The Nature of Science Aspects That High School Students Exhibit During Debating a Controversial Socio-scientific Issue

دراسة جوانب طبيعة العلم التي سيظهرها طلاب الثانوية خلال مناظرة قضية علمية اجتماعية مثيرة للجدل.

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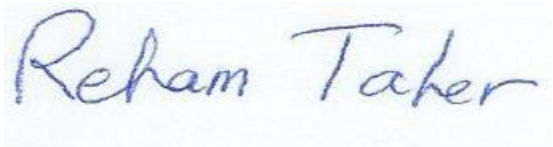

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Abstract

Over the last century, a lot of investigations were done to enhance the students' understanding of the nature of the scientific knowledge, as well as, to have the educators agreed to put the nature of the scientific knowledge at the center of the scientific literacy. Effective scientific literacy development in our students requires linking science to the society, and allowing the students to explore the scientific knowledge while dealing with the challenges of the real world. The purpose of this study is to explore how students comprehend science, especially in its tentative, subjective, and social/cultural embedded nature.

This study was carried on a group of sixty students of twelfth grade, following their debate about a socio scientific issue, in which a qualitative design was used to collect the data. The tools used were open-ended questionnaire, and one-to-one interviews in order to clarify their conceptions about the nature of the scientific knowledge. Results specified that the participants had good understanding of the nature of the scientific knowledge categories intended to be explored; in addition, this study recommended using scientific argumentation of socio- scientific issues as an effective tool in enhancing the students understanding of the nature of science.

Keywords: Nature of science (NOS), Socio- scientific issues (SSI), and Argumentation in science.

الملخص

على مدى القرن الماضي، أجريت الكثير من الابحاث لتعزيز فهم الطالب لطبيعة المعرفة العلمية، وكذلك أجمع المربين علي وضع طبيعة المعرفة العلمية في مركز محو الأمية العلمية. من أجل وصول طلابنا الي محو امية علمية فعالة فيجب ربطها بالمجتمع، وتمكين الطلاب من استكشاف المعرفة العلمية بالتعامل مع تحديات العالم المحيط. والغرض من هذه الدراسة هو استكشاف مدى فهم الطلاب لطبيعة العلم المؤقتة، الذاتية،و تضمنه لمناحي اجتماعية و ثقافية.

وقد أجريت هذه الدراسة على مجموعة تتكون من ستين طالب من الصف الثاني عشر عقب قيامهم بمناظرة قضية اجتماعية علمية ، و قد تم استخدام التصميم النوعي لجمع البيانات. عن طريق الاستبيان المفتوح، و المقابلات الفردية لتوضيح تصوراتهم حول طبيعة المعرفة العلمية . و قد اظهرت نتيجة البحث امتلاك الطلاب المشاركين لفهم جيد لطبيعة فئات المعرفة العلمية المراد استكشافها، كما أوصت الدراسة باستخدام المناظرات المختصة بالقضايا الاجتماعية العلمية كأداة فعالة في تعزيز فهم الطلاب لطبيعة العلم.

الكلمات والعبارات الرئيسية:طبيعة العلم – قضايا اجتماعية علمية – الجدال العلمي.

Dedication

Writing this dissertation was one of the challenges that I have experienced in my life. And without many people's help, I would have never reached this achievement.

A special dedication to my parents , who taught me the importance of hard work and persistence. A special feeling of gratitude to my dear husband Mohamed Abou Khatwa, who supported, and inspired me to be successful and develop my career, as well as, to my lovely children Mariam and Omar; for always trying to make me smile.

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Chapter 1: Introduction

"Effective scientifically literate citizens"; is a desired target that science education aims to reach, and scientific literacy is defined as the ability to go through and evaluate an argumentation based on evidences, and to properly reach conclusions from such arguments (Collins, 1998; Roberts, 2007; Lederman et al., 2013), therefore, raising a scientifically literate generation requires a good understanding of the nature of the scientific knowledge, so as to enable the students to perceive the scientific attitude and the technique of collecting and evaluating evidence in order to reach conclusions. For scientific literacy to be effective, it should be connected to the real world problems especially the controversial ones. Debating in science is an effective instructional strategy to enhance the understanding of NOS aspects, because it relies on the students arguing a topic in science, using in this argumentation skills like searching for reliable and valid evidences and reasoning of those evidences to refute each other (Walker et.al, 2000). In addition, counter argumentation of a socio- scientific issue, (in which debating is an example of), proved to make high school students acquire better understanding of the nature of science aspects such as: subjectivity, tentativeness, and empiricism in the study by Khishfe, 2012.

But this study focuses on subjectivity, tentativeness, and social and cultural embeddedness, as it is carried in the UAE where the social and cultural contexts are important factors.

The importance of this study is based on the different context it offers, which is being carried on Arab students in Arab country as UAE, which emphasizes the role of social and cultural dimensions of such society.

1.1 Nature of science aspects

The nature of the scientific knowledge can be referred to as the epistemology of science, as a way of knowing, or sometimes to the set of values and beliefs associated with the development of the scientific knowledge (Lederman, 1992). Hence, students should be introduced to the NOS aspects and be trained to use them effectively as a way of promoting their scientific literacy. Effective scientific literacy involves relating the scientific knowledge taught to the students with their daily life issues, and on a wider scale to prepare them to be able to take proper decisions in issues related to human life, technology and environment (Driver et al. 1996).

Many attempts have been done by science educators through the previous decades to list or specify some aspects of the scientific knowledge such as the scientific knowledge being tentative (not constant, can always change), empirically based (depends on observation from the natural world), subjective (must reflect human beliefs and conceptions), socially and culturally embedded (affected by the scientist culture and responds to his/ hers society), plus many other aspects that educators and philosophers are still arguing about (Lederman et al., 2013). These many categories of the scientific knowledge indicates that science is a comprehensive enterprise, in fact some science educators use the term NOS to represent the interdisciplinary structure that illustrates what is science really about, and how it works (Forawi, 2011).

Some studies suggested putting the scientific knowledge into two categories: the first category is distal knowledge which represents the formal scientific knowledge that the students understand while, the second category is the proximal knowledge that relates to the students' perceptions of their own beliefs about science and this category can be reached through practicing science. In other words dealing with scientific issues that require more than recalling the distal knowledge, will additionally require the students reflecting their own beliefs and views about science (Hogan, 2000).

The importance of teaching and learning the nature of science comes from many reasons such as making our students appreciate science and become more interested in science, have clearer image about science strengths and limitations and more important comprehend the role of science in decision making in many of the environmental and societal issues (Matthews, 1994; McComas et al., 1998 and Clough, 2011). National science and teachers association assured the necessity of having an accurate and common view of the nature of science by those who are involved in science teaching and learning (NSTA's position statement, 2000). Understanding the nature of scientific knowledge should be our aim in science education because those NOS views, whether accurate or not, will play a key role when our citizens will judge public issues that involve science and technology (Shamos, 1995). In an interesting study, (Rudolph, 2007) claims that some business and political groups take advantage of the public's misconceptions about doing science to create suspicion about issues such as global warming, biological evolution and other controversial issues which anticipate the necessity of teaching the NOS in all science courses in accurate and effective way, and not only restrict science as adds-on when time permits.

Furthermore, there is a very important view of the NOS, as it also includes the individuals' understanding of how the scientific knowledge is developed, from where it originates, who utilizes this scientific knowledge, and how the individuals consider themselves; as producers or users of science (Walls, 2012). This view goes along with the importance of considering scientists as a social group that affects and is affected by the surrounding community.
Finally, when talking about the 21st century skills, which we aim our students to acquire, we'll come to an understanding that they should conceive the nature of the scientific knowledge in its many aspects. As a matter of fact, NOS is a rich hybrid area that includes many dimensions such as: history, sociology, and the philosophy of science, to enable us to compose a picture of how scientists, as a social group, work, and how the surrounding society reacts to the scientific endeavors (MCCOMAS, 2004).

1.2 Socio- scientific issues in science teaching and learning

According to Sadler (2004), we can define Socio- scientific Issues (SSI) as issues that come from connecting science and society, such as genetic cloning, human genome, global warming, alternative fuels and stem cell (Sadler, 2004). These issues that are present in our daily lives usually involve argumentation or dilemmas (Kolstø, 2001a). Consequently, our views of teaching science should involve moral and ethical issues and emotional aspects which can be called teaching socially-relevant science (Sadler et al. 2010). Since enhancing scientific literacy, which includes having the scientific knowledge plus the ability to use it to take formal decisions regarding a controversial societal issue, is a basic goal of effective science education then socio-scientific issues should be integrated in this process (Sadler and Zeidler 2005a). To add to the relation of socio-scientific issues with effective scientific literacy, we must pay attention to the fact that many students are interested in science but when it comes to learning science in school, they find it difficult and irrelevant to the outside world (Lindahl, 2003; Lyons, 2006; Osborne et al. 2003). In a study by Ottander and Ekborg on the Swedish science education and based on ROSE project, it was found that students feel that the science content is set which leaves nothing to be discussed so there grow a gap between what students are really interested in and what they are taught in school science, so Ottander and Ekborg mentioned the importance of introducing new strategies for teaching science in schools that relate the taught science with the outside world and they suggested working with socioscientific issues as a new strategy that will enable

the students to use science in the outside world (Ottander & Ekborg, 2012). In a study by (Grace and Ratcliffe, 2003), which described the characteristics of socio-scientific issues such as being important for the society, address local or global dimensions, include poltical and societal framework, involve values and ethical values, require the understanding of risks and probabilities and finally no particularly "right" or "wrong" answers, as well as socioscientific issues strengthen the 21st century skills such as communication, collaboration, critical thinking and creativity. Argumentation and descision making are well established in dealing with socio-scientific issues especially the controversial ones, plus challenging their rational, social and emotional skills (Sadler, 2004). My research identifies that socio-scientific issues are a useful approach to learn and understand the nature of science and promote citizenship education (Sadler et al.2007).

Engaging the students in informal resoning and argumentation as well as their understanding the aspects of scientific knowledge are important in discussing socioscientific issues as discussed in the study by (*Fowler* et al., 2009) which reached a conclusion that using the context of socioscientific issues while teaching science promoted the students moral sensitivity and therefore promoted their overall moral development.

1.3 Debating in science education

Debating is a method of structured argumentation. It includes some aspects such as factual accuracy, logical consistency and emotional appeal and by presenting a better framework or context, one side may prevail the other. As a consequence, scientific debates can be described as a method through which a topic with some scientific context is being argued using accurate selection of facts, logical thinking and revealing personal emotions.

Interest in argumentation, such as debates, has increased clearly in science education in the past few years (Bottcher & Meisert, 2010). This is mostly because argumentation is having a great impact on science education as described by Aleixandre and Erduran, as it allows the access to cognitive and meta- cognitive processes through modeling for the students, encouraging the development of communicative and critical thinking skills, encouraging the students to talk and write the language of science, developing reasoning especially that based on rational criteria, and finally promising the achievement of scientific literacy (Jimine´z-Aleixandre and Erduran, 2008). (Sadler, 2006)stressed on the importance of argumentation in science education especially on a

socio- cultural issue, as it has an important role in scientific communities, maybe because scientific debating is a very important method that enables the students to act like scientists in their scientific behavior, as it includes finding evidences, practicing critical thinking skills, making assumptions and inferring outcomes when related to a socio-scientific issues (Zeidler, 1997). Also student- centered learning which is a demand of educators in the 21st century can be accomplished by using scientific debating, because it enhances the pedagogical learning of science. Moreover, the skills that debating offers for the students, are required by many work fields nowadays (Kane & Wolfskill, 2013). Apparently, not only the pedagogical content of the students is enhanced, but also debating can improve their self discipline, motivation to learn science and teach them to take responsibilty (Maija & Samusevica, 2014). Also, the recent framework of (NRC, 2012) and (NGSS lead states, 2013) recognized argumentation as an essential practice to science learning and as well central to the scientist's intellectual activities (Falk & Broadsky, 2013).

We can even use scientific debating as a scientific inquiry approach, as debating generates a convincing and persuasive argument that aligns theories and evidences to support or oppose a claim (Samson & Clark, 2008), taking in consideration that debating in science includes the epistemological criteria in science, for example, the importance of providing evidential backing of knowledge claims (Hogan & Magelienti, 2001), linking the theoretical framework with the observations, establishing credible evidences (Driver et al. 2000), and introducing arguments based on reasoning (Zeidler,1997). The misconception that scientific inquiry is linked only to practical work has been mentioned in many studies (Newton et al. 1999; Berry et al. 1999; Edmondson & Novak, 1993). In 2003, a survey was conducted about the Korean middle school science textbooks which revealed that only 3% of the practical work helped the students to learn how to use data to support conclusion (Kim et al. 2003). This is because in most science inquires the focus in on doing rather than thinking or discussing, which limits our students' ability to look at scientific inquiry from a wider angle, as scientific data does not have to be only collected from practical experiment, but scientific data can come also from scientific research that aims building strong evidences such as argumentation, as practical inquires that do not require discussing science can lead to serious outcomes (Heekyong & Jinwoong, 2006).

Science and ethics are two important disciplines that can merge through socio-scientific issues that can be put into action by debating and argumentation, this kind of merge is having a very

strong impact on our society and should be included in the science curriculum in order to achieve science humanistic goals (Saxena & Behari, 2016).

1.4 Background of the Research

Seeking effective citizens who can face the challenges of the 21st century with its many controversial issues, requires different approaches of providing scientific knowledge. Science should be taught in its multiple aspects such as the nature of scientific knowledge and the behavior of a scientist. Thus debating on a controversial socio-scientific issue is one of these approaches that offers science learning in a different way, a way that will allow the students to practice the 21st century skills which are: critical thinking, communication, collaboration and creativity.

Socio-scientific issues, especially the controversial ones, are a very powerful link to connect the aspects of the scientific knowledge with our daily life and hence promote scientific literacy, (Sadler et al. 2004) stated that connecting NOS and socio-scientific issues is an interpretation of scientific literacy, additionally, this study also emphasized that if students are able to use their thinking skills about personal and social issues scientifically, then they are using their understanding of the nature of scientific knowledge to solve a socio-scientific issue. Based on this, comprehending NOS aspects needs debating socio- scientific issues as one of them will ultimately lead to the other, as debating a socio-scientific issue will involve collecting and comprehending scientific data related to the issue, analyzing this data, being exposed to the ethical and moral aspects of the issue and supporting one point of view (Sadler et al., 2004), this is simply a practice of the aspects of scientific knowledge such as science being tentative, socially, and culturally embedded and subjective. In other words debating a controversial socio-scientific issue such as the embryonic stem cells research will allow the students to show how they understand the nature of scientific knowledge. Also incorporating the students in peer argumentation related to socio scientific issues, such as the case discussed in this study, can make the students look at the issue from different angles, not only the consequential one, for example, the ethical consideration and the human rights (Berne, 2014). Furthermore integrating socio scientific issues in science classrooms can significantly improve the students' interactions and argumentation skills by making them more deep and detailed (Gutierez, 2015).

So in this current study, the high school biology students underwent an experience of debating each others on a socially and ethically controversial issue, which is continuing the research on embryonic stem cells with all the hustle going around it, as supporting its importance of saving many lives, or banning it for its doubtful effectiveness and unethical source of obtaining the embryonic stem cells. Following the debate, an open ended questionnaire and students' interviews were used to investigate what aspects of the scientific knowledge did the students show during their debating activity especially tentativeness, social embeddedness and subjectivity. The focus on these three NOS aspects comes from the researcher point of view that based on the nature of the debate topic, these NOS aspects should appear during the students argumentation.

1.5 Statement of the Problem

Most countries are calling for educating students to become effective citizens, and hence have the scientific literacy that enables them to judge their actions and the world around them. One of the countries that is so keen on promoting scientific literacy is UAE, as his Highness Sheikh Zayed Bin Sultan Al Nahyan, president of the UAE (1971-2004) stated that "The wealth of any nation is its intellectuals, and the progress of people and nations is judged by the level and extent of education they reach.", as well as UAE stresses on the importance of having a high rank in scientific literacy among similar group of high performing countries and economies in which UAE was successful to achieve the 44th position in PISA test of scientific literacy, (Fig.1), preceding other Arab countries such as Jordan, Tunisia and Qatar (media report- PISA 2012).

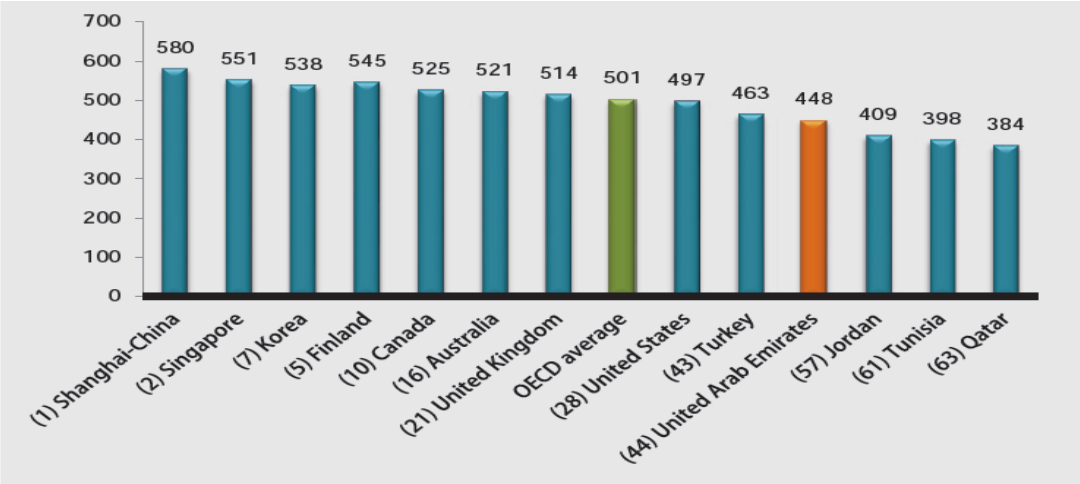

Figure 1: A global comparison of average scientific literacy - PISA 2012

The problem is that, many schools continue to rely on the traditional teaching methods that are based on lecturing and memorizing of learning the scientific content, obscuring the students' vision of the other faces of science, and minimizing the students' area to show their conceptions about science. This will creat a gap between what they really learn in their science classes, and the market needs. In the attempt to narrow this gap UAE Comission on Academic Accreditation launched in 2012 "The Emirates Qualifications Framework Handbook" (QF, 2012). This QF drew five strands framework to recognize learning outcome statements for ten qualifications, the five strands being: knowledge, skill, autonomy, responsibility and role in the context of the society, the QF stresses on the transformation from traditional learning settings to effective modern learning environment (Al-Hadithy, 2015).

Coping with the UAE target in improving the quality of education so as to meet the societal needs which has to involve enhancing the students' scientific literacy, we as teachers and educators must help the students express their understanding of scientific knowledge, even if in implicit way, by giving them the chance to practice the aspects of scientific knowledge through different ways, one of which is introduced in this study, which is debating a controversial socio-scientific issue such as embryonic stem cells research.

1.6 Purpose and Questions of the Study

The main purpose of this study is to explore which aspects of the nature of scientific knowledge that high school students demonstrate during debating a controversial socio-scientific issue, embryonic stem cell research. The study takes place in an American international school in the UAE where 60 students of 12^{th} grade are observed during debating the mentioned topic, in addition an open ended questionnaire. There were also, the students' interviews that are given to them to clarify their understanding of the NOS aspects investigated (science is tentative, subjective and socially/ culturally embedded). Clarifying the students understanding of the NOS aspects is important as NOS is an important part of science education and should be taken seriously (Clough, 2011).

This study is conducted to answer the following questions:

1- Which NOS aspects from those intended to be investigated (subjectivity, tentativeness and social/ cultural embeddedness) will the students demonstrate while carrying out a socio scientific debate?

2- If any of the investigated aspects will not appear, what is the reason behind that?

Inspired by the great case study carried by (Sadler, Zeidler and Chambers, 2004), "Students conceptualization of the nature of science in response to a socio-scientific issue", which investigated students' conceptualizations of the nature of science (NOS) aspects such as empiricism, tentativeness, and social embeddedness, through having eighty- four high school students involved in a study carried out by allowing the students to read contradictory reports about global warming followed by answering some questions to measure their understanding of the aspects of scientific knowledge, Sadler found that 80% of the participated students were able to identify data which shows their understanding of empirical aspect of scientific knowledge, students were affected in their responses by the social and cultural effect which affected their judgements. In my study I include science as being subjective due to nature of the topic being used in the debate as it includes many aspects that can touch each student's personal life, since embryonic stem cell research might find the cure to treat many diseases such as cancer, diabetes, cancer, etc.., so the subjectivity in dealing with scientific knowledge might appear in this debate.

1.7 Scope of Work

Based on the writing above, there is a great need of allowing students to comprehend the real aspects of scientific knowledge, to experience the behavior of a scientist, and to raise as effective citizens to their communities and countries. But first we need to clarify their conceptions about scientific knowledge, which might appear during debating a controversial socio-scientific issue in which they will experience the behavior of scientists.

This is intended to be done by looking at the aspects of science from the ones intended to be investigated which will appear while the students carry their debate, as well as, justifying if any will not appear. The debate experience and data collection took two weeks, and was entirely carried out in the school.

The topic of the debate, "embryonic stem cells research", was chosen as an important scientific issue, currently grasping the attention of the society, and has many dimensions that can affect scientific research. What is more, this issue is mentioned in a very brief way in the textbook, which will require the students to extend their learning experience beyond the textbook.

1.8 Structure of the Dissertation

This study consists of five main chapters. This chapter presented the key aspects of the study, which include the main domains involved in the study such as: the nature of scientific knowledge aspects, the importance of introducing the students to controversial socio-scientific issues and the role of argumentation especially debating strategy in promoting the students learning of science.

The second chapter focuses on the literature review that clarifies the conceptual framework in which the study is based on, the importance of nature of scientific knowledge in science education, scientific reasoning and debating, and the nature of science and socio-scientific issues. The third chapter presents the type of methodological approach and methods which are used to collect the data. The fourth chapter will explain all the details that are related to the data analysis and the results, whereas the last chapter, number five, presents the discussion of the main results, conclusions, limitations, and the recommendations.

Chapter 2: Literature Review

The purpose of this study is to investigate which NOS aspects from those intended to be investigated (subjectivity, tentativeness and social/ cultural embeddedness), the high school students will exhibit during their debate on a controversial socio-scientific issue such as embryonic stem cells research. Different points of view will be represented by a literature review that is related to the NOS, socio-scientific issues and debating in science. The literature review includes four key sections; the first one focuses on the conceptual framework, while the second section illustrates the importance of NOS in science education, followed by the third section relating to scientific reasoning and debating. The last section connects socio-scientific issues and nature of scientific knowledge.

2.1 Conceptual Framework

"Students should know that progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments" (American Association for the Advancement of Science 1993: 19), allowing the students to argue and present acquainted opinions on issues related to their society or history and by using science knowledge and technology, which is just consistent with the previous quote. If we offer to our students a controversial societal issue that involves a scientific aspect, and most of them do, we will encourage them to search for the understanding of the issue, process the information related to it, investigate the moral and ethical points of view regarding that issue and finally adopt a position on this issue (Sadler et al. 2004). According to (American Association for the Advancement of Science 1990, National Research Council 1996), both the ability to argue a socio-scientific issue and understanding the nature of scientific knowledge contribute to scientific literacy which is the main goal of science education, so undoubtedly there is an agreement on the importance that students poss a good apprehension of the nature of the scientific knowledge if we are seeking effective scientific literacy. In order to accomplish this we need to investigate what the students' actual conceptions of NOS are, in order to help them improve their understanding (Akerson & Abd-El-Khalick, 2005).

Science, technology and society have been interconnected in science reforms, and the mutual effect between them is certainly proved to have a great impact on scientific literacy, so if

students make the integration between science and society , they will be able to connect science to life and thus be engaged in a meaningful learning practice (McComas, 1996). Socio-scientific issues offer a great opportunity to make such integration, as they trigger the curiosity of the students to search and investigate the topics, as they are relevant to our surrounding society. Moreover, SSI address a very important aspect in science, which is the moral/ethical consideration that is frequently missed in the science classroom instructions.

Researchers have been focusing on assessing how students understand the aspects of NOS for many years (Lederman, 1992), and during these many efforts were used to analyze the students understanding of those aspects using many instruments like the, Science Attitude Questionnaire (Wilson, 1954), the Test on Understanding Science (Klopfer & Cooley, 1961), the Nature of Science Scale (Kimball, 1967), the Nature of Scientific Knowledge Scale (Rubba & Andersen, 1978), and the Views on Science– Technology–Society (Aikenhead & Ryan, 1992). Those instruments limit the access to the details of how students understand NOS aspects (Sadler et al. 2004), using more qualitative methods such as these ones used in the current study will give clearer image of how students comprehend and deal with the science knowledge .

Based on the study by Sadler , Chambers & Zeidler in which they inspected the NOS aspects, such as cultural embeddedness, the meaning and interpretation of data and tentativeness, which high school biology students will exhibit during discussing a controversial socio-scientific issue " global warming" (Sadler et al. 2004). In this study the topic will be different which is "embryonic stem cell research", as this controversial issue offers a good opportunity to encourage students to collect data, interpret it, display cultural influence on the science enterprise, and the inconsistency of some scientific ideas. The aspects of NOS to be examined here are slightly different from those of Sadler's study as per the researcher point of view, subjectivity is added as the topic discussed can reflect how students will perceive that science is coming from scientists who have different ideas, background, personalities so the evidences collected and related by students can show this aspect.

2.2 The importance of NOS in science education

Undoubtedly, the nature of the scientific knowledge has significant importance over the past years and it is strongly recommended to include these aspects in the science classes' instructions

(AAAS, 1993; NSTA, 1962; NSTA, 1990; NRC, 2000), especially when we look at scientific literacy and find that its conceptualization is now "science for all" which indicates that science should be used by all citizens in taking decisions in societal and democratic issues, so educators believe that scientific literacy requires developing an informed understanding of how science is done and how scientist works, in other words students should understand the aspects of scientific knowledge (Tala & Vesterinen, 2015). Also (Norris & Philips,2003) extended the term scientific literacy to include the ability of the individual to distinguish between science and non-science, understanding the application of science, independence in learning science, the ability to think scientifically and use scientific knowledge in problem solving, understanding the nature of science and its relation to the culture, appreciate the tentative nature of science and knowledge of science risks and benefits. By looking to this extension of scientific literacy we'll find how much of it is connected to NOS, and to the ability of the citizens to think about the surrounding community, look for the data independently and make sure of its credibility. This is why we should allow our students to explore scientific issues related to their society independently and reach conclusions based on their understanding of how science work, and by engaging them in arguments such as debating we can explore their conceptions and thus work to enhance or reform them.

In another study by (Driver et al. 1996), it was clarified that the understanding of scientific knowledge will be reflected in everyday life, in understanding of the socio-scientific issues and in the participation of decision making process.

As summarized by many researchers, the nature of the scientific knowledge includes many ideas, such as: science is an attempt to explain natural phenomena, science has impact on technology, models have important role in science, and science is the product of large social and cultural setting. These ideas need to be appreciated by the students in their science learning (Lederman et al. 2002; Clough & Olson, 2008; Sandoval, 2005), but the focus of this study will be on science as being socially and culturally embedded, subjective and tentative. Students will not simply learn such aspects about science if the teacher tell them in class "science is tentative", but would rather help them to understand these aspects by encountering them in everyday life, and connecting them to SSI .

According to (NSTA, 2000) recommendations, twelfth graders should have adequate understanding about science as being tentative, subjective, culturally embedded, creative and

imaginative. These are aspects that the research reforms recommend that our students should not leave school without comprehending them, so perceiving the nature of the scientific knowledge aspects is a necessity if we are planning to establish an effective scientific literacy. As Next Generation Science Standards (NGSS), develop the integration of three aspects of science standards such as: disciplinary core, science and engineering practices, and crosscutting concepts. In Appendix H, NOS was discussed in the engineering, crosscutting aspects, as students should know that science is empirical, tentative, and subjective (Fanning & Adams, 2015).

As it is shown in the previous text, including NOS aspects in the science education is a necessity so as to know how our students think of science and subsequently enable them to acquire the right conceptions about its nature? As discussed by Abd-El-Khalick in his study about NOS and science teaching , he elaborated that in teaching NOS aspects, pedagogical approaches that are student centered, require collaboration and are inquiry based in nature should be given preference (Abd- El- Khalick, 2013), and that is exactly what this study is trying to display , giving more preference to teaching strategies such as debating in science which is student centered, demanding collaboration and is inquiry- based in nature, as the teacher only offers the topic while the students have to search for the data, analyze, observe and reach conclusions. During their debate we can investigate their ideas about NOS and thus help them reform their conceptions.

In (Soyal, 2015) critical review about connecting NOS and argumentation, he concluded that the interaction between NOS and argumentation enhances the comprehension of NOS aspects as he analyzed many studies such as the study by (Yerrick, 2000) who worked on low achieving students by asking them to be engaged in activities that included justified arguments, the data obtained by the end of the study showed improvement of the students' understanding of the NOS aspect "tentativeness". Also the study by (Bell & Linn, 2000) which investigated 172 middle school students argumentations, these students had no explicit NOS instructions but the post test results were taken after the argumentation showed improvement in their understanding of NOS. And by taking a look at the study by (Kenyon & Reiser, 2006) carried on 64 middle school students who participated in inquiry based activity that involved argumentation, where their understanding of NOS was positively sustained.

Based on what is illustrated above, it is concluded that there is a need of an innovative science curriculum that includes, if not based on socio-scientific issues (SSIs), an intervention for a

better understanding of NOS. In the study by (Schalk, 2012), it was suggested that a SSI based curriculum should be developed as it was illustrated that the intervention of SSIs offered a realistic opportunities for the students to reach scientific literacy involving the nature of science, and also it was shown that the participants formal epistemological knowledge of science improved, probably because they realized that the scientific knowledge is never absolute but subject to change.

Another very important factor is the teachers' conceptions of the nature of science, as science teaching is not only delivering knowledge by the teacher through instructions, but also the integration of the nature of the scientific knowledge in these instructions (Nuangchalerm, 2013). So science teachers should have good understanding of the nature of science, as well as, realize how to teach science in their classrooms in a way that illustrates to the students the role that science plays in the societal decisions (Driver and et.al 2000).

2.3 Socio- scientific issues

Socio scientific issue (SSI) can be defined as the social dilemmas, that are linked to science conceptually or technologically. So (SSI) have gained a great attention recently, due to the aim of science educators to link science to the society (Tekin & Yilmaz, 2016). This relationship can be accomplished by encouraging the students to deal with the science based issues going around them and which might shape their future later on (Driver et al., 2000; Kolsto, 2001a).

Socio scientific issues were related to scientific literacy, as they help students in justifying the decisions they made about the environment and wellbeing, which is the aim of scientific literacy. Perhaps the reason behind this lies in the ability of the students to understand the science behind such topics, and thus can make sensible decisions about people health and the challenges to their environment (Rennie, 2005).

Many examples of SSI can be exposed to the students and have a great importance in the world nowadays , such as: global warming and climate change, cloning, genome project, and stem cells (Sadler, 2002).

Socio scientific issues can be an effective pedagogical strategy to enhance the students' communication skills by improving their collaboration with others, stimulate their reasoning,

and spread common social awareness, beside impacting the ability of the students to value others' opinions , and raise their active assertions (Chung et al. 2016).

2.4 Socio-scientific issues and nature of scientific knowledge.

As clarified before that scientific literacy is a societal demand , and as it was also linked to understanding of the nature of science aspects in the text above, it is important now to clarify that students should develop a functional understanding of these aspects, meaning that the students should be able to practice those aspects of NOS when participating in a public discussion about science, science policy and scientific research reasoning. This can be found in socio-scientific issues like: climate change or stem cells research. Most of the studies showed that teachers as well as students do not possess an adequate understanding of NOS, because the understanding the nature of science aspects needs to be developed through relating science to actual societal cases such as socio-scientific issues (Tala & Vesterinen, 2015). But unfortunately even if in our curricula and instructions we incorporate the NOS as a way to reach scientific literacy, ensuring that their understanding of NOS will be used correctly when dealing with societal issues, as students may articulate NOS definition and aspects, but when apply them in real life experience find it challenging, and extremely difficult then we will realize their misconceptions about NOS (Walker & Zeidler, 2003). From this point on introducing the students to socio-scientific issues especially through debating will enable us to monitor their understanding and will enable them to practice their conceptions about NOS.

So in their study Tala and Vesterinen concluded that studying NOS should include investigating real cases and research practices, which can be done by allowing the students to study a case in detail to know about its dimensions then compare how they work upon such cases to the NOS lists of aspects (table.1) . This is similar to the idea used in this study because actually they argue that students learning about NOS should not be dependent only on the teacher giving direct instructions on those aspects or inquiry methods used in the school lab, but should extend outside the school to the society of the students by practicing socio- scientific issues.
So arguing socio-scientific issues will reveal unintentionally the students conceptualization about NOS. In the study conducted by (Zeidler et al.,2002), eighty- two high school students were

presented with some moral dilemmas in which their NOS views about socio-scientific issues were monitored, specifically two aspects of NOS appeared in the argumentation which were 'social / cultural embeddness' and 'empiricism'.

Sadler assured that socio- scientific issues offer a way to investigate the nature of science, connect the students to scientific literacy, and link between science and society movement (Sadler, 2004). This means that SSI will allow us to see how students conceptualize science and enable us to promote this conceptualization and hence promotes the important goal of science education which is furthering effective scientific literacy.

Finally, embryonic stem cells are cells that can divide into any type of cells in the body, and also multiply an unlimited number of times thus called pluripotent cells, being the best type of pluripotent stem cells, the ones taken from the blastocyte stage of embryonic development is used in promising scientific researches (Mandal, 2013). This was the main focus of the controversy raised.

2.5 Debating a socio-scientific issue in science classroom

Scientific debating is said to be using formal argumentation with a person or agroup upon an issue related to science using scientific evidences to convince the audience to take the point of view of one of the two sides. It has many synonyms such as argumentation, controversy and disputation (dictionary.com). Unfortunately, studies had shown that there is a shortage of pedagogical approaches through which students are given the voice (Driver et al. 2000), as most of our teaching strategies depend on the teacher or instructor given the voice. Even if we ask them to be engaged in an inquiry, teachers still will provide the students with the context of work. Arguments such as debating based on evidences are crucial to comprehend how scientists work , therefore our students should learn how to develop reasoning for their claims, and they must justify why they adopted such a claim (Fulton & Poeltler, 2013). In their study Fulton and Polelter came to a conclusion that argumentation promotes the students understanding of scientific content as they carried the experiment on 2nd grade students, and they recommended by the end helping students develop skills for argumentation as it is worthy spending time in it.

Using argumentation strategy , as in debating, in science classrooms can change the traditional view of science class from being a reservoir of scientific facts to an environment that encourage

students input and participation which directly goes along with the demand of having creative student centered classroom (Lave & Wenger, 1991). Argumentation will not only make students learn about science and encourage them to participate is science activities but also change their ideas about science practices, especially when we allow students to explore controversial scientific and societal issues through debating scientific claims(Nuangchalerm, 2010), as the students collect, consider evidences from different points of views, interpret and reach conclusions. Then they understand the nature of science as a dynamic and complex enterprise (AAAS,1990). Investigating controversial scientific issues through debating will enable the students to understand science in its multiple sides (Geddis, 1991).

From the advantages of debating a socio scientific issue, as the one carried in the current study, that the students are allowed to explore the given topic independently, collect data related to it, analyze it, adopt positions and hence develop a better understanding of the topic. This will enhance their content knowledge as they go beyond the information given in the textbook so they have better quality of reasoning. In a study by Sadler, he suggested that the differences in content knowledge are related to variations in the quality of informal reasoning (Sadler & Zeidler, 2005). The intent of using SSI in science education is that it is personally meaningful to the students and it engages them in a process that requires using evidential reasoning, thus creating a proper context for understanding the scientific knowledge (Sadler, 2004a; Zeidler, 2003).

In the study by (Osborne el al., 2004), they concluded that in secondary school, it was difficult to establish a culture of scientific reasoning in science classrooms, so several studies were carried to know how to create such a culture, some concluded that this can be related to the use of argumentation (Furtak, et al. 2008). In this study Furtak used a conceptual model **(Figure.2)** adopted from (Brown et al. 2008) to analyze the classroom discourse for scientific reasoning. The model is composed of three main parts: application, interpretation and analysis. Application refers to the validity of the claim even to be used in simple circumstances, interpretation is the way evidences are compared, integrated and synthesized and finally analysis by which data is grouped, compared and combined. This is all done during debating a controversial socio-scientific issue such as “embryonic stem cell research”, where students will collect the date required to form claims, analyze them, interpret as putting and comparing pieces of evidences together, and finally apply during the discourse of the debate to check its validity. Actually,

Furtak demands having a strong scientific reasoning culture in our science classrooms, that can be made by using scientific debates as it complies to the conceptual model mentioned.

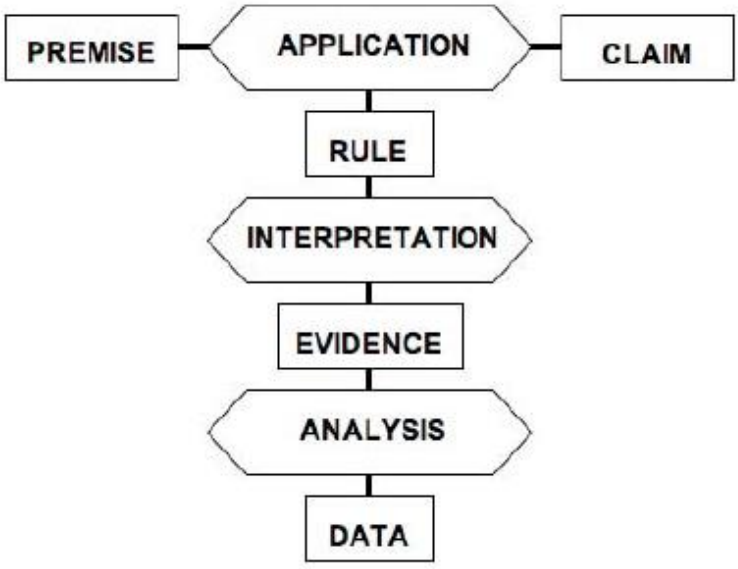

Figure 2. Model of scientific reasoning

Finally, the inclusion of socio scientific issues in the discourse of scientific argumentation improves the students' understanding of the NOS, and their quality of argumentation even without the explicit argumentation instructions as proved in the study (Khishfe, 2014).

Chapter 3: Methodology

In sight of the literature review, there is a necessity of investigating how our students are comprehending the nature of scientific knowledge. In this study it is suggested that it can be done through arguing a controversial socio-scientific issue such as the embryonic stem cell topic. An international school in Sharjah, which is following the American curriculum was involved in this study, exploring the conceptions of high school students about the nature of the scientific knowledge by involving sixty of grade 12 students in a scientific debate about the controversy of carrying out a research on embryonic stem cells. It implicated arguing about a societal issue that required scientific research. Different types of instruments were used to collect data such as an open ended questionnaire given to all participants after the debate, followed by semi-structured one to one interviews to 12 of the participants to clarify more of the students' comprehension of the investigated NOS categories (subjectivity, tentativeness and socially/ culturally embeddedness).

The study was carried on secondary level students particularly grade 12 students upon completion of a debate on embryonic stem cells research. The debate preparation took 2 weeks from the students in order to collect data, and form arguments. The same topic was debated on 3 different classes of grade 12, after which the open ended questionnaire was given to the participants and the interviews of a sample of the participants were done.

The methodology will explain the use of the mentioned instruments, as well as the key points of the research approach used in this study. Also the reason behind using this methodology and its consistency with the goals of the study will be discussed below.

3.1 Research Design

In this section the procedures used in carrying out the study will be displayed. Since the purpose of the study is to explore the conceptions of the high school students about the nature of science categories like: tentativeness, subjectivity, and social/ cultural embeddedness, so there is a necessity for using a qualitative method in such a study (Maxwell, 2005). And, as mentioned by (Creswell, 2014), in the qualitative interpretive design, researchers might study individuals narrative, processes exploration, case studies, or ethnography. The rationale of using a qualitative method is based on the idea that such research techniques target achieving in depth understanding of an exploratory topic, such as exploring the

previously mentioned NOS in the students views (Suranga & Kalsi, 2015), especially through the argumentation of a socio scientific issue. In addition this topic was not adequately investigated (Sadler et al., 2004). In the study by (Tekin & Yilmaz, 2016), which analyzed the articles published between 2004 – 2015 dealing with SSI in scientific education in five selected science education journals (SE, JRST, S&E, IJSE, and RSE), , mostly qualitative approach method was used.

As well as, the qualitative techniques enable the gain of more insight into the students thoughts than the quantitative techniques do, because the qualitative give the students the chance to express their opinions and views without restricting them to predetermined answers (Lederman et al., 2002). Also qualitative techniques are used in data collection stage using open ended questionnaire and semi structured interviews, and in data analysis stage such as: using a descriptive and statistical analysis based on thematic coding (Cooper and Schindler, 2008).
The philosophy of the research approach is being a constructivist (combined with interpretivism) view, as the research is exploring how students see science when related to a real life experience, such as debating the controversary of using stem cells from embryos to save lives. Interpretivism is mentioned because this research was not based on a preset theory, on the contrary, the researcher's intent was to make sense of the responses of the students about the NOS with more focus on tentativeness, subjectivity and social/ cultural embeddedness.

Since this study is exploratory in nature, as the the researcher aimed during this research process to explore which NOS aspects from those intended to be investigated (subjectivity, tentativeness and social/ cultural embededness) will the students demonstrate while carrying out a socio-scientific debate, therefore, this study required using qualitative method to best address the research questions, and understand all their aspects (Creswell, 2014), as by this method the research queries can be clarified to justify the purpose of the study.

The outline of the analysis of the qualitative method depend on the segmentation and taking the data apart, as well as putting it back together in a way that composes a picture to understand the investigated issue. In this study the data collection, analysis and discussing the findings were going hand in hand. For example when interviews were made, the researcher wrote some notes that meant to be used in chapter 5. This because in qualitative research, from framing the research questions to the literature review, data collection and analysis everything goes in parallel. As qualitative data is dense, in the data analysis not all the data were used, as the

researcher screened out the data collected to aggregate them into three to seven themes (Guest et al. 2012), as it will be displayed in chapter four.

The data was analyzed both inductively and deductively, as the researcher worked back and forth between the data collected and the NOS categories aimed to be investigated to reach a comprehensive set of themes that can serve the purpose of the research, then the researcher looked for the similarties and differences between the students responses to analyze them (Creswell, 2014),. This combination of deductive and inductive interpretation for clearer analysis of what the students really view.

The study involved several stages of collecting data. Firstly the researcher introduced the open ended questionnaire for all the sixty participants, in which the questions did not ask about the students views about NOS directly, as they are not taught explicitly in the school where the study was conducted, but instead the questions were addressing those NOS categories implicitly as opinon based questions through which their answers can reveal their conceptions. Secondly the researcher felt the importance of one to one interviews to only 12 of the participating students in the study, those students were chosen randomly, as the researcher wanted to know in general how high school students perceive the scientific knowledge through their experience of debating a socio scientific issue, regardless their gender, critical thinking abilities, or their academic achievement.

In brief the framework of this research is a qualitative approach, using a case study design that is inspired by a previous one done by (Sadler et al. 2004). The research methods used were open ended questionnaire and semi- structured interviews after which data was analyzed in inductive-deductive way, and the philosophy of this approach was constructivism/interpretivism.

3.2 Site and Sampling

The population study is meant to investigate a subgroup taken from a general population and share analogous characteristics on the topic that is related to the standard of sampling (Mertens, 2010). In this study the researcher aimed to explore the high school students' perspectives about the nature of science categories, so the sub group chosen as sixty students from grade 12 of the

same school which is a private international school in Sharjah, they heve different nationalities but mostly descends from Arabic origins, their age is between 16-17 years old, almost all participants are same age. In the first instrument, open ended questionnaire, all the participants were involved , females almost represented one third of the participants which is unsymmetrical stratified sampling but due to the researcher choice of a school, where females are less than males, this will be mentioned later in the limitations of the study, while in the second instrument, the one to one interviews, only twelve out of the sixty participants were involved.

3.3 Procedure, Questionnaire and interview Protocol

As displayed in the literature review, arguing a socio scientific issue that is taking place in our world is one of the promising educational strategies to understand the NOS as suggested by educators (Boran & Bağ, 2016). Therefore, it was important that exploring the students' conceptions about the NOS involved such a strategy.

As shown in (table, 1), there were three phases in this study. Firstly all the participants carried out a debate of the same topic " embryonic stem cells research" in which they were divided randomly into teams and had to collect data, form claims and argue them during debating. The participating students depended on themselves, although the researcher was their biology teacher, but she intended not to interfere in this phase so that the conceptions of scientific knowledge they will show later is entirely theirs without being affected by the researcher's conceptions.

Following the debate, phases two and three were introduced as two tools were used to collect data, preliminary an open-ended questionnaire derived from the studies done by (Sadler et al. 2004) and (Walker et al. 2000) to explore the students conceptions about the NOS categories focusing on subjectivity, tentativeness, and social/ cultural embeddedness. Then a one to one interview, semi- structured in nature based on the fact that when carrying an exploratory study, researchers prefer to use specific sets of questions which are open ended in nature serving two targets. One, investigators can have read through their interviewees without the limitations of the closed ended questions, and two, provide the space for the interviewees to add more to what the researcher might have aimed for (Chenail, 2011).

The data collected from the two tools were used to draw a picture of how students conceptualize science, and the findings are discussed in the following chapter.

Phase 1	Phase 2	Phase 3
Students debating an SSI (embryonic stem cells)	Open ended questionnaire given to all 60 participants	One to one interviews to randomly selected 12 students
	Questions included were : 1- Did the societal factors (issues not related to science) influence your opinion while writing your arguments? Please explain your answer. 2- What kind of data did you collect to carry out your debate (scientific only, moral and ethical only, societal only, all the mentioned)? 3- Why do you think, scientists were having different opinions about embryonic stem cell research? 4- Did your opinion about embryonic stem cells research change before and after carrying the debate? Please explain your answer. 5- Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?	Questions included were: 1- What in your opinion is science? What makes science (or scientific discipline such as physics, biology,etc.) different from other disciplines (as: philosophy or history)? 2- Does developing scientific Knowledge require experimentation? Please explain your answer with examples. 3- Scientists perform investigations when trying to find answers to the questions they put. Do you think scientists are affected by their personal beliefs and backgrounds during their investigations? If yes in which stage do you think they do (data collection or drawing conclusions? 4- Some scientists think that science is infused with societal and cultural values meaning that science reflects the social, political, economical and intellectual norms of the surrounding society. Do you agree? Why and why not? 5- During preparing for the debate did your views about science change? If yes, please justify your answer.

Table, 1: The phases, tools and questions used in this study

3.3.1 The students' questionnaire

The first tool used in this study is the open ended questionnaire given to all the participating students, consisting of five questions derived from two studies by (Sadler et al., 2004) and (Walker et al. 2000), those studies explored the students' conceptions of the nature of the scientific knowledge in response to a challenging socio scientific issue through qualitative approach methods where open ended questions were contained. In Sadler's study the focus was on empiricism, tentativeness, and social embeddedness, while in Walker's study , the NOS was addressed in general. So here the researcher combined the two questionnaires and framed five open ended questions which focused on subjectivity, tentativeness, and social/cultural embeddedness.

As displayed in appendix 1, the first, and second addressed the social/ cultural embeddedness; the third and fifth addressed the subjectivity of science, while the fourth addressed the tentativeness of scientific knowledge. All the students were given this questionnaire to allow

every participant to express their understanding of science through in direct questions that required expressing their opinions and explanations for their answers. This type of questionnaire is consistent with the exploratory nature of the study and is a technique of the qualitative approach, also it encourage the participants to show their ideas and point of views.

3.3.2 The semi-structured interviews

Using more than one tool in research studies can provide triangulation as data is combined from more than one resource (Cohen et al., 2000). Giving that the qualitative research requires various method sources of collecting data to develop a comprehensive view of the phenomena to be explored, as the data is not collected to support the theory as in quantitative research, but the data is interpreted to offer an explanation to the phenomenon to be explored (Carter et al., 2014). For those reasons, there was a necessity of adding these interviews to the study (appendix 2), which was derived from a study by (Lederman et al., 2002) that aimed to develop a way of assessing the learners conceptions about nature of the scientific knowledge, through framing some questions that are used in an open ended questionnaire as well as individual interviews.

Five questions were selected from Lederman's study in which the first question aimed to display how the students see science different from any other disciplines such as philosophy or history, second and fifth questions addressed tentativeness of science by focusing on the idea that science is not fixed and can change as new findings appear, third question addressed subjectivity of science if the students can view scientists affected by their beliefs and backgrounds, and question four addressed the social/ cultural embeddedness of science if the students agreed that science is infused with the society and culture.

These interviews involved asking questions, listening to and recording answers from the participating students in a semi-structured format that had in depth manner. The questions selected were interpretative in nature mostly asked about the students' opinions and justifications. The interviews didn't include all the participants, only 12 randomly chosen participants in which six were males and six were females.

3.3.3 Credibility and trustworthiness of the open- ended questionnaire and the semi-structured interviews

Considering the credibility and trustworthiness of the tools used in this study, triangulation of multiple data resources was incorporated in this study (open ended questionnaire, in addition to one to one interviews), and the findings of each were analyzed separately using coding methods through spreadsheets software making the study's trustworthiness and credible (Lincoln et al. 2011). In addition the researcher used a rich descriptive way of analyzing data, with direct quotes from the participants' answers, to convey the findings so that results are more realistic. Also the researcher was the biology teacher who called for the debate, though her role in the debate was only to observe, but the researcher developed in depth understanding of the phenomenon under study, as the participants were her students and the debating was during the biology classes. This experience with the participants reinforces the validity of the study.

Also, the researcher checked the transcripts and discarded any that contained obvious mistakes (in the open-ended questionnaire, one participant switched answers), and also responses were revised many times with the equivalent themes to see if matched or not, and codes were revised accurately (Gibbs, 2007). (See appendix 3 for the spreadsheets used in statistical analysis).

Further more, although qualitative generalization is limited in qualitative research, and the importance of a qualitative study lies in the fact that it addresses particular themes or specific science which does not demand generalization (Greene & Caracelli, 1997), but since the tools used in this study already derived from questionnaires used in major studies that used to investigate the same phenomenon (Sadler et al. 2004, Walker et al. 2000 & Lederman et al. 2002), the researcher claims the possibility of generalizing the findings of this study which will be discussed in chapter five.

3.4 Ethical Considerations

Ethical issues are very important and challenging stage when conducting a proper study, in order to follow the ethical principles, a letter from the British university in Dubai (BUiD) was sent to the school's principal, in which the study was conducted, (appendix 4). Also according to the

university policy, all the data collected should remain confidential along with the identities of the participants, and the participants were asked for permission to participate in the study with mentioning that they are free not answer questions if they feel so.

As mentioned by (Punch, 2005), it is important to elucidate and resolve any ethical dilemma before hand. And researchers should protect their study participants, develop trust with them, enhance the integrity of the research, protect the research from misconduct and improper use that might affect their institutions or workplace (Israel & Hay, 2006).

So based on what was illustrated above, all the appropriate ethical compliance was taken into consideration while conducting this study, as the agreement of the school administration on the purpose of the study and all the procedures used for collecting data was obtained from the beginning.

In addition, the students who were the participants of this study were told that they are free to withdraw at any time without any negative consequences, as mentioned in the questionnaire they answered and as mentioned to them by the researcher individually (see appendix 1).

Finally, a final report containing the research problem, along with the conclusions and recommendations will be shared with the school administration to help them plan into rigorous science education that our students deserve. In the next chapter the findings of the qualitative method and the data analysis will be displayed.

Chapter 4: Results and Data Analysis

The main purpose of this study is to explore which NOS aspects from those intended to be investigated (subjectivity, tentativeness and social/ cultural embeddedness) will the students demonstrate while carrying out a socio scientific debate, and if any of the investigated aspects will not appear, what the reason behind that is. The current chapter presents the outcomes of qualitative data collected through open-ended questionnaire given to the students following their debate about embryonic stem cells, in addition to, one-to-one interviews with some of the participated students in order to obtain greater insight into the students conceptualizations about the mentioned aspects, a content analysis for the qualitative collected data was done in which a descriptive method was used to display their responses and extract some quotes which directly declaim the investigated aspects. As well as, a statistical analysis was done to these responses using both hand coding method and spreadsheets software to convert qualitative data into quantitative one (Creswell, 2014).

4.1 Demographic Information

The target of this questionnaire is to explore the students comprehension of the targeted categories of the nature of scientific knowledge of high school students in an international school in the UAE, (N=60). The table below, illustrates the results of the demographic information which include gender, age of the students, and the grade they belong to.

Gender	Female	37%
	Male	63%
Age	16 years	47%
	17 years	53%
Grade level participating	Grade 12	100%

Table 2: Percentage of students' demographic information.

4.2 Students conceptions about the nature of science categories reflected in the open ended questionnaire.

An open-ended questionnaire was used as a first tool to investigate the conceptions of the 60 students who participated in this study about the nature of science while carrying out their debates, followed by the second tool which is the interviews that included 12 from above

mentioned students so as to pursue in depth the students understanding of the categories of scientific knowledge.

The open-ended questionnaire that included five questions addressing their conceptions about the nature of science categories meant to be investigated: tentativeness, subjectivity and social/ cultural embeddedness. For each nature of science category, the responses of the students to the questions related to each category will be displayed and some direct quotations are used from the students' answers, followed by the statistical analysis of the common themes that appeared in their responses displayed as count number in figures and proportions in charts, and the results indicated by the major response categories as presented below.

4.2.1 Tentativeness of scientific knowledge category

Asking if the students opinion about embryonic stem cells changed before and after carrying the debate, this question aimed to explore whether the students believe that scientific knowledge and scientific ideas can change or they are rigid and immutable , thirty seven responses came in support to their opinions about such a topic changed after going through this experience which indicates that the students do agree that science is not fixed, after carrying out a research or experiment (such as the debate), and that the outcomes may change according to the emerging data. This was displayed in the second part of the question that required explaining their answers, most of the affirmative responses stated that the reason behind the change of their opinions was the evidences they collected that changed their ideas about the topic. Some of the quotes related to these responses:

"Yes, after finding out a lot of **evidences** it changed the way I view the embryonic stem cell research."

"Yes, before the debate I used to find nothing wrong with destroying embryos to help others. Now, I find it **scientifically** and morally wrong in a lot of ways."

"Yes, we **searched** and read more about embryonic stem cells, so my opinion changed."

"Yes, because I was **researching** and I increased my knowledge."

"Yes after **research** I strongly agree with the ban of embryonic stem cell research."

"Yes after going through this **experiment** of the debate, I learned that it is more important to save lives."

The statistical analysis of the positive responses for question 4 as shown in the Chart.1 and figure.3 below indicates that nearly half of the students imputed the reason behind the change in their opinions before and after the debate to the different results they obtained after carrying out their research, which complies with the tentativeness of scientific knowledge as results and opinions can always change.

Statistics	
Evidences	4
Multiple data	8
More research	10
Different results	15
TOTAL	37

Figure.3 The statistics of themes included in the students responses for Q.4

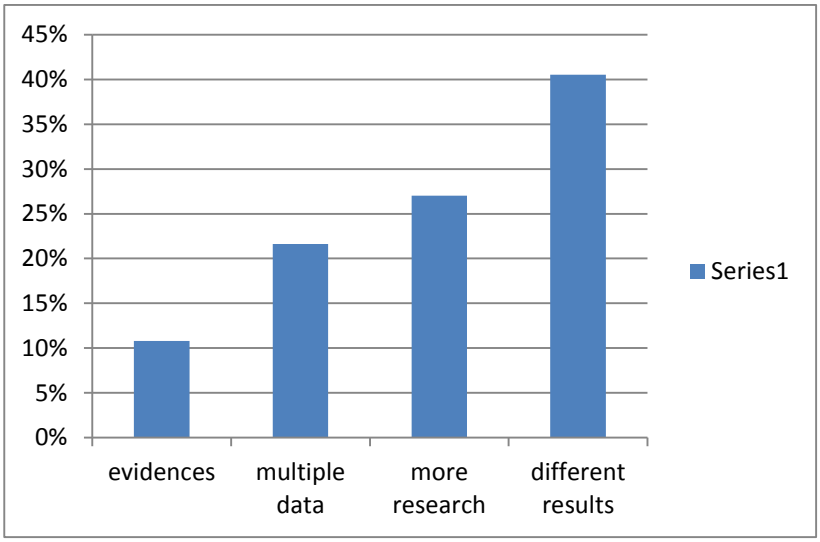

Chart.1 The proportion of themes included in the students responses for Q.4

4.2.2 Subjectivity of scientific knowledge category

Subjectivity of scientific knowledge was investigated in question 3 & 5 in the questionnaire. Question 3 asked about the reason why scientists are having different opinions about embryonic stem cell research, to explore the understanding of the students to the idea of how science being subjective can work differently from one scientist to another, especially because science is the work of man, all the sixty responses came to justify the difference in the opinions of scientists that they are having different point of view, back ground and even morals. These responses indicate how the students understand that scientific knowledge is subjected to many factors surrounding the scientist who practices science. Some of the students answers are quoted as follow:

"Because every scientist has a **point of view** in life and different life situations, like some have children and family, but others don't."

“ Because they have different **backgrounds**.”

“ Because humans are **not all the same** and we all have different opinions.”

“ Different point of view because of **different fields** they are involved in.”

“Different religion and different **background**.”

“Different **personality**.”

The statistical analysis of the responses for question 3 as shown in the Chart.2 and figure.4 below indicates that approximately third of the students comprehend that the reason behind scientist having different opinions about the same topic is because students are having different points of views, as well as many students explained that scientists are affected by the surrounding factors or scientists are having different beliefs. These responses indicate how students understand that science is subjective as it is influenced by the scientists’ personal factors (such as beliefs or points of views) and the factors surrounding them.

Statistics	
Different points of views	20
Different beliefs	10
Different personalities	9
Different backgrounds	6
Different mindset	5
Surrounding factors	10
TOTAL	60

Figure.4 The statistics of themes included in the students responses for Q.3

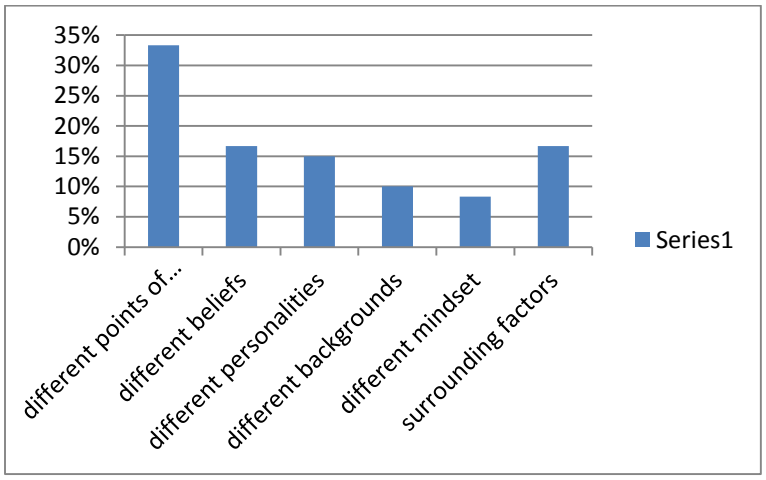

Chart.2 The proportion of themes included in the students responses for Q.3

Question 5 offers another controversy to the students but not related to the topic they argued about, the question requires justification from the students to the dilemma of having different conclusions, although data is the same, about the universe state as some scientists are thinking it is expanding, others believe it is shrinking while the rest of the scientists still believe it is static. This question tries to explore the students understanding of how scientific data can be interpreted differently according to the scientist who dealt with this data. The question is a simulation to the controversy they went through in their debate. The responses came that fifty eight believed the

reasons behind different scientists' interpretations although same data were that they are having different views, see data differently, different mindset and work in different atmosphere. These responses indicate how most of the students comprehended that scientific conclusions are subjected to different interpretations done by scientists who are different. Also quotes of their responses were as follows:

" Because our conclusions are affected by the way we think and we are **think differently**."

"I believe that everyone **view the world** the way they **want** to.."

"Everyone is having his own opinion and **way of getting answers**."

"Different **mindset**"

"Everyone has his **own ideology** and so theories can **change**."

The statistical analysis of the responses for question 5 as shown in the Chart.3 and figure.5 below indicates that again third of the students thought that the reason why scientists reach different conclusions although collect the same data is because they that have different points of view, also many students mentioned that scientists are having a different mindset. This is an indicator that science is subjective and cannot be discrete from the scientist's state.

Statistics	
Different way of thinking	10
Different mindset	13
Different way of data collection	8
Different backgrounds	9
Different point of view	20
TOTAL	60

Figure.5 The statistics of themes included in the students responses for Q.5

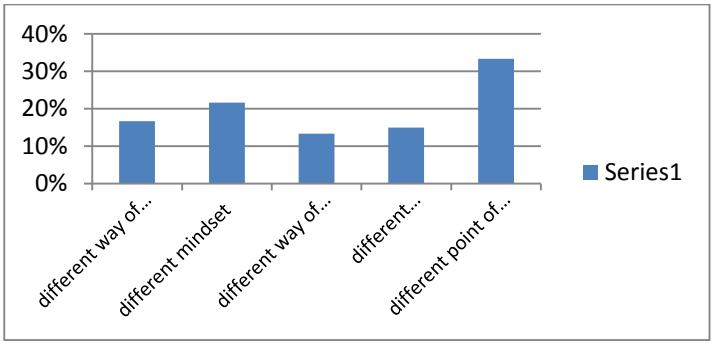

Chart.3 The proportion of themes included in the students responses for Q.5

4.2.3 Social and cultural embeddedness of scientific knowledge category

Scientific knowledge being socially and culturally embedded is addressed in question 1 and 2 of the questionnaire. Question 1 asks about if societal factors influenced the students' opinions while writing their arguments, meaning to clarify if the students recognized other factors, than scientific ones, that might be involved in framing the argumentation. The results were forty eight

supporting the presence of other factors, than science, that affected their opinions in the debate. These factors were mentioned in the other part of the question that required explanation, such as the huge need of finding a cure to diseases destroying the society, legalizations in the country, societal dangers, societal statistics, ethics and religion. Most of the students believed that such topics that interfer the society should include other factors than science. Some of the quotes of their replies were:

"Yes, because this is **real** life."

"Yes, because in **my country** its illegal to abort an embryo, so this makes such a research impossible."

"Yes, emotional and **ethical issues** influenced my opinion."

"Yes, **expensive treatments** and the number of children dying."

"Yes, because in **my country** no one will accept killing embryos to do science."

" Yes, because according to my **religious principles** it is forbidden to conduct such a research.."

The statistical analysis of the positive responses for question 1 as shown in the Chart.4 and figure.6 below indicates that the students conception of the importance of the societal benefit from the scientific research which cope with the social embeddeness of scientific knowledge as science in so much involved and affected by the society that it has been carried in.

Statistics	
Legalization	3
Societal benefit	32
Unethical	1
Economical effect	1
Cultural factors	8
Religion	2
Personal	1
	48

Figure.6 The statistics of themes included in the students positive responses for Q.1

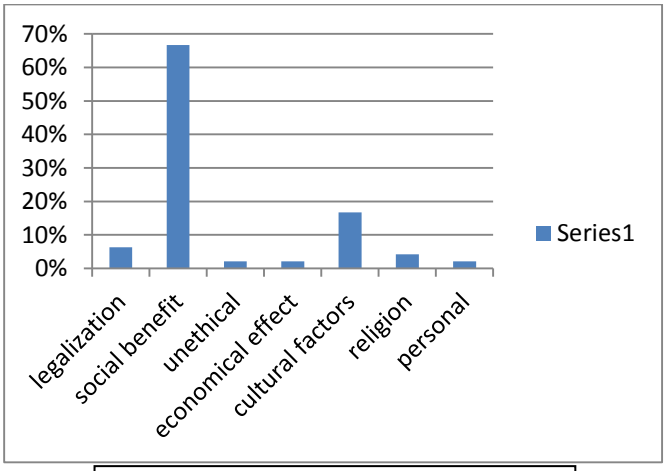

Chart.4 The proportions of themes included in the students positive responses for Q.1

Question 2 asks about the type of data collected to carry out the debate. This question tries to explore how the students choose their data and if they believe that scientific experiment such as this debate involves scientific data only. The question gives the students examples of data categories, so as to make it clearer for them, such as: scientific only, moral and ethical only, societal only or all the mentioned. The results came that forty three believed that the data

collected were from all the categories, which articulate how the students were affected by other factors that interfere in the scientific knowledge practice other than science facts only.

The statistical analysis of the responses for question 2 as shown in the **Chart.5** and **figure.7** below indicates that the majority of the students collected data of scientific, societal, moral and ethical contents, again emphasizing the inclusion of societal, moral and ethical in doing science.

Statistics	
All the mentioned	45
Scientific only	4
Moral and ethical only	3
Scientific and societal	4
Societal only	4
Total	60

Figure.7 The statistics of the type of data collected for the debate as answers for Q.2

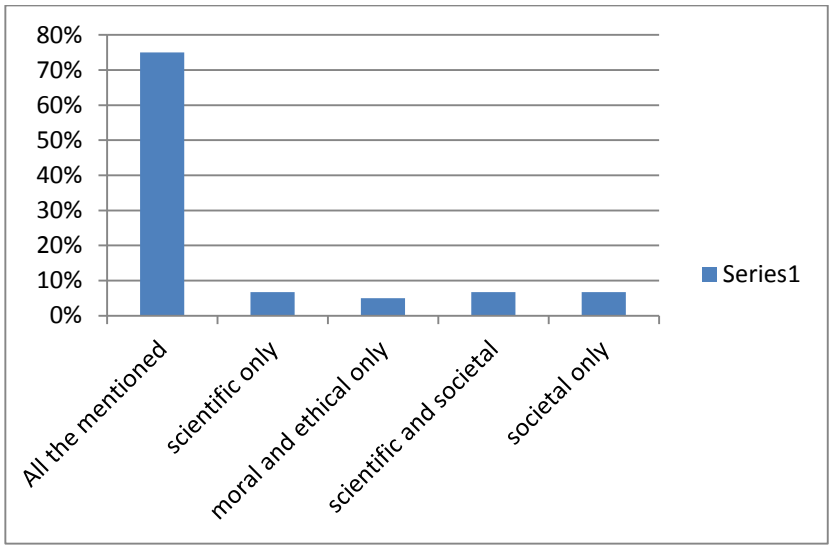

Chart.5 The proportions of the type of data collected as per the students responses for Q.2

4.3 Students conceptions about the nature of science categories reflected in the interviews

The second tool used in this research was face-to-face interviews which were standardized, open ended interviews, which included 5 questions addressing the students in closer way about their opinions in science, relation between science and experimentation, the effect of the scientist's background, science and society and finally their views about science after finishing the experience of the debate. The aim of the interviews was to allow the students to express themselves in a more autonomous way, in addition stress on definite concepts that the researcher wanted the students to react to. The three nature of science categories were addressed in the questions asked, and the responses of the students will be displayed in this section, followed by the statistical analysis of the common themes that appeared in their responses displayed as count number in figures and proportions in charts.

4.3.1 Science is different from other disciplines

In the one-to-one interviews, the first question meant to allow students express their conceptions about science in a more autonomus way, as it asks the students how they can define science, and how science is different from philosophy or history. This question in fact addresses all the scientific knowledge categories that were aimed to be investigated. The researcher wanted to see whether the students think science is rigid and immutable like historical facts, or it is non empirical like philosophy.

The students responses were all evolving around the idea that science is the study of life, which reveal their conceptions about how science is comprehensive. Some quotes from their responses:

" Science is the study of **life**"

" Science tell you **how** the world around us **works**"

"Science is the way to explain **natural phenomena**"

"Science is the way we can **understand** our **world**"

The second part of question 1 which asked the students to differentiate between science on one side and philosophy and history on the other side, most of the students answers were talking about how science can change while history cannot, and how science is an empirical discipline which requires experimentation while philosophy, from their point of view, is a discipline which is based on thoughts. Some quotes from their responses are:

"**Scientific** concepts can **change** like Newton's laws while in **history can't change** the historical events."

" **Science** is done through data collection, experimentation, **observation** and conclusions while **philosophy** is **only** about ideas and **opinions**."

The statistical analysis of the students responses to the differences between science, and history is explained in figure 8 and chart 6, most students identified science as a discipline that is changing while history is rigid.

Statistics	
Science is tentative, history rigid	8
Science is empirical, history discriptive	4
TOTAL	12

Figure.8 The statistics of responses of the students on the difference between science and history

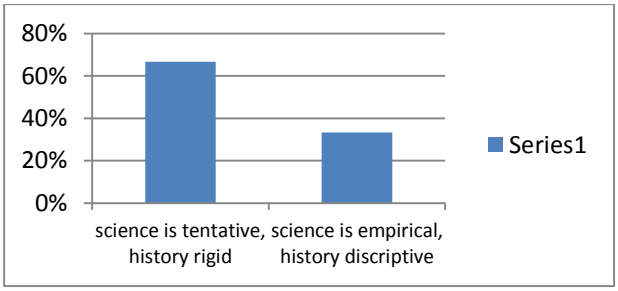

Chart.6 The proportions of responses of the students on the difference between science and history

The statistical analysis of the students responses to the differences between science, and philosophy is explained in figure 9 and chart 7, showing that the majority of the students believed science is based on observations while philosophy is based on opinions and thoughts.

STATISTICS	
Science observation, philosphy opinions	8
Science experimentation, philosphy meditation	4
TOTAL	12

Figure.9 The statistics of responses of the students on the difference between science and philosphy

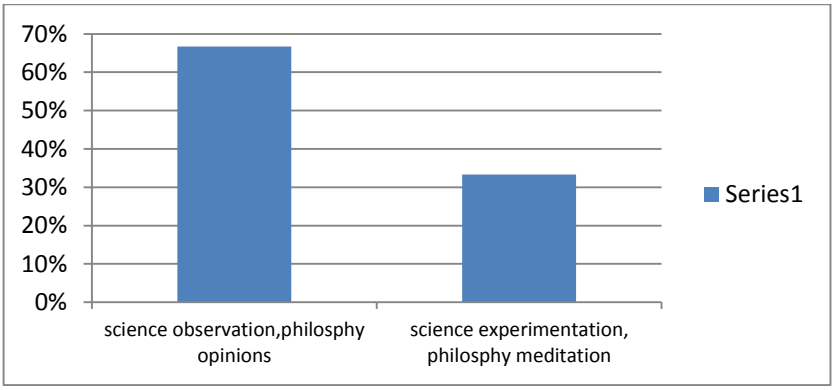

Chart.7 The proportions of responses of the students on the difference between science and philosphy

4.3.2 Science is tentative

In the interview, question 2 was meant to address the tentativeness of the scientific knowledge. The question was asking about the necessity of experimentation for developing scientific knowledge, and all the 12 students who participated in the interview agreed on its necessity and when the question required mentioning an example to justify the answer, all the students used examples from physics such as: gas laws, electric circuits, optics and difference in density. These examples from physics reflect inference which will be discussed in chapter 5.

Question 5 as well aimed to investigate the tentativeness of science by asking the students if their views about science changed , eight answered positively and in the second part of the question that required justification, half of the students who answered positively , said that they see science not rigid and can change by the way we see, and explain data. These answers reflect their understanding of the investigated scientific knowledge category, but the rest of the students gave other answers such as: they see science a very broad discipline, some realized that science needs money to function and that science includes a very important ethical face. Quotes of their responses are as follows:

"**Science** is **not fixed** as most people believed, I was against the embryonic stem research, but after collecting data and during our arguments, I'm now pro."

"**Science** is a very **wide** thing, we must consider everything when we are taking decision in science. Such as the **money** needed, the ethical point of view and our **culture**."

"**Science** needs **ethics** to work properly."

The statistical analysis of their responses was represented in figure 10 and chart 8.

STATISTICS	
Science is tentative	4
Science is comprehensive	2
Science is ethical	1
Science needs money	1
TOTAL	8

Figure.10 The statistics of responses of the students on how they see science while going through their debate

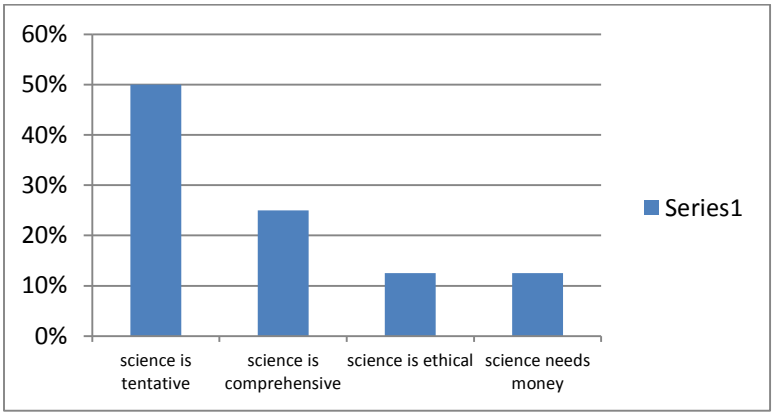

Chart.8 The proportions of responses of the students on how they see science while going through their debate

4.3.3 Science is subjective

In question 3, the subjectivity of science was directly investigated by asking the students if the scientists are affected by their personal beliefs and backgrounds while carrying out their investigations. All the interviewed students agreed that scientists are affected. The second part of the question that asked about which part they are affected more: data collection or drawing conclusions, and most of the responses supported the influence of personal beliefs and backgrounds on drawing conclusions.

The statistical analysis for the responses of this part question 3 is demonstrated in figure 11 and chart 9, showing that students comprehend that the effect of the scientists' backgrounds and beliefs will appear while drawing their conclusions meaning that scientist can interpret data differently which is congruent with the students responses to question 5 in the open ended questionnaire.

Statistics	
Drawing conclusions	10
Collecting data	2
Total	12

Figure.11 The statistics of responses of the students on the affect of backgrounds and beliefs on data collection and conclusions

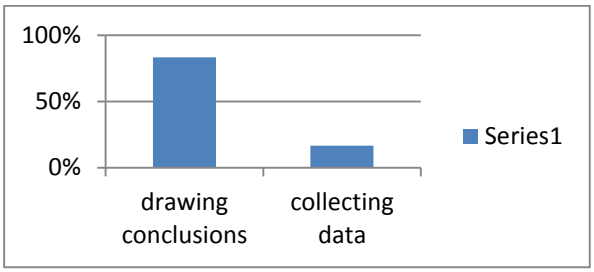

Chart.9 The proportions of responses of the students on the affect of backgrounds and beliefs on data collection and conclusions

4.3.4 Science is socially and culturally embedded

In question 4, the interviewed students are asked if they think science is infused with the societal and cultural values, and all the students answered positively and justified their answers due to many reasons such as the effect of economy on scientific research, the political decisions that controls scientific research, the issues researched by science are those needed by the community and the culture is affecting the direction of scientific research. Some quotes of their responses are :

"Our **society needs** the **scientific** research to save lives."

" If the scientist doesn't have **money** to support his **research**, it will be weak because of not enough trials."

" **Poor** countries are **not** having **good education**, nor scientific research."

"The **governments decide** which **scientific** research they will fund."

" We should use our **scientific** knowledge to help our **countries**."

The statistical analysis for the responses of question 4 as shown in figure 12 and chart 10, shows that half of the students believe that science reflects the economical norm of the society, while the rest believe that science reflects the social norm of the society.

Proportions	
Science reflects the society	8%
Science needs money	50%
Science is serving the society	33%
Governments controls science	8%

Figure.12 The statistics of the responses of the students on infusion of science with different norms such as economy and society

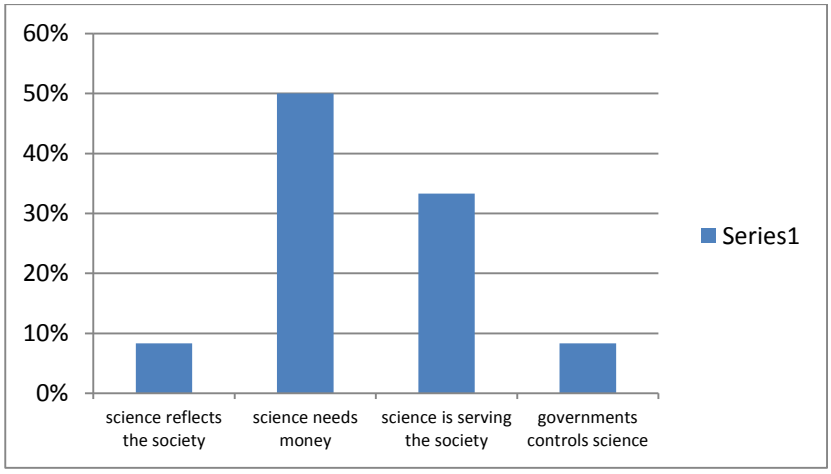

Chart.10 The proportions of responses of the students on infusion of science with different norms such as economy and society

Chapter 5: Discussion and Conclusions

Learning about the nature of scientific knowledge, can be successfully accomplished by allowing our students to search and argue scientific issues that continuously rise in our society, as the case offered in this study. To be a scientifically literate, it requires not only understanding the subject matter, but also understanding the nature of science (Lederman et al. 2012), and having an effective scientifically literate generation in such a challenging world requires involving the students more in the process of doing science, through which they explore its nature with the minimum interfere of teachers and educators (Zeidler, 1997).

5.1 Discussion

This research study which is having a qualitative approach, suggests the possession of the high school students a noticeable understanding of nature of science categories that were intended to be investigated (subjectivity, tentativeness, and social/ cultural embeddedness). This was shown in their responses after going through the socio-scientific debate.

5.1.1 The students demonstration of science tentativeness

Science is tentative, as it is subjected to change at any time in the presence of new evidence or it can be re-conceptualized as data interpretation change (Akerson & Abd-El-Khalick, 2005).
The students understanding of the tentative nature of scientific knowledge was observed clearly through their responses. In question four, in the open ended questionnaire, the majority answered positively (these responses are displayed in section 4.2.1) indicating that they do believe that science is not rigid or fixed discipline. In fact in the justification responses, about 40% of the affirmative responses stated it is because different results were obtained after the research, as well as quiet a number referred the reason to carrying out more research, and the emerging of multiple data that required them changing their minds.

There is a need to mention that some students, who replied positively, brought up that the moral dimension, as well as, the scientific one made them change their opinions. This indicates that going through such a societal issue that has a moral dimension made the students realize the

importance of the moral phase of science (although this was not the intent of the question), this will be mentioned in the recommendations later in 5.4.

When a random sample of students were interviewed, this aspect of scientific knowledge was again addressed in question two and four (results are displayed in section 4.3.2), question 2 asking about science and experimentation, all the students agreed and gave examples of how experiments changed the science course like Newton and the apple and the optics laws, this reveals how they feel that science can change by changing results or outcomes and for this reason experimentation is essential in science. But what was interesting that all the participants gave examples from Physics not from biology, which was the main focus in the debate topic, so the researcher felt it is important to add another question, which is question five, to focus on their understanding of tentativeness through the debate experience that they went through, so question five asked directly if their views to science changed through their debate, the majority answered positively and in the justification part, the tentativeness and comprehensive nature of science appeared as most of them answered they comprehend now that science can change and is not fixed and some added it is very broad.

5.1.2 The perceptions of students about science being subjective

Science is subjective as it involves human creativity and inferences, and the invention of explanations, (Lederman et al. 2012).

The students understanding of the subjectivity of the scientific knowledge was clearly observed in their responses in the open-ended questionnaire , particularly to question three and five. Question three explored indirectly how the students comprehend the subjective nature of science. All the students justified the different opinions they witnessed of scientists about the topic of their debate. The highest proportion was due to different points of view of the scientists and how their beliefs and surrounding factors can affect them. It is remarkable that all the students through this debating experience were able to conceptualize that science is the work of man, and thus it will be affected by human nature. In question five the same category of NOS was addressed differently. In order to obtain more accurate results of this NOS aspect, it was in the form of a case displayed to the students about the universe, and they were asked to explain how

scientists interpret the same data differently. A large number of the participants justified it was different points of perspectives, as well as, contrary mindsets that the scientists have.
Results were the same when the same NOS aspect was targeted in the interviews. In question three, the students showed good understanding of the subjectivity of science through agreeing on the effect of personal beliefs, and backgrounds on the scientists who are investigating an issue. The majority perceive that scientists are more affected during drawing conclusions (results displayed in section 4.3.3), this can be explained as the students who were going through the debating experience were themselves affected during drawing conclusions stage. This is because in this stage the subjectivity of the scientist prevails, as data is being interpreted, and it requires the invention of explanations (Lederman et al. 2012).

5.1.3 The perceptions of students about science being socially/ culturally embedded

Science as a human enterprise is practised to serve the society, and society itself is so much affected by the aspects of the people's culture living within. These aspects involve social fabric, economical situation, political considerations, phiolosophy and religion (Lederman et al. 2002).

Addressing this NOS aspect, the students showed a good understanding of the social and culture infusion with science. In question one and two of the open-ended questionnaire, almost two thirds of the participants agreed that societal factors influenced their opinions while writing their arguments, most of them justified that scientific research should be done for the societal benefit, and that cultural factors affected their opinions and the majority of the students agreed they collected data that had scientific, moral, ethical and societal content (results are displayed in section 4.2.3).

The understanding of the social/ cultural category did not differ in the interview, as the students' responses for question four reveal that the students do believe that science is a reflection of the social, political, economical, and intellectual norms of the society. Not only this but most of them justified that science needs money, and is practised to serve the society (results are displayed in in section 4.3.4) This greatly copes with the aspect of NOS as science is socially embedded as it is affected by the society as well as, serves it (Lederman et al. 2012).

Finally, question 1 in the interview was put to give the students the freedom to talk about their opinions about science and how it is different from philosophy or history. The researcher wanted to explore more about the students views about science generally without focusing on certain feature. The responses of the students revealed how comprehensive they see science, and that they believe it is the way by which they can deal with nature. This reflects that students are ready to accept the explicit teaching of NOS, as they have such a broad view about science. Based on this educators need to address the nature of the scientific knowledge clearly to merge the scientific content they are offering with the right understanding of its characteristics, so as to use the scientific knowledge effectively (Akerson & Vlorich, 2006).

5.2 Conclusion

This research was carried out to explore which of the intended NOS aspects (subjectivity, tentativeness and social/ cultural embeddedness), will the students show while carrying out their debate, and if any will not appear what will be the reason behind this. And through the qualitative approach in which the researcher was close to the participants, the results came to emphasize that the students do comprehend the above aspects of the nature of the scientific knowledge as they were all shown in their responses to the questionnaire and during the interviews.

When the researcher chose the aspects of science to focus on, she kept in mind the nature of the debate the students were going to hold, as it is related to a controversial socio-scientific issue that involves social and culture dimensions. Although, the main research purpose was to explore how they will show their understanding, but the researched aimed as well to convey an experience of using SSI in which the students will depend on themselves entirely to learn how science works, and it showed success to a great extent, even more than the researcher expected.

Based on this, schools need to implement educational strategies that can help the students understand the characters of science and how science is done. In this study arguing a socioscientific issue revealed how students view science, but other strategies are there too, such as: interpreting and evaluating contradictory reports, class discussions about societal dilemmas that science is a part of them, and students introducing case studies for scientific issues needed by the society (Sadler et al. 2004).

Although this study addressed the NOS implicitly, the importance of explicitly teaching those NOS in classrooms is not denied, especially if taught at a younger age (Akerson & Vlorich, 2006) and (Lederman et al. 2013).

Finally, as quoted by one of the students "Science is the study of life", so socio- scientific issues is a way of linking science to our lives, and can be one of the tools that accomplish better understanding of science, especially if linked with the curriculum. Debating on the other hand, proved to offer an opportunity for the students to develop critical thinking techniques as they search, validate, interpret data, and write arguments.

5.3 Limitations

There are some limitations in this study. First, it represents a small sample of student, and was carried over a short period of time. Second, it includes only grade 12 students whereas other high school grades should have been involved. Third, the debate involved only one topic, and it would have been better if carried on several socio-scientific issues. Finally, the sample of participants who answered the questionnaire was unsymmetrical, as the number of males in the school where the study was conducted was more than the females.

5.4 Recommendations

Although this study was explatory in nature, which is consistent with the qualitative approach, it is recommended to carry out similar research but on a large scale, where mixed method is used for more generalizable data and results. And in order to have clearer image, this study can be carried on more schools and grades.

Since educators know how science and society are infused together, curricula and text books should be more concerned with socio scientific issues that are present around us.

Although it was not the primary intent of the study, the students showed in their responses concern with the moral phase of science, which highly recommends the inclusion of issues that have moral dimension in the science curriculum.

Furthermore, it is recommended that training and awareness are offered to teachers on the importance of having scientific debates in their classrooms, and how to implement them in an effective way.

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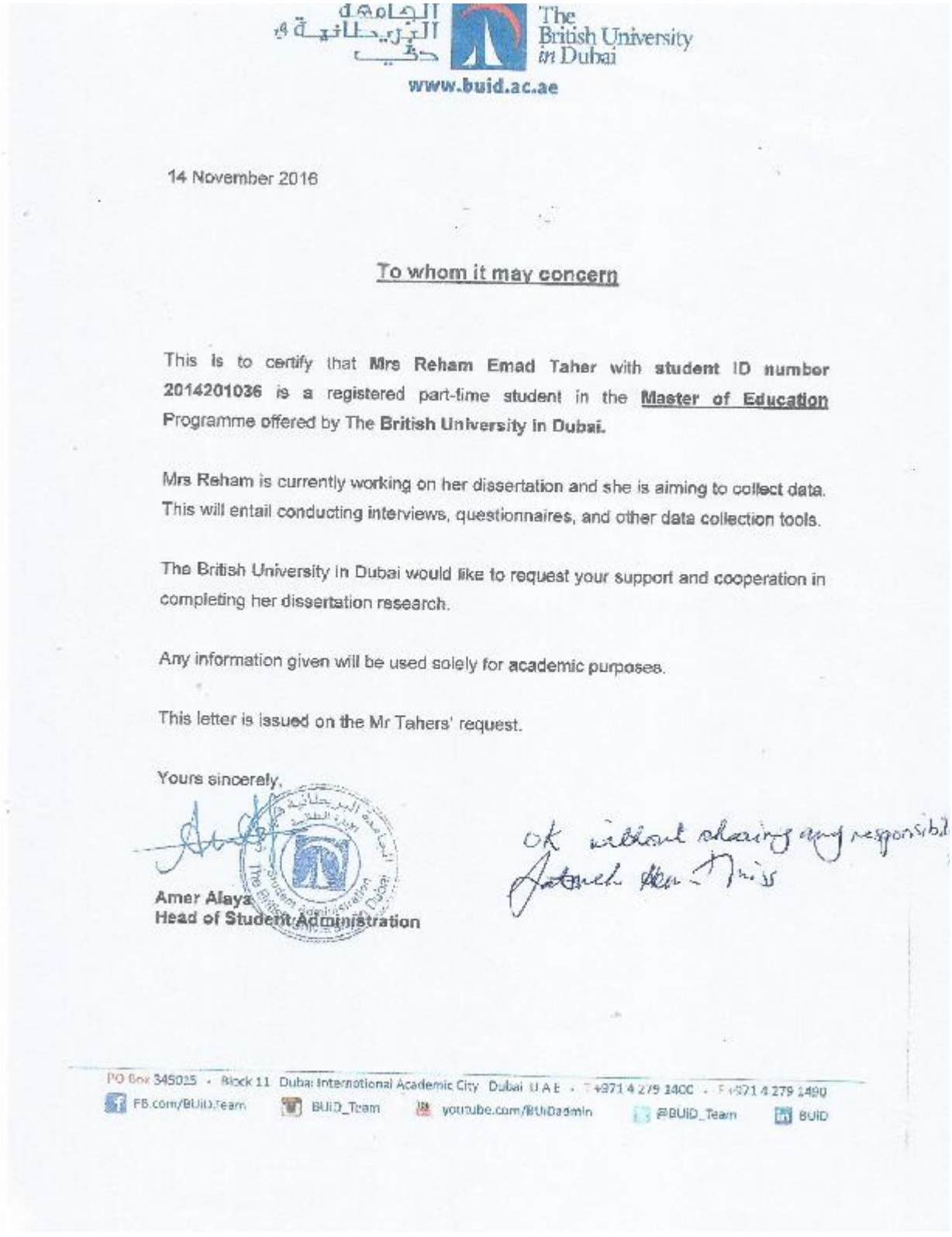
Appendices

Appendix 1: School Permission



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

14 November 2016

To whom it may concern

This is to certify that **Mrs Reham Emad Taher** with **student ID number 2014201036** is a registered part-time student in the **Master of Education** Programme offered by The **British University in Dubai.**

Mrs Reham is currently working on her dissertation and she is aiming to collect data. This will entail conducting interviews, questionnaires, and other data collection tools.

The British University in Dubai would like to request your support and cooperation in completing her dissertation research.

Any information given will be used solely for academic purposes.

This letter is issued on the Mr Tahers' request.

Yours sincerely,

Amer Alaya
Head of Student Administration

ok without sharing any responsibil

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Appendix 2: The Students' Questionnaire

Students' Questionnaire about NOS aspects during debating "embryonic stem cells research"

A)Statistical information	You are free not to answer any question that you are not comfortable with, and you are free to withdraw from the study at any time without any negative consequences.
1. Gender 2. Age 3. Grade	1. Female. 2. Male. 2. _____Years 3. _____

B) Based on the evidences you collected during the preparation for your debate about "embryonic stem cells research" please answer the following questions:

1- Did the societal factors (issues not related to science) influence your opinion while writing your arguments? Please explain your answer.

_____

_____

_____

_____

_____

2- What kind of data did you collect to carry out your debate (scientific only, moral and ethical only, societal only, all the mentioned)?

_____

_____

_____

_____

3- Why do you think, scientists were having different opinions about embryonic stem cell research?

_____

_____

_____

4- Did your opinion about embryonic stem cells research change before and after carrying the debate? Please explain your answer.

_____

_____

_____

5- Some astronomers believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

_____

_____

_____

Appendix 3: The semi-structured interview questions

1- What in your opinion is science? What makes science (or scientific discipline such as physics, biology,etc.) different from other disciplines (as: philosophy or history)?
2- Does developing scientific Knowledge require experimentation? Please explain your answer with examples.
3- Scientists perform investigations when trying to find answers to the questions they put. Do you think scientists are affected by their personal beliefs and backgrounds during their investigations? If yes in which stage do you think they do (data collection or drawing conclusions?
4- Some scientists think that science is infused with societal and cultural values meaning that science reflects the social, political, economical and intellectual norms of the surrounding society. Do you agree? Why and why not?
5- During preparing for the debate did your views about science change? If yes, please justify your answer.