, results are presented in the same sequence. Firstly, students' pre-NOSS scores are analyzed in order to show the initial NOS conceptions that students hold before the treatment. Secondly, both descriptive and inferential statistics are calculated in order to measure the effect of the guided inquiry instructional strategy on students' NOS conceptions. In addition, both first and second sections are coupled with a detailed comparison between pre and post NOSS-subscales' scores for both the control and experimental groups in order to illustrate the effect of the instructional strategy on students' NOS conceptions. Thirdly, the same trend of calculations in the second part is followed for measuring the effect of the guided inquiry on students' environmental biology achievements.

4.1 Students' Pre-NOS Conceptions

In order to answer the first research question about the NOS conceptions that students hold after they have experienced the new International Hartcourt science curricula since the academic year 2007-2008, students' views are collected by using the results from the NOSS questionnaire from the pre-case. Students scored significantly less than the scale average of the questionnaire (15.18) out of the final score (50) of the NOSS (Figure 1).

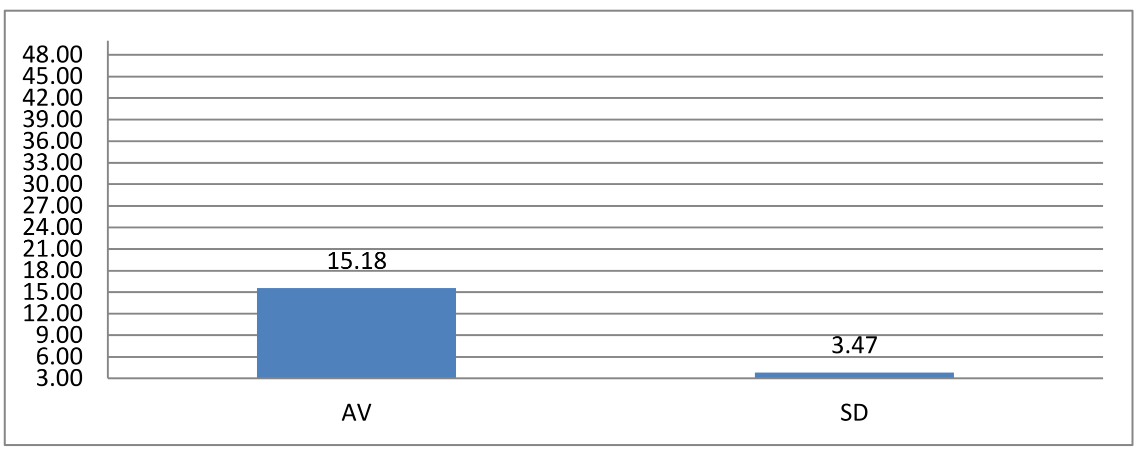

Figure 1. Total average score of the students' NOS conceptions.

The total average scores in the subscales of the NOSS indicate that the students could not pass the scale average of any of the subscales as shown in Table 3.

NOS aspects NO.	1	2	3	4	5	6	Total
Average (AV)	1.38	2.24	1.77	3.37	1.74	4.68	15.18
Standard Deviation (SD)	1.05	1.36	1.21	1.63	1.27	2.26	3.47
Maximum value	6.00	10.00	8.00	8.00	6.00	12.00	50.00

Table 3. Total and subscales' AVs and SDs of the pre-scores of the NOSS.

Descriptive statistics of both the experimental and control groups in each pre-subscale are presented in Table 4 and figure 2 respectively. Since students' scores are lagging behind the average scale of the final grades of the total pre-NOSS and subscales, students NOS views could be described as inadequate.

NOS subclasses	EXPERIMENTAL GROUP					CONTROL GROUP					
	AV	SD	SE	VAR	Mode	AV	SD	SE	VAR	Mode	Full grades
Scientific method	1.89	0.8	0.1	0.58	2	0.9	1.1	0.2	1.12	0	6
Scientific Knowledge	2.05	1.5	0.2	2.21	3	2.43	1.2	0.2	1.48	2	10
Scientific Theory	1.97	0.9	0.1	0.73	2	1.55	1.5	0.2	2.1	1	8
Role of Scientific Community	3.11	1.8	0.3	3.18	2	3.63	1.4	0.2	2.1	4	8
Theory Laden	1.5	1.3	0.2	1.61	2	1.98	1.3	0.2	1.56	1	6
Value of Science	4.58	2.4	0.4	5.66	4	4.78	2.2	0.3	4.74	5	12
Total score	15.11	3.9	0.6	15.29	14	15.3	3.1	0.5	9.32	16	50

N= 76

Table 4. Descriptive statistics of both the experimental and control pre-NOSS scores.

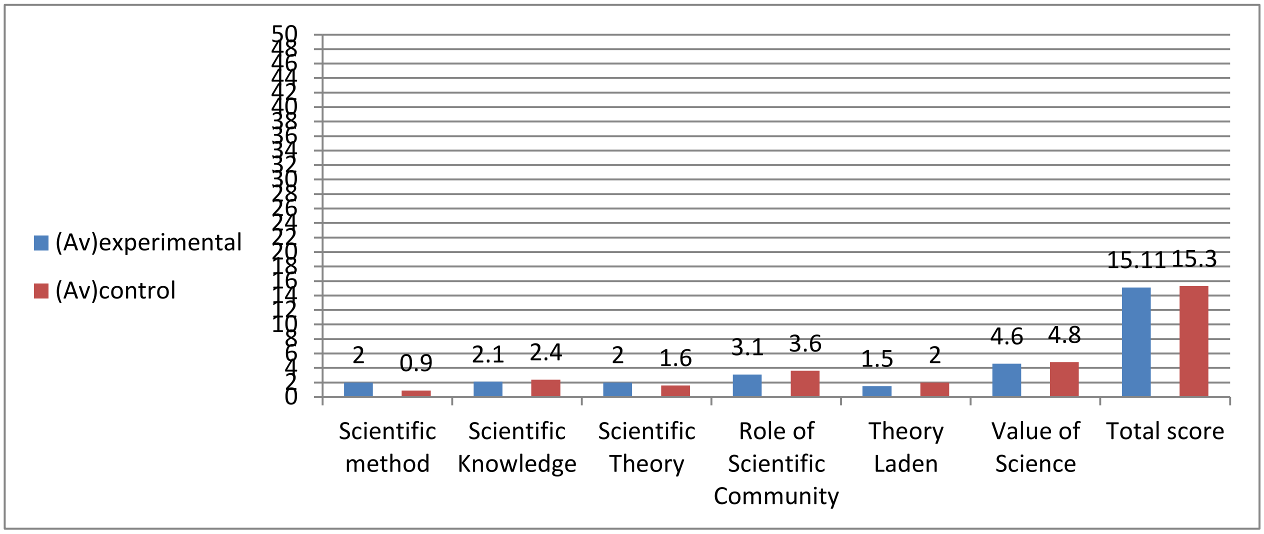

Figure 2. Students' averages of pre-NOSS subscale scores of both the experimental and control groups.

Students, nor in any subclass, were able to pass the average scale of the subscales of the NOSS. However, in category four, the role of scientific community, and category six, the value of science, students achieved a little bit more than one third of the final grades of these categories. In the remaining subscales of the NOSS, students stuck behind the one third of the final grades. Generally, modes of the subscales also reflect a repetition of uninformed choices to the most of the NOSS questions.

4.2 Guided Inquiry and Students' NOS Conceptions

As it is the norm in studying the effect of an independent variable on a dependent one, independent t-test was conducted to indicate the differences between the control and experimental groups at the beginning of the study. Differences between students' means of pre-NOSS scores of both the experimental and control groups were judged by this result ($t\ (74) = 1.4; P > 0.05$) as shown in table 5. Moreover, the Person correlation was calculated between the total students' scores of pre and post-NOSS, and result was ($r = 0.04$, $n = 76$, $P > 0.05$). Relying on the former inferential statistics, there was no significant difference between students' average scores in the control and experimental groups at the beginning of the study, as well as there was no correlation between students' pre-post scores of the nature of science scale questionnaire. Very weak correlation between the total pre-post scores means very low effect of the students' individual differences on their scores, where the effect should be mostly from the treatment itself.

Group	N	X	SD	t	df	P
Experimental Group	36	15.11	3.91			
				1.4	74	0.303*
Control Group	40	16.00	3.71			

N = 76: * P value is significant at P< 0.05.

Table 5. Comparison of pre-NOSS scores for control and experimental groups.

In order to compare the effect of the two instructional strategies on students' NOS outcomes, independent t-test was conducted for this purpose between the experimental and the control post-NOSS scores. The independent t-test shows that there is no significant treatment effect (t (74) = 1.47; P > 0.05) as shown in table 6. As this result, guided inquiry instruction could not affect students' performance with regard to their post-NOSS scores as well as the traditional instruction. Moreover, the calculated effect size equals (0.26), which reflects that the difference between the two means is weak and guided inquiry instructional strategy could not affect students' NOS views.

			Post-NOSS			
Group	N	X	SD	t	df	P
Experimental group	36	16.1	3.88			
				1.47	74	0.15*
Control group	40	15.13	4.16			

N= 76: * P value is significant at P< 0.05.

Table 6. Descriptive statistics and independent t-test results for post-NOSS for both experimental and control groups.

Table 7 compares the effectiveness of the two ways of instruction on both the experimental and control groups by conducting paired t-tests for pre-post scores of each group. Results came also not significant in the two cases as follows: (t (35) = 1.58; P > 0.05) and (t (39) = 0.16; P > 0.05) respectively. This means that neither guided inquiry, as instructional strategy, nor traditional way of instruction could affect students' NOS views.

Experimental Group	N	X	SD	t	df	P
POST	36	16.21	2.09			
				1.58	35	0.123
PRE	36	15.11	3.91			
Control Group						
POST	40	15.13	4.16			
				0.16	39	0.877
PRE	40	15.25	3.05			

* P value is significant at P< 0.05

Table 7. Pair t-tests between both experimental and control pre-post NOSS scores.

Figure 3 depicts clearly the convergence between the students' averages after the treatment. However, going deeply in the detailed results of students' post-scores of both groups will present a clearer picture about students' NOS views after the students, in the experimental group, have practiced scientific process skills through guided inquiry lessons and activities for one month. Table 8 presents also the descriptive statistics of each subscale of the post-NOSS of the experimental and control groups.

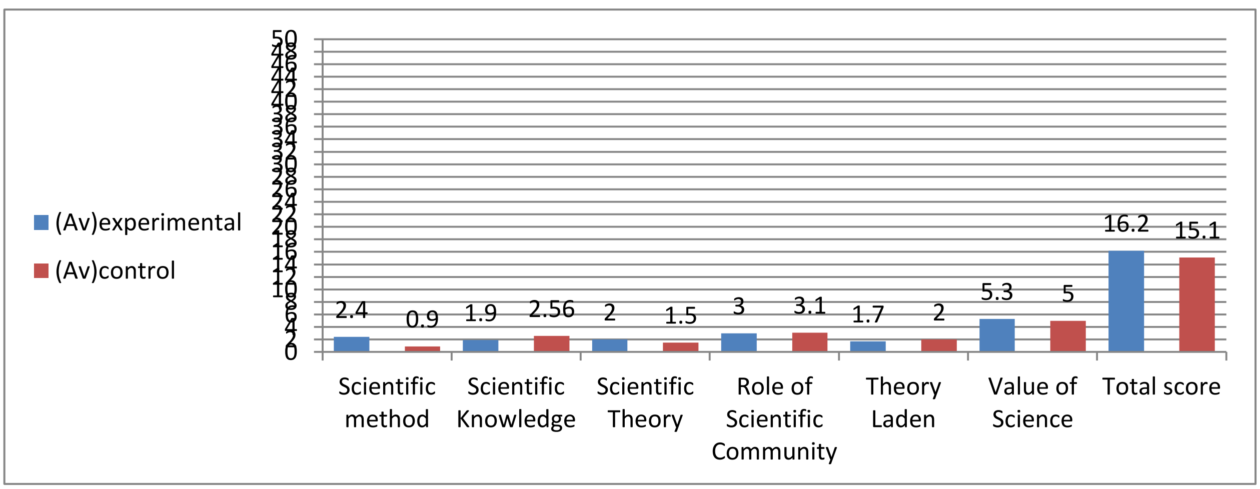

Figure 3. Students' averages of post-NOSS subscales' scores of both the experimental and control groups.

NOS subclasses	EXPERIMENTAL GROUP					CONTROL GROUP					
	AV	SD	SE	VAR	Mode	AV	SD	SE	VAR	Mode	Full grade
Scientific method	2.4	0.7	0.1	0.5	2	0.9	1.4	0.2	1.9	0	6
Scientific Knowledge	1.9	0.9	0.2	0.9	2	2.6	1.8	0.3	3.3	2	10
Scientific Theory	2	0.8	0.1	0.6	3	1.5	1.6	0.3	2.7	0	8
Role of Scientific Community	3	0.9	0.1	0.8	3	3.1	1.5	0.2	2.1	4	8
Theory Laden	1.7	0.7	0.1	0.5	2	2.0	1.1	0.2	1.3	3	6
Value of Science	5.3	1.0	0.2	1.1	6	5.0	1.5	0.2	2.4	7	12
Total score	16.2	2.1	0.34	4.4	16	15.1	4.2	0.7	17.3	21	50

N= 36

Table 8. Descriptive statistics of post-NOSS scores of both the experimental and control groups.

Fluctuations are unnoticed in the averages except in subscale one and six where dependent t-tests between pre and post-cases, of the experimental group only, revealed about significant differences as follows: ($t(35) = 2.53$; $P < 0.05$) and ($t(35) = 2.05$; $P < 0.05$) respectively. The remaining t-tests have no (P) value smaller than the critical alpha ($\alpha = 0.05$) (for all paired t-tests see Appendix K).

4.3 Guided Inquiry and Its Effect on Students' Academic Achievements

In order to answer the second research question, how does use of guided-inquiry instructional strategy affect students' achievement in environmental biology, students' EBAT scores, as dependent variables, are called for analyses by using SPSS version 19. The way of instruction is the independent variable in this section of the study with two levels according to the two types of instructional strategies, guided inquiry and traditional way of instruction. Table 9 shows students' average score, standard deviation and the (p) value of the independent t-test for pre-EBAT of the control and experimental groups. T-test result is presented as follows ($t(74) = 0.4$; $P > 0.05$). This result indicates that there is no significant difference between means of the experimental and control groups at the beginning of the experiment. In order to prove that there is no correlation between pre and post-EBAT scores, the value of the Pearson correlation (r) is calculated and the result is (r = 0.38, n = 76, P > 0.05). This means that there is no significant effect of the students' individual differences on their scores of the EBAT; however this value of correlation limits any prospective effect to the type of treatment rather than to the students' individual differences.

Group	N	X	SD	t	df	P
Experimental Group	36	9.00	3.55	0.4	76	0.69*
Control Group	40	9.38	4.62			

N = 76: * P value is significant at P< 0.05.

Table 9. Comparison of pre-EBAT scores for control and experimental groups.

After the treatment, independent t-test between the experimental and control groups in respect to their post-EBAT scores was conducted in order to compare the effectiveness of the two ways of instruction on students' environmental biology outcomes as shown in table 10. The result was as follows: (t (74) = 2.19; P < 0.05). As this result, guided inquiry instruction achieves better students' performance in the post-EBAT scores than the traditional instruction. Moreover, the calculated effect size as (d) value equals (0.5), which reflects that the difference between the two means is meaningful in a practical sense (Creswell 2008).

	Post-EBAT					
Group	N	X	SD	t	df	P
Experimental group	36	14.92	5.31	2.19	74	0.031*
Control group	40	12.1	5.76			

N = 76: * P value is significant at P< 0.05.

Table 10. Descriptive statistics and independent t-test results for post-EBAT for both the experimental and control groups.

Table 11 compares the effectiveness of the two ways of instruction on both the experimental and control groups by conducting paired t-tests for pre-post scores of each group.

Experimental Group	N	X	SD	t	df	P
Post	36	14.84	5.26			
				7.19	35	1.59 E-08*
Pre	36	9	3.55			
Control Group						
Post	40	12.1	5.76			
				2.99	39	0.0049*
Pre	40	9.38	4.62			

* P value is significant at P< 0.005.

Table 11. Pair t-test between both experimental and control pre-post EBAT scores.

It is clear from Table 11 that calculated P value of the experimental group reflects a stronger significant effect of the guided inquiry instructional strategy on students' achievements comparing with the effect of traditional teaching strategies.

Chapter V: Discussion, Conclusions and Implication

5.1 Students' Pre-NOS Conceptions

Consistently with several research studies, students' NOS conceptions are internationally still lagging behind the NRC, NSES and other benchmarks (Abd-El-Khalick & Lederman 2000; Dogan 2011; Dogan & Abd-El-Khalick 2008). To some extent, students in this research do not differ from the general status of inadequate views of NOS. Looking to the NOS as a vital and essential part of the science literacy, as mentioned in the introduction, students' scientific literacy is still wanting. This was also stated by Thomson (2008) when he summarized the low achievement of the UAE students' 2003 and 2007 science scores in TIMSS, which generally were less than the average scale (500). And too, in the same trend Haidar and Balfakih (1999) investigated students' epistemological views in the UAE secondary schools, and results were as inadequate as in the case of this research study. For example, they reported that most of their sample students perceived the progress of the scientific knowledge as accumulative. Moreover, a considerable number of their sampled believed that scientific models are deemed true representations of natural reality. This situation is found the same in this current research study, where students see the scientific method as linear process and scientific knowledge increase gradually with accumulation of new knowledge rather than, in sometimes, as jumps. Haidar and Balfakih (1999) also found that students' culture, in almost as Islamic background, has an intimate link with their informed epistemological believes about science. On the other hand, the authors ascribed uninformed epistemological believes, presented by the sample of their study, to the UAE science textbooks that are stuffed almost entirely with facts and formulas but allocate a scarce fortune to the NOS concepts that provide science as "a set of socially negotiated understandings of the universe" (Haider & Balfakih 1999, p.23), whereas the contemporary vision is to include the social context of science while teaching sciences (AAAS 1990). They had sentenced that "a curriculum of different country or society does not convey the same message. Same experience does not necessarily give the same product for different students" (Haider & Balfakih 1999, p. 25).

Worth mentioning, Haider (1999), in another study, investigated more than 150 pre and in-service science teachers' views about NOS in UAE, and results were almost similar to the former study. He described teachers' NOS perceptions as mixed between tradition and religion. He expected a 'symbolic violence' case in both teachers and students while delivering and studying science consequently, and 'collateral learning' was suggested to diminish such violence. Tairab (2001) also reported the same situation in Brunei when he found that pre and in-service teachers as well as students showed similar mixed views in regard to the NOS and technology, and he relied on the classroom practices to tackle this situation. From the forgoing, it seems that students' NOS views in UAE are stagnant since 13 years, it's really very frustrating.

The third domain of science, NOS, is considered poorly addressed in science curricula, and if it is tackled, it is often misrepresented in science textbooks. The systematic transition from scientific theories to laws and the linearity of the scientific method are some of these misconceptions in science curricula as many studies also revealed (Abd-El-Khalick, Waters & An-Phong 2008; Bell 2004). For example, biology and chemistry textbooks, for grade 10 in UAE governmental schooling, as well as physics textbook, for grade 11, present the scientific method in a linear shape with a step by a step model. This misrepresentation is being one of the investigated myths in this research study. Tenth graders have experienced an explicit linear model of the scientific method in the first part of the biology textbook. Students' answers in this part of the NOSS emphasize this view about the scientific methods. Most students, in the NOSS, take the opportunity for flattering what they had already learned in this regard. This situation comes clearly coherent with what Haidar and Balfakih (1999) stated about the UAE science textbooks as well as declares the authority of these textbooks on students' NOS perceptions.

Irez (2009) endorsed this authority of the biology textbooks on Turkish students' views about NOS, when he found that lacking of sufficient and appropriate NOS representatives in the biology textbooks lead students hold many misrepresentations about interconnections between science and religion. Three years later, Dogan (2011) reported the same situation about inadequate conceptions of NOS aspects such as:

imagination, creativity and the social and cultural context of the scientific knowledge in Turkey also. Dogan also held science textbooks responsible for his findings, in terms of providing science as only a content of knowledge but not as also combined with NOS aspects. Moreover, as it is in the UAE public secondary schools, Dogan pinpointed markedly the Turkish teachers' commitment to delivering and covering the contents of regular curriculum, in order to prepare students eligible to pass the exams for entering universities. Classroom practices and the learning environment are mainly affected by such pressures, and thus students' NOS conceptions are either deficient or garbled. The author outshined the literary students' NOS conceptions comparing with science track students. He attributed this better performance to the active influence of social subjects at variance with the abstract science subjects in science track schooling. The implemented biology textbook for 10 grade in UAE public schools is rich in its content knowledge without any clues to the epistemological, historical, sociological, and philosophical of the scientific knowledge and science process skills aspects. In addition, teachers in UAE public schools have the same commitment to the content of these books in terms of the national final exams. This situation is similar to the former Turkish studies which makes findings of this research study are consistent with findings of many researches.

5.2 Guided Inquiry and the NOS Concepts

In regard to the second research question, the effectiveness of guided inquiry as instructional strategy on students' NOS conceptions, students' total scores of NOSS at the conclusion of this research study do not differ from those at the outset. Comparing average scores for each subscale of the NOSS shows a fluctuation between pre and post cases with no significant differences except in subscale No. 1, the scientific method, and subscale No. 6, the value of science, where differences came significant at 0.05 of alpha value in regard of the experimental group only. It seems that the implemented guided inquiry lessons and activities could not improve the uninformed NOS conceptions hold by tenth grade students. Results in this research study are consistent with many previous research studies that examined the impact of guided inquiry, as implicit way of teaching the NOS concepts, on students' NOS conceptions (Abd-El-Khalich, Bell & Lederman 1998; Moss, Abrams and Kull 1998; Abd-El-Khalich & Lederman 2000; Khishfe & Abd-

El-Khalick 2002; Akerson & Abd-El-Khalick 2002; Akerson, Hanson & Cullen 2007; Bell 2009). These former studies deemed inquiry activities alone are insufficient for constructing and/or improving the understandings of the NOS concepts in students' minds. However, many incorporated approaches which are mixing the guided inquiry, as an implicit way of teaching science process skills, and direct courses about philosophy and history of science were implemented for this purpose as what Forawi (2011) did in his study. His results were clearly significant in favor of the experimental group when he implemented this mixed approach. Moreover, explicit-reflective approach of instruction coupled with inquiry activities is found to be the most successful in improving teachers and students' views of the NOS alike. Explicit-reflective instruction is defined as "drawing the learner's attention to key aspects of the NOS through discussion and written work following engagement in hands-on activities" (Akerson, Hanson & Cullen 2007: 573). Reflective approach entails learners thinking of how their works through inquiry activities relate to the scientists' work. In brief this way of instruction helps learners sensitize underlying NOS ideas while practicing scientific process skills through inquiry activities. This strategy in teaching NOS concepts requires primarily that NOS concepts be as explicit objectives of science lessons.

Worth to mention that, lessons' objectives, which are presented in the biology textbook, did not pay any attention to the nature of the target environmental knowledge. Moreover, considering the teacher's commitment to following the outlines of the curriculum and delivering the contents of the textbook will not expose students to NOS concepts. In addition to that, former situation will also eliminate the effect of the contributing factors to students' NOS conceptions such as teacher's informed NOS views, classroom practices and as a result the nature of the assessment tools. These defects in considering NOS aspects as main parts of the science textbooks' objectives were clearly stated by many studies (Chabalengula et al. 2008; Abd-El-Khalick, Waters & An-Phong 2008; Bell 2004; Haidar and Balfakih 1999).

Khishfe & Abd-El-Khalick (2002) found that engaging students in guided inquiry activities could not affect students' NOS conceptions positively as it is the case in the explicit-reflective approach. The authors concluded that implicit inquiry-oriented instruction takes care with content of knowledge and process skills only. And, practicing these skills does not necessarily mean delivering the NOS meanings. Moreover, NOS concepts are not a by-product that can be acquired by osmosis while doing inquiries, or in another way students will not learn the details of respiration once they practice the process of breathing (Abd-El-Khalick, Bell & Lederman 1998). This research study has found the same findings when guided inquiry lessons and activities were designed based on the biology textbook objectives. Merely guided inquiry lesson plans were found efficient in delivering content knowledge and practicing scientific process skills but not in developing informed NOS conceptions.

In this context, it is important to distinguish between the process of science and the NOS knowledge. In addition to the example mentioned in the literature before, another good example is that the process of controlling the variables during inquiries does not lend students to the logic of experimentation as a NOS-related aspect. The aforementioned table 1 clearly presents the differences between the processes of science and the underlying NOS aspects behind these processes. One important point here is that, students during guided inquiry activities might not encounter all scientific processes and skills underlying the guided inquiry activities. For example, students in the experimental group did not share the teacher the questioning and planning stages for the guided inquiry activities. This was because of students' lacking the ability to pose scientific-inquiry questions and scientific procedures for data gathering, which are the core difficulties that confront students in such inquiries (Colburn 2009; Kirschner, 2008). In this case, students may not encounter a full scientists' work. Thus, truncated understandings of the nature of the scientific processes may form in the students. However, yet it is still scientific inquiry while students are struggling to analyze data, build conclusions and answer the posed questions in the worksheets. This case was clarified by Monteyne and Cracolice (2004, p.1559) when they stated that "a key element of guided inquiry is that data analysis is left to the students, but not the data collections" (cited in Lee 2009, p.17). Upon that, teachers should sense students' starting points and help them improve their scientific inquiry skills and involve through and through in designing authentic and full guided-inquiries.

Students’ post scores in the first and sixth subscales of the NOSS, the scientific method and the value of science in the community, were significantly better comparing with the pre cases. This improvement can be ascribed to the former feature of the inquiry activities that are caring with process skills. Students during the guided inquiry activities, in a group work, questioned directly about the necessity of following the hierarchal classic view of the scientific method. The teacher allowed students’ work if it was right and logic without the imperative need to follow the sequence mentioned in this subscale of the NOSS which is, forming hypotheses, collecting data, analyzing data and making conclusions. Being aware of such NOS issues and holding discussions around them are intimately related to the explicit-reflective approach as mentioned before, and this direction was held responsible for the improvements of the post scores in subscale No.1 of the NOSS. Understanding such NOS ideas is considered as a cognitive outcome that entails explicit-reflective instruction but not only the implicit guided inquiry activities (Abd-El-Khalick, Bell & Lederman 1998; Khishfe & Abd-El-Khalick 2002; Akerson, Hanson & Cullen 2007). The case in the sixth subscale of the NOSS, the value of science in the community, was not far from the former explanation. Communication among students during the group work under the instructor supervision about the importance of studying science subjects and the value of scientific decisions in students’ daily life and thus the community as a whole, represents, somehow, a kind of explicit-reflective instruction which is favor in this realm.

Finally in this regard, Bell (2009) met half way when he suggested in his paper a ‘purposive instruction’ which deals explicitly with the NOS issues, not by direct instruction but by connecting them to contexts of history, philosophy and socio-scientific aspects through inquiry activities and process skills. He described these process skills as ‘a potential lesson about the NOS’ and will help students learn through doing science.

5.3 Guided Inquiry and Academic Achievement

In regard to the third research question, the effectiveness of guided inquiry as instructional strategy on students’ academic achievements, results came clearly effective in terms of the grater academic achievement in favor of the experimental group. This result is not unique, however several studies support the superiority of the guided-inquiry as an instructional strategy over the traditional education (Khan et al. 2011; Opara 2011; Barthlow 2011; Ketpichainarong, Panijpan and Ruenwongsa 2010; Schwarz and Gwekwerere 2007; Crawford 2000). Guided inquiry, as a constructivist teaching strategy, fosters students' higher order thinking skills while they are engrossed in solving problems and thinking critically as well as verifying and refining concepts such as in biology. This way of instruction allows students to develop meaningful scientific knowledge, build their own conceptualizations about science and scientific knowledge as well as actively learn, with ample time, while grappling with objective-based question(s) rather than reciting and dispensing knowledge on a spoon feeding way (Brown, P. 2010; Brown S. 2010). Moreover, spending appropriate time on an optimal learning cycle for understanding questions, searching for answers, explaining findings, forming and testing hypothesis, making inferences and all in social communicated group work will prompt students' optimal level of cognition and skills and expose them to the normal scientists' work.

Students in the experimental group were actively engaged either physically or mentally in learning situations. On the contrary, students in the control group were passively listen to lectures or followed steps in laboratory manual instructions as a cook book in order to accomplish their tasks. This active, self-directed environment embraces not only acquiring the concepts or the content knowledge but also skills in how to "approach a problem, identify important resources, both design and carry out hands on investigations, analyze and interpret data, and, most importantly, recognize when they have answered the question or solved the problem" (Matyas 2000, p.5). In addition, guided inquiry, as a supportive environment, promotes students' highest and best skill level, which is the optimal level of performance, more than the functional level (Barthlow 2011). What is striking, in such student-centered learning environments, is that students learn to prioritize information, and decide which is most important and which is least helpful especially in this increasingly vast information era (Matyas 2000).

Communication skills amongst students and social work are also in the light, in terms of the group work during guided inquiry sessions. Students in the experimental group used to learn how to distribute tasks on the group members for the sake of one object, which may be solving a problem or answering work sheet questions. Many studies advocate learning through social-constructivist environments in regard of the better academic achievements, science literacy positions, self-confidence and research competences (Brickman et al. 2009; Opara 2011). Evaluation of the formative and summative worksheets reflects clearly the effectiveness of the group work. Lee et al., (2010) and Bilgin (2009) reported the fruition of the group work in the guided inquiry classes especially in the lab sessions.

What was striking, that the teacher's greatest efforts during the guided inquiry activities and classes were mainly directed to supervise, guide and maintain students' tasks in scientific investigations more than to control and manage students' behavioral issues, as it is the situation in normal laboratory lessons. Although inquiry-group work classes are generally characterized with activism and dynamism, students in these classes were seemed to be more motivated and attached to their tasks. Many studies have emphasized these growing positive attitudes towards learning sciences through inquiry instructional strategy (Chang & Tasi 2005; Taraban et al. 2007; Bilgin 2009).

5.4 Conclusions

This research study showed that Emirati 10 grader students' views about the NOS in the investigated school are alarming. Additionally, based on the interconnection between scientific literacy and NOS, the students' scientific literacy ranks are also inadequate. Students' low achievement in the final biology exam for the first semester of the academic year 2011-2012, in addition to their traditional views about NOS support former claims.

Generally, the science curriculum is crucial to the development of students' NOS conceptions. This case is not confined to the UAE regular school curriculum. According to many studies, several countries in Asia, Africa, Europe and USA are familiar with the same situation (Chabalengula et al. 2008; Dogan 2011; Forawi 2010 and Irez 2009). Based on teachers' commitment to the science textbooks' contents, these books are held accountable for many misconceptions and misrepresentations of the nature of science in students' minds. Because of its authority in preparing students for the post-secondary education, its impress is crystal clear on students' NOS views. Although science curriculum is a key, but not the sole, element in forming and developing recommended NOS conceptions, and thus preparing scientific literate students. Many other factors are deemed competitive in this domain and cannot be overlooked. Teacher's views about NOS, teaching strategies inside the classrooms and the way that followed for assessing such learning outcomes are of those critical factors that affect significantly delivering the NOS concepts. However, teachers' commitment to cover science curriculum literally, for the sake of passing successfully to the university undergraduate stage, usually marginalizes those critical factors and keeps science curriculum the most watched factor into focus.

This research study showed that guided inquiry alone is insufficient in developing adequate views of the nature of science in students. Although inquiry activities provide a window of opportunity for students to practice the scientific process skills that produce scientific knowledge in a constructivist approach, these process skills do not tell students about epistemological, historical, philosophical and sociological aspects of science. Science as a process is markedly misrepresented in the biology lab manual. Most activities are characterized as traditional blueprint model of the lab cook-book and step-by-step experiments. In this sense, a consensus is existed that different levels of scientific inquiries are the way of presenting science like what scientists do in order to discover knowledge. These ways of practicing science deliver not only the scientific concepts and body of knowledge in a meaningful way, but also the scientific approach as a habit of mind for in and out-school scientific decision making, and preferably in a social context in the light of group working during inquiries. "Since scientific literacy is not a process of purposeful work in the process of teaching and learning" (Stefanova, Minevska & Evtimova 2010, p.117), it is desired to be sustained for out-school daily life and social environment. Thus, authentic inquiries that inspired from students' local environments are held helpful for students to get sound understanding of the scientific decisions within their social context.

Guided inquiry is considered as a vehicle for conveying knowledge and as knowledge in itself. Thus students are recommended to learn both through and about it.

No one can be blind to guided inquiry superiority over didactic ways of teaching and learning, especially in science education. This excellence of the guided inquiry usually comes from prompting the higher mental functionalities of the students' physical and mental skills. Students through inquiry are prone to understand well, rather than to stack up information, in terms of stimulating the higher order thinking skills such as problem solving, critical thinking and approaching scientific problems through logical and scientific ways of thinking. Scientific process skills are in the priority in the guided inquiry classes. Upon that, students have a chance of grappling with data in a meaningful way that resembles scientists' work during their scientific investigations. This applause of the guided inquiry as instructional strategy is not at all, however it depends on informed planning process that appropriately aligns between students' competences and inquiry skills.

Preference of the guided inquiry sessions overreaches the better academic achievement superiority to work as a motivation power for keeping students engrossed in their tasks. Guided inquiry approach in teaching and learning sciences is recommended in terms of its inclusive effects. Either in the lab work or in the theoretical classes, students as long as they deal with different materials and sources relishing the midst of searching and answering questions critically, their science literacy, research skills and self-confidence all are considerable and important targets during guided inquiry classes. It also makes students more attached to the learning environment. Additionally, during such a constructivist approach, teacher's power is purposefully invested to the favor of the learning process and guiding students, and thus reducing wasted time and energy.

Based on the fact that teacher usually encounters different students-cognitive levels in the classroom, so that different levels of student-centeredness are required in this regard. Accordingly, the simple description, scaffolding, of the teacher's role in guided inquiry classes, which at first glance, reflects an easier burden with a less responsibility than it is in the traditional instruction, where the teacher is the sage on the stage, implies more than that. However experiencing guided inquiry showed that teacher's role is more complex and active. It constantly changes, while keeping abreast of students' positions during the learning cycles.

5.5 Implication

Based on the convergence between science and science literacy and taking into consideration the contemporary and constructivist views of educational reform agendas, science curriculum should take into its account the content knowledge, NOS concepts and science as a process and habits of mind alike in order to achieve science literacy in students. However, facts, concepts, lows and theories are bulked large in national science textbooks. On the other hand, out of concern for students' NOS views and thus science literacy, science curriculum should be radically revised in order to meet this modern vision of science education. Curriculum designers, science educators and science teachers, as interest parties in this realm, should pay serious attention to the aspects of science epistemology, history and philosophy of the scientific knowledge and science as a way of knowing with the social context of the scientific knowledge while designing and developing science textbooks. These aspects of NOS should be explicitly touched and listed in science teaching objectives. Adopting NOS as a fundamental goal in science teaching should also be presented coherently with students' local environment and culture background. Students are prone to understand science when scientific ideas are in harmony with their every day practices. Upon that, importing science curriculum from different cultures and external socio-backgrounds, as current science Hartcourt International curriculum, will lead students to a kind of mental conflict that renders appropriate understanding to the NOS aspects. Strange names and exemplars that are far from students' minds and imagination may hamper students' cognition, so lend them unable to assimilate new concepts and knowledge in their existed schema.

Nature and process of science as educational goals should be explicitly stated in curriculum and the lesson objectives. Students' attentions should also be explicitly drawn to those NOS aspects. NOS conceptions are considered as cognitive outcomes, and it could not be perceived automatically as a by-product outcome while practicing inquiry activities.

In order to integrate the efforts, teacher development programs are on the front of the reforming efforts to meet enactment documents of reformed education. Developing the pre-service and in-service teachers' conceptions of NOS, especially in the elementary and intermediate cycles of education, should be of the priority on the agenda of education. Assessing students' acquisitions of NOS and science process skills is an imperative, if we want to be sure that students are grasping these important domains of science and science literacy. In this sense, reforming educational assessment tools should be congruent with the new trends of the reform documents and the reform-based instruction as well as reformed science curriculum. This curriculum should explicitly include nature and process of science as a main part of its objectives.

As a recommendation, this research study opens the door for more future investigations for measuring the effectiveness of other science teaching methods that help provide content knowledge, NOS and science as process at the same time. Moreover, expanding time of intervention and/or changing the content knowledge are potential points for future research.

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Appendices

Appendix A: Inquiry Matrix

Figure 1 below shows a matrix with two dimensions of the inquiry activities as demarcated by Fradd et al. (2001). In this matrix, while the vertical dimension represents the hierarchical levels of inquiries in regard of the student centeredness, the horizontal dimension distributes the respective tasks that vested in both the teacher and students during these activities.

Inquiry levels	Questioning	Planning	Implementing	Concluding		Reporting	Applying
			Carry out Plan Record	Analyze data	Draw conclusion		
0	Teacher	Teacher	Teacher	Teacher	Teacher	Teacher	Teacher
1	Teacher	Teacher	Students/ teachers	Teacher	Teacher	Students	Teacher
2	Teacher	Teacher	Students	Students / teachers	Students / Teachers	Students	Teacher
3	Teacher	Students / teachers	Students	Students	Students	Students	Students
4	Students/ teachers	Students	Students	Students	Students	Students	Students
5	Students	Students	Students	Students	Students	Students	Students

Figure 1: Science Inquiry Matrix (Guisti, 2008, p. 6).

Based on the Science Inquiry Matrix, as we go up in the inquiry levels, the more independent the students get by self-directing and actively involving in inquiry sessions. Moreover, per one activity student centeredness may vary according to the amount of directions from the teacher and/or materials. Thus, the previous matrix can be demonstrated as shown in Figure 2 by amending the inquiry levels field of the matrix.

More ←	Amount of learner self-direction	→ Less
Less ←	Amount of direction from teacher or material	→ More

Figure 2: “student-centered spectrum” (Martin-Hauser, 2002: 36).

Simple inquiry levels are characterized by confirmed inquiry as in level 0 and level 1. Students in these two levels follow cook-book, step-by-step procedures after the teacher has explained the target concepts to them. In brief, teacher in these two levels serves as a “dispenser of knowledge” while students hold very limited responsibility.

Structured inquiries are not so different from confirmed ones. The timing between delivering the target knowledge and applying the inquiry activities is the crucial difference between them. In structured levels students are held more accountable in implementing inquiries to reach the target concepts, even if it is under the teacher assistance and supervision. Level 2 and 3 represent the structured inquiry (Bell, Smetana and Binns, 2005, p.33).

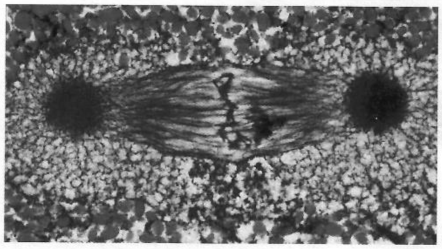
Level 5 in the inquiry matrix, called open inquiry, is the closest to the real scientists work. Foos (2003, abstract) described the students’ role during open inquiries as “students state the problem, formulate the hypothesis and develop their own working plan”.

Appendix B: Table of Contents and a brief description of the 10th grade Biology textbook

المحتويات

الفصلُ 4

تكاثُر الخلايا 70



الجزءُ الثاني

الفصلُ 5

مدخلٌ إلى علمِ البيئة 92

الفصلُ 6

الجماعاتُ الأحيائيّة 106

الفصلُ 7

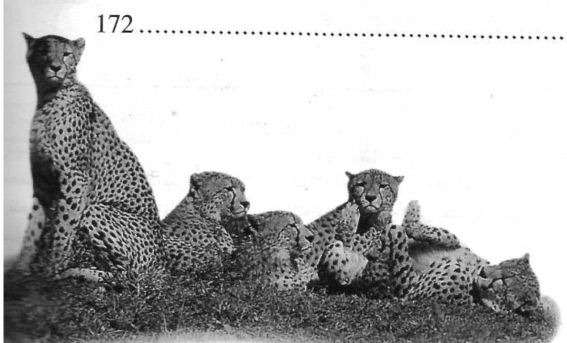
علمُ بيئةِ المجتمع الأحيائي 118

الفصلُ 8

النظم البيئيةُ والغلافُ الأحيائي 134

الفصلُ 9

علمُ المحيط البيئي 160



The origin of all science Harcourt International curricula is Canada. A Lebanese committee was responsible for translating the books into Arabic. Five books are provided for each subject. Two books are allocated for each student, one as student's book and other as activity book. The remaining three guide books are for the respective teacher, which are teacher's book, activity book and assessment book. The content of the biology curriculum is distributed into two separate textbooks. The first part is concerned with fundamentals of biology such as; characteristics of the living things, biochemistry, cell components and its functions and the reproduction of cells. Most lessons are abstract and related activities are not directly designed to demonstrate the concepts, but rather as applications on these concepts. Shortage in lab preparations is the main constraints in enabling students clarify and verify the abstract biology concepts. The second part is only about the ecology with five chapters that compromise 19 sections. Noticeably, all places, animals, plants and names in the second part are related to the North American ecosystems, which are very far from students' local environment and culture. The teacher's guide book provides both detailed chapters' and lessons' plans. It is clear that the body of knowledge is the main concern of the biology book. Most activities in the lab-book are of the cook-book type and students have no choice except the following the numbered steps in the activity book to accomplish the activity.

As a misconception about the scientific method in the book, The 'Scientific Method' is the title of the second section of the first chapter in the biology book. In the preface of this section the book says "whatever the subject that scientists investigate, they generally use a scientific approach of limited and specific ways to gain knowledge" (Ministry of Education- Biology student textbook for 10^{th} grade 2012, P. 9). At the end of the same section, the book summarizes that "scientists generally follow one single scientific approach that consists of several scientific steps" (Ministry of Education - Biology student textbook for 10^{th} grade 2012, P. 16) and these steps are shown in a linear flowchart.

Appendix C: Consent forms

PARTICIPANT CONSENT FORM

Please tick (√) the following boxes to indicate your agreement:

☐ I have read the information provided about the purpose of the study.

☐ I understand that the data collected will be completely anonymous and that my privacy and confidentiality will be respected.

☐ I understand that I have the right to withdraw from this study at any time without prejudice.

☐ I understand that any reports that will result from the data collection will not identify any individual participants.

☐ I am willing to participate in the study (e.g. be part of the sample for observation and completing what is needed for the study, complete the questionnaire, be interviewed,...etc.)

Name: ______________________________________

Signature:_________________________________ Date: _________________

الجامعة البريطانية في دبي
The British University in Dubai

Date: April 1, 2012

Anas Ben Al-Nader Secondary School, Roll Dadnah, Al Fujairah.

Dear Principal, Mr. Ali Salem Al Danhani

The British University in Dubai offers a Master's of Education (Med) degree to interested students, teachers, and professionals in the United Arab Emirates to maximize their career opportunities and increased their knowledge. The MEd program has been designed in collaboration with the School of Education of the University of Birmingham, one of Britain's leading schools of education. The Med program is approved and accredited by the Ministry of Higher Education and Scientific Research, UAE and has graduated many students since its start in 2004 in several different areas in education. The purpose of this letter is to kindly ask you to allow Mr. Ahmad Sharif Hasan a student in this program, to be able to make visits to your school, to conduct a research by observing or administering questionnaire, or interviewing,etc. teachers or/and students or administrators with you agreement and direction. As part of the University's research ethical guidelines, the data collected will be anonymous and will be treated with utmost confidentiality.

Finally, we look forward to your kind cooperation. The research visits should take place within the period of September 2012 to December 2012. If you require any additional information, please don't hesitate to contact Dr. Sufian Forawi at sufian.forawi@buid.ac.ae or 050 1270746.

Sincerely Yours

Dr. Sufian A. Forawi,

Science Education Associate Professor

MEd Coordinator

Appendix D: Nature of Science Scale (NOSS)

Examine all options before responding; select the single best answer. Do not write or make any marks on this question sheet; mark your answers on the provided answer form only. Return this question sheet along with your answer form. Thank you.

Scientific method

1- In order to solve a wide variety of scientific problems, scientists only need to follow "The Scientific Method."

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

2- Scientific ideas are based on reason and evidence, and not on guesses, hunches, or insights.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

3- Scientists through their scientific investigations follow these steps: create a hypothesis, collect data, analyze data, and form conclusion.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

Scientific Knowledge

4- Scientific knowledge is cumulative. It increases with increasing observation.
*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

5- Scientists think of scientific knowledge as beliefs supported by repeatable and observable evidence.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

6- Well established scientific conclusions will generally remain unchanged with the passage of time, but are subject to change in the light of new evidence.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

7- Scientists may believe some scientific results even if they are not finding an understandable scientific explanation to these results.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

8- Innovation of new technologies may lead to a change in the scientific knowledge even if it was reliable in the past.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

Scientific Theory

9- A scientific theory is the most reasonable guess that scientists can make until they can collect better data.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

10- Scientists discover theories, because theories are there in nature and scientists just have to find them.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

11- Hypotheses eventually become theories, and theories eventually become laws.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

12- Scientific models (e.g. the model of an atom) are copies of reality, since they describe reality as it is.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

Role of Scientific Community

13- Scientists should review and check the work of other scientists, especially if that work will serve as the basis for other scientists’ future efforts.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

14- Good scientists will seek scientific knowledge, even if it might conflict with their personal beliefs.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

15- Cases of disagreement among scientists represent unhealthy phenomenon, which is indicating a defect in the conducted research methods.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

16- The main point of replicating studies in science is to reduce error.

*** Strongly Disagree * Disagree * Don’t Know * Agree * Strongly Agree**

Theory Laden

17- When scientists collect and analyze facts, they will produce results that are known with complete certainty.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

18- The scientific perceptions formed in the individuals about the world rely on the prior experience and understanding of the individual.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

19- Observation is influenced by theories scientists hold.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

Value of Science

20- Knowing how science works helps me better understand everyday life.
*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

21- Students who do not major/concentrate in science should not have to take science courses.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

22- Only scientific experts are qualified to make scientific judgments.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

23- When scientific results conflict with my personal experience, I follow my experience in making choices.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

24- It is important to understand how society interprets scientific evidence.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

25- Scientific knowledge is constantly changing, so there is no point in learning about it.

*** Strongly Disagree * Disagree * Don't Know * Agree * Strongly Agree**

Answer sheet

Question No.	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
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Appendix E: Environmental Biology Achievement Test (EBAT)

Examine all options before responding; select the single best answer. Do not write or make any marks on this question sheet; mark your answers on the provided answer form only. Return this question sheet along with your answer form. Thank you.

1- The best example for the relationship between a producer and a consumer is:

a) A snake that eats a bird

b) A fox that eats a mouse

c) A lion that eats a zebra

d) A zebra that eats grass

2- Parasites:

a) Are growing in parallel with their hosts growing

b) Are usually smaller that their hosts

c) Rarely kill hosts

d) a + b + c

3- Feeding a tick on human blood is a good example for:

a) Parasitism

b) Mutualism

c) Competition

d) Predation

4- Which is considered as an example for mimicry?

a) A venomous organism looks like a harmless one

b) Colors that make the animal invisible in his habitat

c) A harmless organism looks like a venomous one

d) Two venomous organisms with the same colors for their body parts

5- A Feature that makes plants able to protect themselves against herbivorous is:

a) Thorns and needles

b) Adhesive lint and cruel leaves

c) Chemical defenses

d) a + b + c

6- Which of the following happens when the same food and area are the requirements for many organisms that belong to the same species?

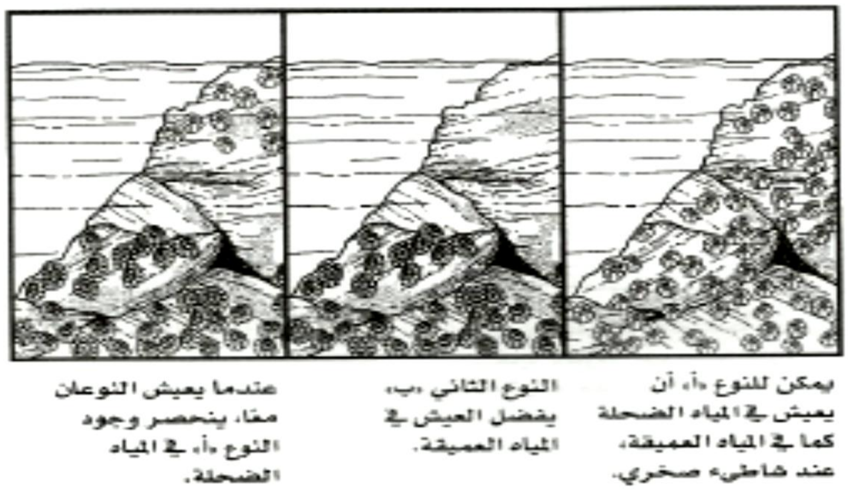
a) Primary succession

b) Competition

c) Secondary succession

d) Competition among different species

The following sketch represents experiments that conducted into two, A and B, marine animals stuck on rocks and live in the same area.



7- From the former sketch, the two species that try to use the same resources are:

a) Parasites b) Competitors c) Organisms share benefits d) Symbiotic organisms

8- See star usually prays different organisms such as oysters, an ecologist, who is studding an ecosystem in an ocean, conducted an experiment that required removing the starfish from the ecosystem. After removing the starfish:

a) The ecosystem became more diverse

b) Food nets became more complex in the ecosystem

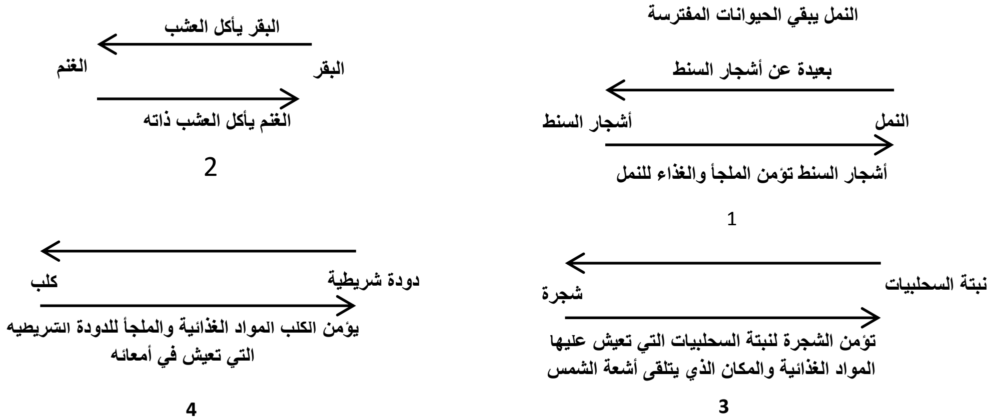
c) The ecosystem shrank

d) Number of species in the ecosystem dropped down

9- The symbiotic interaction between plants and bees, which transfer pollen grains to plants, is an example for:

a) Commensalism b) Competition c) Mutualism d) Parasitism

Sketches below illustrate different types of symbiotic interactions:



10) Referring to the figure above, the symbiotic represents in figure 4 is:

a) Commensalism b) Competition c) Mutualism d) Parasitism

11) Referring to the figure above, the symbiotic represents in figure 2 is:

a) Commensalism b) Competition c) Mutualism d) Parasitism

12) Referring to the figure above, the symbiotic represents in figure 1 is:

a) Commensalism b) Competition c) Mutualism d) Parasitism

13) Referring to the figure above, the symbiotic represents in figure 1 is:

a) Commensalism b) Competition c) Mutualism d) Parasitism

1	Both organisms get benefit from each other
2	One of both organisms gets benefit from the other. The other organism does not get benefit as well as does not hurt.
3	One organism takes advantage of another; however the first one causes harm because of this relationship.

14) From the table above, the table represents three types of:

a) Competition b) Periodic patterns c) Symbiotic d) Secondary succession

15) From the table above, which pair of organisms generally represents type 1 of the symbiotic relationship?

a) Wolfs & sheep b) Shrimps & see cucumber

c) Parasitic worms and white-tailed deer d) Shellfish and algae

16) Referring to the same table, the relationship of number 2 in the table called:

a) Commensalism b) Competition c) Mutualism d) Parasitism

17) Diversity of organisms is to measure:

a) Number of species in a bio-community

b) The total individuals in a bio-community

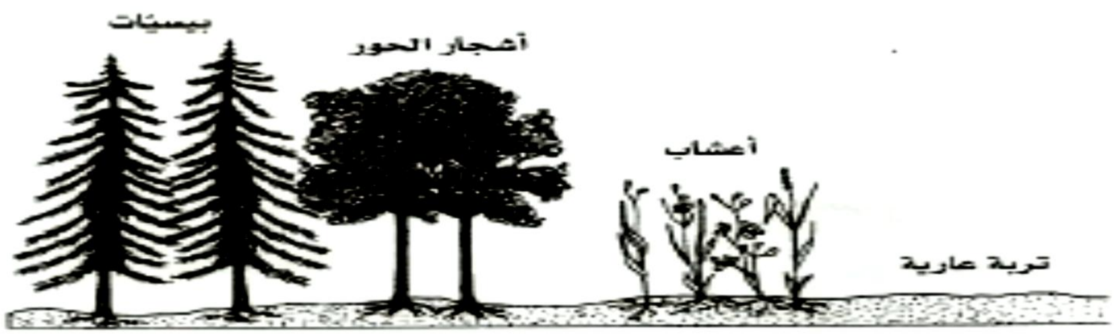
c) Number of plants in relevant to the number of animals in a bio-community

d) Number of species and richness ratio for each type of species in the bio-community

18) It is assumed that many species in the tropics are vulnerable to extinction due to:

a) Global warming b) destroying hebetates

c) Overhunting d) Predation by new animals that introduced to the community



19) Which of the following is not a characteristic of a stable society?

a) Good resistance to harmful insects

b) The ability to quickly resist the effects of drought

c) High richness in species

d) Low number of predators

20) Returning to the drawing above, the process described in this drawing called:

a) Competition b) Succession c) Symbiotic d) Commensalism

21) Succession is:

a) The ability of the organism to survive in the environmental surroundings

b) Number of species that live in an ecosystem

c) Regular relay of species replacement in the ecosystem

d) Energy movement through food chain

22) Which type of succession that happens after combustion of a forest

a) Primary succession b) A succession in an old field

c) Secondary succession c) Lake succession

23) Secondary succession happens:

a) When a generation of organisms replaces a previous generation

b) When a replacement to a previous bio-community happens

c) When a new food web emerges

d) No one of the former answers

24) Which of the following is not of pioneer organism properties?

a) Small organism b) growing fast

c) Reproduce slowly d) releases many of seeds

25) The final stage of the primary succession at north latitude may be characterized by a dominant of:

a) Lichens b) Perennial trees with needle-form leaves

c) Small plants and bushes c) Herbs

26) Common plants that are dominant in areas of the early stages of secondary succession are:

a) Bushes b) Lichens c) Herbs d) Trees

Answer sheet

Question No	a	b	c	d
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Question No	A	b	c	d
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Appendix F: Lesson Plans

Lesson Plan 1: Biology science Guided-Inquiry class.

Interactions between Species.

ODE Benchmarks

1- Interconnectedness between species.

*** Species cooperate and compete among themselves inside the ecosystems.**

Name: Ahmad Sharif Hasan

School Name: Anas Bin Al-Nader School

Classroom Number: 1, 2.

Lesson title: Predation/Parasitism/ Competition/Commensalism and Mutualism

Subject Area: Biology/ Ecology

Grade level: 10$^{t''}$ Grade

Time Allocation: 90 Minutes

Grouping: 4 Students

Instructional Planning: The students will be split into small groups of 4 students. The students will be encouraged to grapple with the prepared formative worksheets, videos and slides, and search for data by using the WWW in order to answer the posed questions. Each group should report and model its results while teacher is monitoring and facilitating groups' works. Finally, the students will be assessed by using summative work sheets in addition to the homework and observed during the session.

Learner Analysis: 1- to differentiate between predation and parasitism. 2- To evaluate the importance of mimicry as a mechanism of defense. 3- To describe two defensive mechanisms in plants against herbivorous. 4- To explain how competition affects the ecology of bio-community. 5- To discriminate between Mutualism and Commensalism. 6- To give examples about former symbiotic relationships.

Objectives:

1- To differentiate between predation and parasitism.

2- To evaluate the importance of mimicry as a mechanism of defense.

3- To describe two defensive mechanisms in plants against herbivorous.

4- To explain how competition affects the ecology of bio-community.

5- To discriminate between Mutualism and Commensalism.

6- To give examples about former symbiotic relationships.

Skills included in this lesson:

Classification, Observation, Reasoning, Inference, Conclusion.

Prior Knowledge:

1- Understand the dynamics of the species.

2- Density-dependent limiting factors.

3- The factors that help increase the number of species in the ecosystems, and classification of these factors as density- dependent or density-independent factors.

Model of instruction/instructional strategies:

1- Cooperative guided inquiry group work is the main instructional strategy in these lessons.

2- Discussion through group members and among groups also.

Materials:

White board, Data show, Videos, Slides, Internet access point with laptops, Formative worksheets, Summative work sheets, Colored ear swaps, Hot water, Tea pages, Glasses, Different colored flowers.

Procedures:

1- Lesson is introduced by asking questions about the photo in page 118, and how this Neritic community is similar to the tropical rain forest.

2- Highlighting the relationship between organisms in the same species and among different species also.

3- Splitting students into groups of 4 students for each, and start by themselves to answer the respective formative worksheets.

4- Different videos, slides, photos, fast activities and URLs will be used as different sources of data related to the section objectives.

5- Two quick activities are included in this lesson. The analyzing of predation is the first activity with studying the role of camouflage in the nature. Inferring the importance of flower coloring is the second quick activity. The first activity will be conducted outside the class on the school garden, while the colored petals will be brought to the class for the second activity.

General safety issues: (all these points are fixed for both lab and class periods).

a) What are the safety concerns with this lesson?

1- Don not use wet hands while operating electrical instruments.

2- Be careful, handle slides carefully, dispose broken slides in a separate pot provided by the teacher.

3- Take care when use Iodine dye, it may spoil hands, clothes and eyes if it is in contact with.

b) Make sure students fully understand the following rules

1- No eating or drinking is permitted at any time in the laboratory. Do not bring food into the laboratory. Do not dispose of food waste in specifically directed to do so in an experiment. Never touch or smell chemicals unless specifically directed to do so in an experiment. Never taste chemicals.

2- No horseplay will be tolerated. Walk – do not run, in the laboratory.

3- Work in the laboratory only during your regularly scheduled class period, unless directed otherwise by your laboratory instructor.

4- Never work alone in a chemical laboratory.

5- Keep coats, books, and other belongings on the racks provided in the laboratory. Do not place them on the laboratory bench (and do not bring library materials into the laboratory where they may be damaged). Keep aisles free of obstructions؛ pay particular attention to drawers, cabinet doors and seats in this respect.

6- Before using any reagent or waste bottle, read the label carefully to make certain you have the correct substance .Never rely on the shape, size or color of the bottle – READ THE LABEL.

7- Teacher observance of potentially hazardous behavior will be documented the teacher‘s lab journal.

Instruction:

Instruction will base on the guided-inquiry strategy. The instructor will encourage students to think of creative and insightful ideas to answer posed questions. The start point should be as short warming up critical thinking question(s) with directed discussion. After that, students will form sets and 4 students in each. Each student should take his formative worksheet within the group. A group announcer will be assigned. Lesson objectives will be tackled through the formative worksheet activities. Each group will encounter each activity and at the end announce its answers under teacher supervision and scaffold. Although it is a group work, the teacher may choose randomly a student to explain his own participation. The teacher will round among group to assure all students participation. Discussion among groups is allowed under teacher control. At the end of each activity each group will announce its answers. Groups will share their answers also, and finally right answers will be highlighted. Unless that, the teacher will intervene to correct students path.

Questions:

Refer to the related formative and summative worksheets.

Motivational opening/ Engagement:

1- Each group will report their findings for each activity in an encouraging and competitive environment.

2- Each group will be encouraged to properly use sources of information.

3- Each group will be encouraged to model results on a group sheet.

Development activity/Exploration:

1- What are the aims of this lesson?

2- What are types of symbiotic relations among species?

3- The role of interconnectedness between species in the ecosystem.

Explanation results:

Justifying results critically and scientifically relying on the prior knowledge.

Closing/ Transfer/ Elaboration:

1- Highlighting the main concept of the chapter, the interconnectedness.

2- Connecting final findings with the lesson objectives.

3- Pinpoint the self-learning, critical thinking and problem solving techniques in learning biology.

Assessment/Evaluation:

1- Reporting results.

2- Modeling results.

3- Formative work sheets will be provided to each group and followed by the teacher and then turned in for group grade.

4- Individual summative worksheets will be distributed to students and evaluated.

Lesson Plan 2: Biology science Guided-Inquiry class.

Bio-community characterizations

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<u>ODE Benchmarks</u>

1- Interconnectedness between species.

*** Species cooperate and compete among themselves inside the ecosystems.**

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Name: Ahmad Sharif Hasan

School Name: Anas Bin Al-Nader School

Classroom Number: 1, 2, 3.

Lesson title: Species Richness and Diversity/ Species-area effect

Subject Area: Biology/ Ecology

Grade level: 10^{th} Grade

Time Allocation: 90 Minutes

Grouping: 4 Students

Instructional Planning: The students will be split into small groups of 4 students. The students will be encouraged to grapple with the prepared formative worksheets, videos and slides, and search for data by using the WWW in order to answer the posed questions. Each group should report and model its results while teacher is monitoring and facilitating groups' works. Finally, the students will be assessed by using summative work sheets in addition to the homework and observed during the session.

Learner Analysis: 1- To explain the difference between species richness and species diversity.
2- To describe how the species richness pattern changes according to different latitudes. 3- To explain at least one hypothesis for this. 4- To explain reasons and results of the species-area effect. 5- To explain the two main point of views about the relationship between species richness and the ecosystem stability.

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Objectives:

1- To explain the difference between species richness and species diversity.

2- To describe how the species richness pattern changes according to different latitudes.

3- To explain at least one hypothesis for this.

4- To explain reasons and results of the species-area effect.

5- To explain the two main point of views about the relationship between species richness and the ecosystem stability.

Skills included in this lesson:

Classification, Observation, Reasoning, Inference, Conclusion.

Prior Knowledge:

1- Understand the dynamics of the species.

2- Density-dependent limiting factors.

3- The factors that help increase the number of species in the ecosystems, and classification of these factors as density- dependent or density-independent factors.

Model of instruction/instructional strategies:

1- Cooperative guided inquiry group work is the main instructional strategy in these lessons.

2- Discussion through group members and among groups also.

Materials:

White board, Data show, Videos, Slides, Internet access point with laptops, Formative worksheets, Summative work sheets and geography subject materials.

Procedures:

1- Lesson is introduced by asking questions about different Biomes and their animals and plants normal flora, and also about the relationship between number of species and ecosystem stability.

2- Highlighting the relationship between the geographical position and species richness.

3- Highlighting the relationship between the geographical position and species-area effect.

4- Splitting students into groups of 4 students for each, and start by themselves to answer the respective formative worksheets.

5- Different videos, slides, photos, quick activities and URLs will be used as different sources of information related to the section objectives.

6- Through the lesson, one quick activity is included. Analyzing different biomes in regard of their nature of people, animals and plants that can inhabit in such places.

General safety issues: (all these points are fixed for both lab and class periods).

a) What are the safety concerns with this lesson?

1- Don not use wet hands while operating electrical instruments.

2- Be careful, handle slides carefully, dispose broken slides in a separate pot provided by the teacher.

3- Take care when use Iodine dye, it may spoil hands, clothes and eyes if it is in contact with.

b) Make sure students fully understand the following rules

1- No eating or drinking is permitted at any time in the laboratory. Do not bring food into the laboratory. Do not dispose of food waste in specifically directed to do so in an experiment. Never touch or smell chemicals unless specifically directed to do so in an experiment. Never taste chemicals.

2- No horseplay will be tolerated. Walk – do not run, in the laboratory.

3- Work in the laboratory only during your regularly scheduled class period, unless directed otherwise by your laboratory instructor.

4- Never work alone in a chemical laboratory.

5- Keep coats, books, and other belongings on the racks provided in the laboratory. Do not place them on the laboratory bench (and do not bring library materials into the laboratory where they may be damaged). Keep aisles free of obstructions؛ pay particular attention to drawers, cabinet doors and seats in this respect.

6- Before using any reagent or waste bottle, read the label carefully to make certain you have the correct substance .Never rely on the shape, size or color of the bottle – READ THE LABEL.

7- Teacher observance of potentially hazardous behavior will be documented the teacher‘s lab journal.

Instruction:

Instruction will base on the guided-inquiry strategy. The instructor will encourage students to think of creative and insightful ideas to answer posed questions. The start point should be as short warming up critical thinking question(s) with directed discussion. After that, students will form sets and 4 students in each. Each student should take his formative worksheet within the group. A group announcer will be assigned. Lesson objectives will be tackled through the formative worksheet activities. Each group will encounter each activity and at the end announce its answers under teacher supervision and scaffold. Although it is a group work, the teacher may choose randomly a student to explain his own participation. The teacher will round among group to assure all students participation. Discussion among groups is allowed under teacher control. At the end of each activity each group will announce its answers. Groups will share their answers also, and finally right answers will be highlighted. Unless that, the teacher will intervene to correct students path.

Questions:

Refer to the related formative and summative worksheets.

Motivational opening/ Engagement:

1- Each group will report their findings for each activity in an encouraging and competitive environment.

2- Each group will be encouraged to properly use different sources of information.

3- Each group will be encouraged to model results on a group sheet.

Development activity/Exploration:

1- What are the aims of the lesson?

2- What are the effect of Latitudes and Species-area effect on species richness?

3- The role of species interactions, species richness and human activities on species richness ecosystems.

Explanation results:

1- Justifying results critically and scientifically relying on the prior knowledge.

2- Explaining scientific bases that hypotheses rely on.

Closing/ Transfer/ Elaboration:

1- Highlighting the main concept of the chapter, the interconnectedness.

2- Connecting final findings with the lesson objectives.

3- Pinpoint the self-learning, critical thinking and problem solving techniques in learning biology.

4- Highlighting the relationship between number of species and ecosystem stability.

Assessment/Evaluation:

1- Reporting results.

2- Modeling results.

3- Formative work sheets will be provided to each group and followed by the teacher and then turned in for group grade.

4- Individual summative worksheets will be distributed to students and evaluated.

Lesson Plan 3: Biology science Guided-Inquiry class.

Succession

ODE Benchmarks	
1- Interconnectedness between species. *** Species cooperate and compete among themselves inside the ecosystems.**	**Name**: Ahmad Sharif Hasan **School Name**: Anas Bin Al-Nader School **Classroom Number**: 1, 2, 3. **Lesson title**: Succession in the Bio-community **Subject Area**: Biology/ Ecology **Grade level**: 10th Grade **Time Allocation**: 90 Minutes **Grouping**: 4 Students **Instructional Planning**: The students will sit into small groups of 4 students. The students will be encouraged to grapple with the prepared formative worksheets, videos and slides, and search for data by using the WWW in order to answer the posed questions. Each group should report and model its results while teacher is monitoring and facilitating groups' works. Finally, the students will be assessed by using summative work sheets in addition to the homework and observed during the session. **Learner Analysis**: 1- To define the Succession. 2- To distinguish between primary and secondary succession. 3- To describe the succession that happened in Glacier Gulf. 4- To explain specifications of the secondary succession. 5- To give examples about secondary succession. 6- To clarify the succession complexities.

Objectives:

1- To define the Succession.

2- To distinguish between primary and secondary succession.

3- To describe the succession that happened in Glacier Gulf.

4- To explain specifications of the secondary succession.

5- To give examples about secondary succession.

6- To clarify the succession complexities.

Skills included in this lesson:

Classification, Observation, Reasoning, Inference, Conclusion.

Prior Knowledge:

1- Understand Lichens as a mutualism.

2- Glacier gulf, its position and natural climate.

3- Factors that help increase the number of species in the ecosystems, and classification of these factors as density- dependent or density-independent factors.

4- Properties of weeds as opportunistic plants.

Model of instruction/instructional strategies:

1- Cooperative guided inquiry group work is the main instructional strategy in these lessons.

2- Discussion through group members and among groups also.

Materials:

White board, Data show, Videos, Slides, Internet access point with laptops, Formative worksheets, Summative work sheets and Geography subject materials.

Procedures:

1- Lesson is introduced by asking the students to access an assigned URL for succession and read and learn about this new concept.

2- Highlighting the relationship between photos presented in the book and students explanations.

3- Highlighting the uncertainty and inaccuracy of the typical succession stages.

4- Splitting students into groups of 4 students for each, and start by themselves to answer the respective formative worksheets.

5- Different videos, slides, photos, quick activities and URLs will be used as different sources of information related to the section objectives.

6- Through the lesson, one quick activity is included. Analyzing different photos to model the succession stages.

General safety issues: (all these points are fixed for both lab and class periods).

a) What are the safety concerns with this lesson?

1- Don not use wet hands while operating electrical instruments.

2- Be careful, handle slides carefully, dispose broken slides in a separate pot provided by the teacher.

3- Take care when use Iodine dye, it may spoil hands, clothes and eyes if it is in contact with.

b) Make sure students fully understand the following rules

1- No eating or drinking is permitted at any time in the laboratory. Do not bring food into the laboratory. Do not dispose of food waste in specifically directed to do so in an experiment. Never touch or smell chemicals unless specifically directed to do so in an experiment. Never taste chemicals.

2- No horseplay will be tolerated. Walk – do not run, in the laboratory.

3- Work in the laboratory only during your regularly scheduled class period, unless directed otherwise by your laboratory instructor.

4- Never work alone in a chemical laboratory.

5- Keep coats, books, and other belongings on the racks provided in the laboratory. Do not place them on the laboratory bench (and do not bring library materials into the laboratory where they may be damaged). Keep aisles free of obstructions؛ pay particular attention to drawers, cabinet doors and seats in this respect.

6- Before using any reagent or waste bottle, read the label carefully to make certain you have the correct substance .Never rely on the shape, size or color of the bottle – READ THE LABEL.

7- Teacher observance of potentially hazardous behavior will be documented the teacher‘s lab journal.

Instruction:

Instruction will base on the guided-inquiry strategy. The instructor will encourage students to think of creative and insightful ideas to answer posed questions. The start point should be as short warming up critical thinking question(s) with directed discussion. After that, students will form sets and 4 students in each. Each student should take his formative worksheet within the group. A group announcer will be assigned. Lesson objectives will be tackled through the formative worksheet activities. Each group will encounter each activity and at the end announce its answers under teacher supervision and scaffold. Although it is a group work, the teacher may chose randomly a student to explain his own participation. The teacher will round among group to assure all students participation. Discussion among groups is allowed under teacher control. At the end of each activity each group will announce its answers. Groups will share their answers also, and finally right answers will be highlighted. Unless that, the teacher will intervene to correct students path.

Questions:

Refer to the related formative and summative worksheets.

Motivational opening/ Engagement:

1- Each group will report their findings for each activity in an encouraging and competitive environment.

2- Each group will be encouraged to properly use different sources of information.

3- Each group will be encouraged to model results on a group sheet.

Development activity/Exploration:

1- What are the aims of the lesson?

2- What is the main difference between the two types of succession?

3- Comparing pioneer species to climax community properties.

4- Arrange and explain succession stages.

Explanation results:

1- Justifying results critically and scientifically relying on the prior knowledge.

2- Explaining succession complexities.

Closing/ Transfer/ Elaboration:

1- Highlighting the main concept of the chapter, the interconnectedness.

2- Connecting final findings with the lesson objectives.

3- Pinpoint the self-learning, critical thinking and problem solving techniques in learning biology.

4- Highlighting the stages of the two types of succession, with reference to both pioneer species and climax community properties.

5- Role of succession in the sequential replacing and organizing for types of organisms.

Assessment/Evaluation:

1- Reporting results.

2- Modeling results.

3- Formative work sheets will be provided to each group and followed by the teacher and then turned in for group grade.

4- Individual summative worksheets will be distributed to students and evaluated.

Appendix G: Formative worksheets

United Arab Emirates	**Chapter 7\ Bio-community Ecology**	**Subject\ Biology**
Ministry of Education and Youth	**Interactions between Species**	**Class\ Grade 10**
Fujairah Educational Zone	**Predation and Parasitism**	**Name:**

Lesson Objectives: 1- to differentiate between predation and parasitism. 2- to evaluate the importance of mimicry as a mechanism of defense. 3- to describe two defensive mechanisms in plants against herbivorous.

New Concepts: Symbiosis, Predation, Mimicry, secondary compounds, Parasitism, Parasite, Host, Ectoparasites, Endoparasites.

Returning to the picture p. 118, do you think that there is an interconnection between species? Why? What do we call these interconnections between different species?

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After watching the movies presented by the teacher, which is for the Predation and which is for parasitism? Distinguish between predation and parasitism. You may see movies again.

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Have a look to the Figure (7-1) p. 119, what specifications that make Rattlesnake a very good predator?

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Suppose that the Rattlesnake feeds on the two organisms in Figure (7-2), how do you think that these organisms protect themselves? Use the WWW to get information about the colored frog's skin toxicity.

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…………………………………………………………………………………………

What is behind the soldier's uniform and the battle field?

……………………………………………………………………………………….

How do you match between the former question and what the mantis do in Figure (7-2a)?

…………………………………………………………………………………………

What do we call this mechanism? Define it:
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Mention additional examples about mimicry; see your book p. 120.
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<u>Fast activity</u>: Analysis of Predation. We need four different colored ear swaps (red, green, yellow and blue). Throw the sticks on topsoil in the school garden randomly. Ask your friends to pick up the sticks randomly. Which colors were collected more? And which colors were collected less? Interpret your answers
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How can you connect former idea with Predation?
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<u>Fast activity</u>: prepare a concentrated tea drench, allow it to cool and filtrate it. Taste the extract and then answer the questions. Describe the taste of the extract.
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How does the plant get benefit of this material? Consider the herbivorous in your answer.
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Classify Parasites presented in Figure (7-4).
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Write two paragraph reports about colors of both the king and the coral snakes.

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Lesson Objectives: 1- to explain how competition affects the ecology of bio-community. 2- To discriminate between Mutualism and Commensalism. 3- To give examples about former symbiotic relationships.

New Concepts: Competition, Competitive Exclusion, Recourse Partitioning, Mutualism, Pollinators, Commensalism.

Watch the video that represents the competition between Hyenas and Wolfs for different preys. What do we call this interaction between related species? ……………………., state a definition for this term:

………………………………………………………………………………………

Read the first paragraph from the textbook p.122, for what these animals are grappling for?

………………………………………………………………………………………

what is the scientific name of what happened to the excluded group of wolfs?

……………………………………………………………..

By using the WWW, write two paragraphs report about Dr. Robert Mac Arthur experiment on songbirds. http://www.hammiverse.com/lectures/53/1.html.

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Do you think that competition for recourses affects the structure of the Bio-community? Explain how this will happen.

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Fast activity: Examine the different colored flowers presented to you, what is the importance of this coloring?

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Study Figure (7-5) p. 123, flowers and bat, what benefits does the bat get from the flower?

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What benefits does the flower get from the bat? ………………………………………….

What is the type of the interaction between the flower and the bat? ……………………..

Search another example for Mutualism and explain the interaction between organisms.

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We are going to see a small shot about the Cattle egrets and the Cape buffalo, what benefits does the Cape get from the bird? …………………………………………

What benefits does the Cattle egret get from the Cape? …………………………. What do we call this interaction? …………………………………………………… Search another example for former interaction and explain it.

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Lesson Objectives: 1- to explain the difference between species richness and species diversity. 2- to describe how the species richness pattern changes according to different latitudes. 3- to explain at least one hypothesis for this.

New Concepts: Species Richness, Species Diversity, Climate Stabilization.

Read the first paragraph from your textbook p. 124, do you think that number of species in the ecosystem affects the ecosystem stabilization? Explain.

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Define species richness: ……………………………………………………………..

How we can measure this richness? ………………………………………………...

Fast activity: Study the presented Biomes by the data show and people who live in it. What are the most popular organisms in each biome?

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Discuss with your group why that energy resources are highly available near to the equator? And how this may affect species diversity in this region?

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Figure (7-6) p. 125, shows North America continent, study the keys of the map and then connect between the four seasons and the species richness on the map.

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How does sunlight intensity on the equator affect the rate of the photosynthesis?

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Suppose that the closer to the equator the more diversity of species is available, suggest one hypothesis that interprets former assumption, and explain.

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Read the last paragraph in page 124, and compare finding with your hypothesis.

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If there are two islands on the same latitude, do you think that there is a difference in species richness between the islands? Why?

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Suggest other factors that affect species diversity other than latitude position.

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Coordinating with geography teacher, write one paragraph about the climate of equator region.

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Lesson Objectives: 1- to explain the difference between species richness and species diversity. 2- to describe how the species richness pattern changes according to different latitudes. 3- to explain at least one hypothesis for this.

New Concepts: Species Richness, Species Diversity, Climate Stabilization.

Refer to the chart (7-7), what do you conclude of it? ……………………………………
……………………………………………………………………………………………

All these islands are mostly on the same equator, what factors may affect species richness among them?

……………………………………………………………………………………………

What do we call the effect of island's area on the species diversity? ……………………..

How do you think that the growing population of the human being will affect the existed species? why

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Use this URL site http://www.hammiverse.com/lectures/53/1.html and read about Robert Paine experiment. Summarize the experiment and its purpose as well as the conclusion.

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Use your textbook to read the last paragraph in page 126, what is the other premise that supports stability of the bio-community in addition to the competition?

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What evidence do scientists rely on in interpreting former premise?

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Lesson Objectives: 1- to define the Succession. 2- to distinguish between primary and secondary succession. 3- to describe the succession that happened in Glacier Gulf.

New Concepts: Succession, Primary Succession, Secondary Succession, Pioneer species, Glacier Gulf.

Use this URL site: http://www.biology-online.org/dictionary/Succession to know about succession concept and compare your findings with what is written in your textbook page 127, second paragraph.

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After reading about the primary and secondary succession, what is the difference between the two concepts?

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Provide examples about each type of succession.

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Create a table that organizes the characteristics of pioneer species, discuss these features with your group members.

Refer to the photos in your textbook page 128 about the primary succession in glacier gulf; arrange these photos in respect to the stages in the last paragraph p. 128.

1-

2-

3-

4-

5-

At which stage the pioneer species was the dominant? ………………………………

Do you think that there are regions in your country that succession may take place on it?

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<u>Lesson Objectives</u>: 1- to explain specifications of the secondary succession. 2- to give examples about secondary succession. 3- to clarify the succession complexities.

<u>New Concepts</u>: Climax Community, Succession Complexities.

Depending on what is written in your textbook page 129, describe the events that characterize the secondary succession according to the photos attached in figure (7- 10).
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What is the name of the species that dominates in the final stages of succession?
…………………………………………………………………………………………………
How much former community is stable?
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Describe the transitional stages throughout the succession.
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…………………………………………………………………………………………………
…………………………………………………………………………………….. Do you think that succession stages occur as simple as described in the book/ discuss this with your group? ……………………………………………………………………………...
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Now, can you describe succession as a simple or complex process? Why?
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Create a table that differentiate between pioneer species and climax species characteristics.

<u>Quick activity</u>: cooperatively with your group members, arrange the provided photos for different succession stages and illustrate reasons behind your answer.

Appendix H: Summative worksheets

United Arab Emirates	**Chapter 7\ Bio-community Ecology**	**Subject\ Biology**
Ministry of Education and Youth	**Interactions between Species**	**Class\ Grade 10**
Fujairah Educational Zone	**Summative worksheet**	**Name:**

Concept revision: explain the relationship between the meanings of the two concepts:

1- Predator and Prey:

2- Herbivorous and Secondary compound:

3- Parasite and Host:

Multiple choices: choose the correct answer:

1- One of the provided sentences is considered as a mechanism of defense against predators

------ a) Peaceful species resembles harmful one.

------ b) Two similar peaceful species.

------ c) One species resembles inedible body.

------ d) An individual uses stark colors to warn other individuals of a particular risk.

2- One of the differences between predators and parasites is that parasites

------ a) Are always micro-organisms.

------ b) Eating only what is inside hosts.

------ c) Usually do not cause quick death to the hosts.

------ d) Are not anatomically and functionally prepared.

3- The symbiosis between two species, that only one species gets benefit while the other does not affect

------ a) Mutualism.

------ b) Commensalism.

------ c) Parasitism

------ d) Competition

Short answers: Answer the questions:

1- What benefits do plants get from secondary compounds?

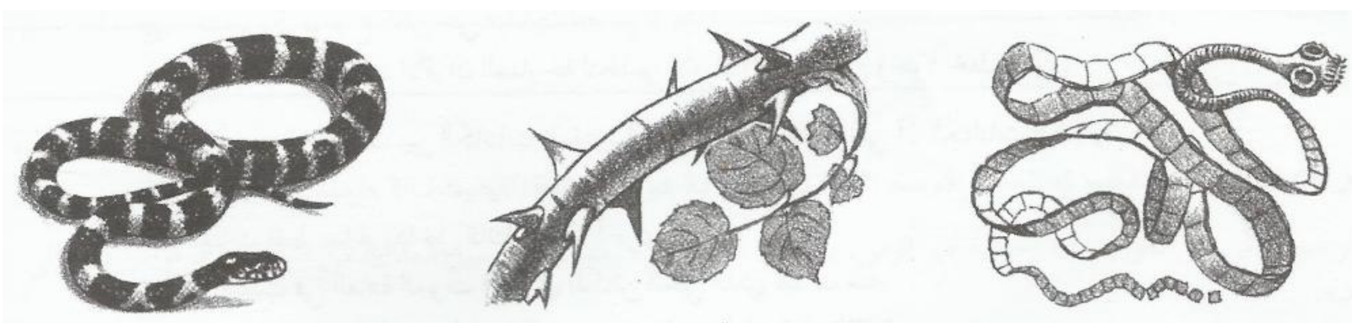
2- What benefits does human being get from secondary compounds?

3- What is the difference between endoparasites and ectoparasites?

Critical thinking: clown fish which is small, sea and tropical fish lives in between tentacles of coral. What kind of symbiotic relationship that is between these animals if coral provides protection for clown fish; at a time which coral does not get anything.

Structure and function: give each sketch an appropriate name choosing from the list

(Pollinator**, Body defense, Secondary compound, Endoparasites, Ectoparasites, Mimicry**).



King snake ……………….. Thorns …………… Tapeworms………………

Butterfly ………………… Dear tick ………………… Poison Ivy ……

Concept revision: Define the given concepts:

1- Species Richness:

2- Species Diversity:

3- Species-area Effect:

Multiple choices: choose the correct answer:

1- The community with high species richness contains

------ a) High numbers of different species.

------ b) High numbers of individuals of each available species.

------ c) A few species, where some of the individual control the majority of the resources.

------ d) Species that are economically valuable.

2- The measurement tool that connect between number of species and richness of each species

------ a) Species richness

------ b) Species diversity

------ c) Community stability

------ d) Interaction between species

3- species-area effect is clearly noticeable in

------ a) Deserts

------ b) Forests

------ c) Islands

------ d) Savanna

4- One of the interpretations about the effect of equator on species richness comparing with temperate grasslands is:

------ a) The habitats near to the equator are newer than habitats in temperate grasslands.

------ b) The available energy in the equator can sustain bigger numbers of organisms.

------ c) Human grows different species of plants for long time in equator regions.

------ d) The climate is more stable in the temperate grasslands.

5- Bio-communities with larger species richness are more stable because:

------ a) The impacts of disturbance are not separated.

------ b) There in no predators that disturb the stable of the community.

------ c) Of a small number of interactions between species.

------ d) Of a large number of connections between species.

Short answers: Answer the questions:

1- The given table shows number of individuals of each species in two bio-communities.

No. of individuals				
	Species W	Species X	Species Y	Species Z
Community A	0	25	10	15
Community B	100	0	175	300

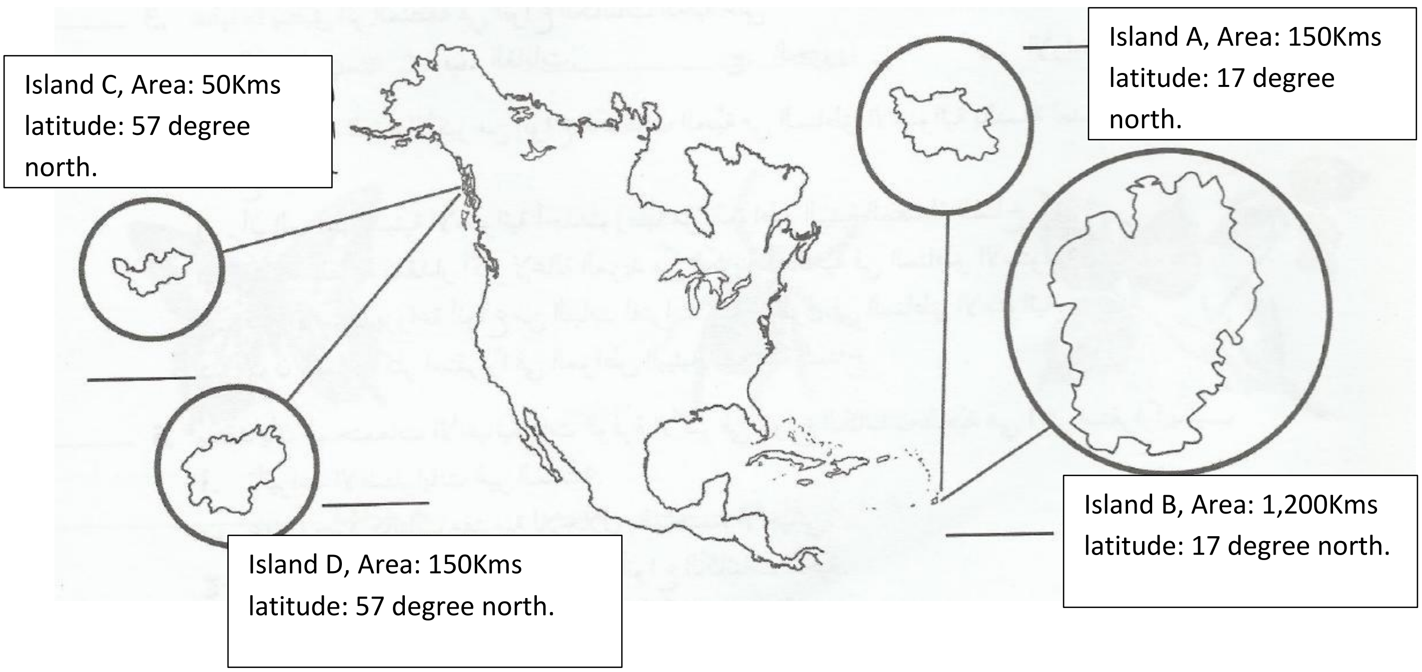
Which community has the largest species richness, explain?

2- How does species richness change according to the latitudes?

3- Why agricultural fields are mostly less stability than natural fields at the same region?

Critical thinking: massive efforts are put on the ground to re-enter the wolfs to the areas that have been removed from it by human activities, explain how does this process affect species richness at these areas?

Structure and function: the given map shows four supposed islands A, B, C, D. order islands from 1 to 4 according to the species richness you expect, 1 is the biggest and 4 is the least.



Concept revision: distinguish between the meanings of the two concepts:

1- Primary succession, secondary succession.

2- Pioneer species, Climax species.

Multiple choices: choose the correct answer:

1- Succession is:

------ a) Alternative word to: blaze, landslide, cyclone, flood.

------ b) Separation a part from the biological community to form a new community.

------ c) Remove the whole ecosystem.

------ d) The serial and gradual change to a species in a particular region.

2- Primary succession may occur:

------ a) In a forest within an area which its trees have been removed.

------ b) In an island which has reformed after volcanic eruption.

------ c) In a neglected farm.

------ d) In a land occupied by a new building.

3- the species that dominate at the first stages in developing a biological community called:

------ a) Pioneer species.

------ b) Climax species

------ c) Dominant species.

------ d) Successive species.

4- The final stabilized point in succession called:

------ a) Stages species.

------ b) Climax species.

------ c) Climate change.

------ d) Biological community development.

Short answers: Answer the questions:

1- Why does the primary succession happen in a very slow rate?

2- Describe two processes of changing naked rocks into soil.

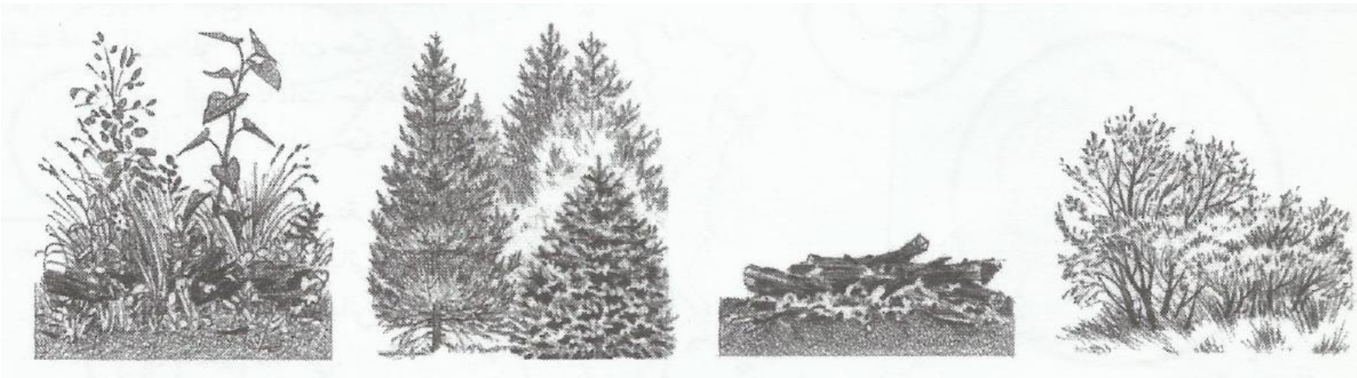
3- Name five events that launch secondary succession.

4- Call three factors that affect the course of the secondary succession in a particular region.

5- What are the characterizations of the pioneer species?

Critical thinking: Volcanic eruption leads to remove the entire plant life of a valley located at the bottom of the volcano. Explain why succession is likely to happen following the volcanic eruption faster on the bottom land of the valley than on the steep slopes of the margins of the valley.

Structure and function: The given pictures are four stages of the succession after a forest blaze. Order pictures appropriately, make No. 1 for the first stage.



Harmful grasses and weeds	Pine trees	Burned wood and aches	Pushes
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Appendix I: Biology Science Guided-Inquiry Lab.

Nitrogen Fixing Bacteria and Root Nodules

ODE Benchmarks	**Name**: Ahmad Sharif Hasan **School Name**: Anas Bin Al-Nader School **Classroom Number**: 1, 2. **Lesson title**: Nitrogen Fixing Bacteria and Root Nodules **Subject Area**: Biology/ Ecology **Grade level**: 10th Grade **Time Allocation**: 50 Minutes **Grouping**: 4 Students **Instructional Planning**: The students will be split into small groups of 4 students. The students will be encouraged to design an experiment by themselves and search for data by using the WWW in order to answer the posed questions. Each group should report and model its results while teacher monitoring and facilitating groups' works. Finally, the students will be assessed by answering the formative and summative worksheets. **Learner Analysis**: 1- To examine root nodules on leguminous plants. 2- To seek the differences between a leguminous plant (beans) and non-leguminous plant (radish). 3- To notice an active culture of Rhizobium.

Objectives:

1- The students will be able to (TSWBAT) examine root nodules on leguminous plants.

2- (TSWBAT) seek the differences between a leguminous plant (beans) and non-leguminous plant (radish) in regard of mutualism.

3- (TSWBAT) notice an active culture of Rhizobium.

Skills included in this lesson:

Determining environmental interaction, Hypothesizing, Comparing.

Prior Knowledge:

Defining of Mutualism and giving examples about it.

Leguminous plants need nitrogen in a shape of NH3 or NO3 as fertilizers; however Rhizobium bacteria need carbohydrates as a source of energy. A relationship between Leguminous plants and Rhizobium may be established in order to achieve these purposes.

You may use internet to read about the Rhizobium and its relationship with Leguminous plants. The structure of the root nodules. The natural presence of the bacteria. Type of plants that bacteria can infect and the difference between green and red nodules on the root. Green nodules are active in cell division but not in nitrogen fixation, while red ones are functional in nitrogen fixation but not in cell division.

Model of instruction/instructional strategies:

1- Lesson is introduced by asking questions about mutualism as a symbiotic relationship.

2- Introducing the nature of the relationship between leguminous plants and Rhizobium.

3- Students are introduced to use materials and instruments to investigate the questions under guided inquiry approach as groups.

3- Results are presented after each part of the experiment.

Materials:

Lab coats, protective eye glasses, light microscopes, forceps, slides and cover slides, Pots for growing plants, prepared slide of infected nodules with Rhizobium, 3D microscopes, Beans seeds, Radish seeds, Scalpels, Rhizobium broth.

Procedures:

a) Cultivation the investigated plants

1- Grow two separate plants one that is able to establish a symbiotic relationship with Rhizobium and another is not. Use available materials on the table and be aware that implants need maintenance and caring.

2- Many pots will be prepared by the supervisor because of time constraint.

b) Examining bean root:-

1- Remove gently the bean plant from the pot and clean carefully clean the root from the soil residues. By your naked eyes, test the root and write down observations in the specified table.

2- Take off one pink nodule and another green one, use the scalpel to make a section in each nodule and notice it under the 3D microscope. Draw the seen at the specified place on the sheet.

c) Examining radish root:-

1- Remove gently the radish plant from the pot and clean carefully clean the root from the soil residues. By your naked eyes, test the root and write down observations in the specified table and then draw a sketch for radish root.

d) Preparing wet mount slides to the Rhizobium:-

1- Remove and clean one nodule from the bean root. Put the nodule on a clean slide in drop water. Cover the nodule with a cover slide and by your fingers press the cover down until you mash the nodule.

2- Use the light microscope to examine cells that contain the Rhizobium.

3- Describe the arrangements of the bacteria in the cells, and then distinguish functionally between the pink and green nodules.

4- Draw what you see on the microscope.

Safety issues:

a) What are the safety concerns with this lesson?

1- Don not use wet hands while operating electrical instruments.

2- Be careful, handle slides carefully, dispose broken slides in a separate pot provided by the teacher.

3- Take care when use Iodine dye, it may spoil hands, clothes and eyes if it is in contact with.

b) Make sure students fully understand the following rules

1- No eating or drinking is permitted at any time in the laboratory. Do not bring food into the laboratory. Do not dispose of food waste in specifically directed to do so in an experiment. Never touch or smell chemicals unless specifically directed to do so in an experiment. Never taste chemicals.

2- No horseplay will be tolerated. Walk – do not run, in the laboratory.

3- Work in the laboratory only during your regularly scheduled class period, unless directed otherwise by your laboratory instructor.

4- Never work alone in a chemical laboratory.

5- Keep coats, books, and other belongings on the racks provided in the laboratory. Do not place them on the laboratory bench (and do not bring library materials into the laboratory where they may be damaged). Keep aisles free of obstructions؛ pay particular attention to drawers, cabinet doors and seats in this respect.

6- Before using any reagent or waste bottle, read the label carefully to make certain you have the correct substance .Never rely on the shape, size or color of the bottle – READ THE LABEL.

7- Teacher observance of potentially hazardous behavior will be documented the teacher‘s lab journal.

Instruction:

Instruction will base on guided-inquiry strategies. The instructor will encourage students to think of creative and insightful ideas to answer posed questions.

Questions:

1- Which plant is able to make a mutualism symbiotic interaction with Rhizobium, Beans or Radish?

2- How bean's root does differ from radish's root?

3- What are the differences between pink and green nodules?

4- Describe the function of the bacteria inside a fresh green nodule and a fresh pink nodule.

5- What is the pink color from and what is its function?

Motivational opening/ Engagement:

1- Each group will report the differences and similarities between bean and radish roots by writing and drawing differences and roots consequently.

2- Each group will be encouraged to properly use microscopes and slide preparation.

3- Each group will be encouraged to report answers on a group sheet.

Development activity/Exploration:

1- What are the aims of this activity?

2- Why do we specify these two types of plants?

3- What do we infer from the observations in table No. 1 and No. 2?

Explanation results:

Justifying results critically and scientifically relying on the prior knowledge.

Closing/ Transfer/ Elaboration:

Why these differences between plants, the differences between the green and pink nodules? What is the aim of this symbiotic interaction between bean's root and the Rhizobium?

Assessment/Evaluation:

1- Reporting results.

2- Modeling results.

3- Formative work sheets will be provided to each group and followed by the teacher and then turned in for group grade.

4- Individual summative worksheets will be distributed to students and evaluated.

Main concepts: Interactions between Species & Mutualism in Nitrogen fixing Process. Lesson Objectives: 1- To examine root nodules on leguminous plants. 2- To seek the differences between a leguminous plant (beans) and non-leguminous plant (radish). 3- To notice an active culture of Rhizobium.

New Concepts: Symbiosis, Mutualism, Rhizobium, Root Nodules.

Skills Included in this Lesson: Determining environmental interaction, Hypothesizing, Comparing.

Use your textbook to revise theoretical knowledge. Define the term 'Mutualism'.

……………………………………………………………………………………..

Give three examples about Mutualism:

……………………………………………...…………………………………………
………………………………………………………………………………...

Leguminous plants need nitrogen in a shape of NH_3 or NO_3 as fertilizers; however Rhizobium bacteria need carbohydrates as a source of energy. A relationship between Leguminous plants and Rhizobium may be established in order to achieve these purposes.

You may use internet to read about the Rhizobium and its relationship with Leguminous plants. The structure of the root nodules. The natural presence of the bacteria. Type of plants that bacteria can infect and the difference between green and red nodules on the root. Green nodules are active in cell division but not in nitrogen fixation, while red ones are functional in nitrogen fixation but not in cell division.

Guided inquiry questions:-

1- Which plant is able to make a mutualism symbiotic interaction with Rhizobium, Beans or Radish?

2- How bean's root does differ from radish's root?

3- What are the differences between pink and green nodules?

4- Describe the function of the bacteria inside a fresh green nodule and a fresh pink nodule.

5- What is the pink color from and what is its function?

Part A: growing the experimental plants

Use materials available in the biology lab in order to grow two types of plants, one that is able to establish a relationship with the bacteria and one that is not. Take care of your plants until the date of the lab. Register your notes about the growing plants, which is faster in growing and which is bigger in size?

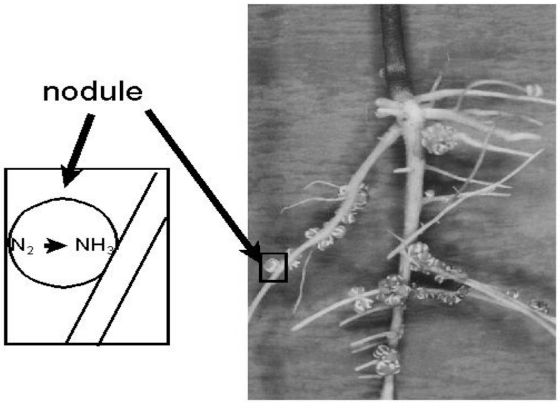
Type of plant	Notes
Beans	
Radish	

Part B:- Examining bean's roots

Remove your bean plant gently from the pot and write down your notes in the table below.

Appearance of the bacterial nodes	
Nodules' color	
Number of nodules	
Number of pink nodules	
Number of green nodules	

Take off one green nodule and by a scalpel make a cross section in it. Use the 3D microscope and describe the bacteria inside the nodule. Sketch your findings in the report sheet and name both a bacterial nodule and a bacterial cell.



Part C: - Examining radish's roots

Remove your radish plant gently from the pot and write down your notes below about any nodules were found and then sketch the shape of the root. Name your drawing with Radish word.

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……………………………………………………………………………………………
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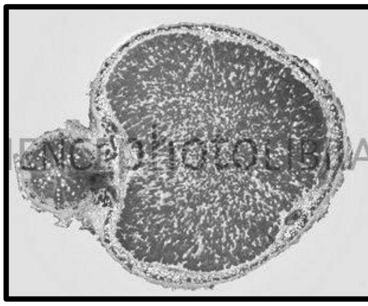
Part D:- preparing a wet mount slide of Rhizobium

As you learned in the first semester about wet mount preparation, mash a fresh nodule on a clean slide and then examine it under the light microscope. Use many power of magnifications and draw a root cell with its bacterial content. Describe bacterial arrangement inside the cell and then compare your findings with the attached standard picture.



Explain the difference between green nodules and pink nodules according to their contents and functions

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…………………………………………………………………………………………
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Summative questions:-

1- Which plant contains the larger number of nodules, bean or radish?

……………………………………………………………………………………

2- How many nodules were found on radish roots? …………………………………..

3- How are Leguminous plants infected with Rhizobium?

………………………………………………………………………………………..

4- What kind of the relationship between leguminous plant and Rhizobium? How do leguminous plants benefit from the bacteria?

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5- If you decided to grow leguminous plants without nodules in order to use it as a control sample, why do you use sterile soil for this purpose?

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Appendix J: Students' photos

Students during guided inquiry group work.

Scanning

Students during NOSS and EBAT pre-tests.

Appendix K: Paired t-tests of both experimental and control groups between pre-post cases in the subscales of NOSS.

Experimental group NOSS subscales	**Results of paired t-tests** t- value	df	P value
1	**2.02**	**37**	**0.015***
2	**0.47**	**37**	**0.64**
3	**0.15**	**37**	**0.88**
4	**0.32**	**37**	**0.75**
5	**0.77**	**37**	**0.44**
6	**2.05**	**37**	**0.046***
Control group NOSS subscales	**Results of paired t-tests** t- value	**df**	**P value**
1	**0**	**39**	**1**
2	**0.35**	**39**	**0.73**
3	**0.08**	**39**	**0.94**
4	**1.57**	**39**	**0.12**
5	**0.2**	**39**	**0.85**
6	**0.66**	**39**	**0.51**

*** Significant at $p < 0.05$**

Table 1. Paired t-tests of both experimental and control groups between pre-post cases in the subscales of NOSS.