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Abstract
This qualitative study examined how college science faculty who teach introductory level undergraduate science courses including the fields of chemistry, biology, physics, and earth science, understand and define science and nature of science (NOS). Participants were seventeen science instructors from five different institutions in the northeastern U.S. and all of them were interviewed. Consistent with previous research, the findings revealed that the participants in this study held sophisticated and complex conceptions of NOS. In some instances their views were in line with the views promoted by science philosophers, and in other instances their views were more mixed and naive. Findings show that engaging in scientific inquiry is not enough to ensure informed conceptions of NOS.

Keywords
Science Education, College Science Teaching, Nature of Science, Qualitative Research

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Science Instructors' Views of Science and Nature of Science

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This qualitative study examined how college science faculty who teach introductory level undergraduate science courses including the fields of chemistry, biology, physics, and earth science, understand and define science and nature of science (NOS). Participants were seventeen science instructors from five different institutions in the northeastern U.S. and all of them were interviewed. Consistent with previous research, the findings revealed that the participants in this study held sophisticated and complex conceptions of NOS. In some instances their views were in line with the views promoted by science philosophers, and in other instances their views were more mixed and naive. Findings show that engaging in scientific inquiry is not enough to ensure informed conceptions of NOS.
Key words: Science Education, College Science Teaching, Nature of Science, Qualitative Research

The history of the advocacy for teaching of nature of science (NOS) in science classrooms is very long and is evidenced by the National Society for the Study of Education (1960) and Hurd (1960) who claim the existence of this goal in American schools as early as 1920 (Karakas, 2010). The National Research Council (NRC) has clearly stated the most recent objectives of science education:

> Science is a way of knowing that is characterized by empirical criteria, logical argument, and skeptical review. Students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture. (NRC, 1996, p. 21)

The American Association for the Advancement of Science (AAAS) further supports this advocacy by stating that "education in science must provide students with an understanding of the nature of science and its place in society" (AAAS, 1989, p. xii).

Furthermore, the nature of science (NOS) has been included as a part of scientific literacy (AAAS, 1989; National Science Teachers Association [NSTA], 1982; NRC, 1996). This is based on the supposition that understanding NOS will enable students, and the general public, to be better consumers of science so that they can make informed decisions when confronted with scientific issues (Karakas, 2010). In order to acquire scientific literacy, it is important to understand how scientific knowledge is generated (Karakas, 2010). Thus, a scientifically literate person must develop an adequate understanding of NOS (Klopfer, 1969; NSTA; Karakas, 2008, 2010). The National Science Educational Standards (NRC) explicitly states that helping students develop adequate understanding of NOS should be one of the primary objectives for all science teachers (Karakas, 2008). However, in order for science teachers to teach about NOS, they need instruction that explicitly addresses the history, philosophy, and the workings of science not only in their pre-service science methods courses, but also in their undergraduate science courses (Karakas, 2008).

NOS has been defined in many ways in science education literature (Karakas, 2008, 2010). In spite of the significant progress toward characterizing science, there is no single NOS definition that fully describes all scientific knowledge and enterprises (Schwartz & Lederman, 2002) and there is always likely to be an active debate at the philosophical level about what NOS is (McComas, 1998, as cited in Karakas, 2010). However, at the level of helping individuals understand the basics of science in order to promote science literacy, there is some basic agreement about NOS among science educators that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded (Lederman, Abd-El-Khalick, & Akerson, 2000, as cited in Karakas, 2010). Two additional important aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws (Lederman et al., 2000).

It is important to clarify that people often confuse NOS with the processes of science. Scientific processes are activities related to the collection and interpretation of data, and the derivation of conclusions (AAAS, 1989; NRC, 1996). For instance, observing and inferring are scientific processes. On the other hand, NOS refers to epistemological commitments underlying the activities of science (Ochanji, 2003). Therefore, a person's understanding that observations are constrained by our perceptual apparatus and are intrinsically theory-leaden is part of that person's understanding of NOS (Ochanji). Even though there is an overlap and interaction between NOS and science processes, it is nonetheless important to distinguish between the two (Karakas, 2010).

Science educators have been persistent in their support for better student understanding of NOS over the past. Development of an "adequate understanding of the nature of science" or an understanding of "science as a way of knowing" continues to be convincingly advocated as a desired outcome of science instruction (Lederman, 1992, p. 331). In line with this advocacy, I try to answer the following research question: how do college science faculty who teach introductory undergraduate science courses including the fields of chemistry, biology, physics, and earth science, understand and define the nature of science? This in turn could help us understand how NOS might be taught in these classrooms and how to better communicate NOS to students, so that we can graduate more informed students and teachers.

Theoretical Framework

The research on NOS has mainly concentrated on K-12 students', teachers', and pre-service teachers' understandings of NOS (Karakas, 2008). There are very few studies that focus on science faculty and their views on NOS. The few existing studies of scientists' views on NOS lack descriptive details (Schwartz, 2004). These studies are comparable to the studies of teachers' and students' views of NOS, in the sense that they imply scientists do not necessarily hold views that are in line with currently accepted views of NOS advocated for K-16 science education (Behnke, 1961; Durkee & Cossman, 1976; Glasson & Bentley, 2000; Irez, 2006; Karakas, 2008, 2009; Kimball, 1967, 1968; Pomeroy, 1993; Schmidt, 1967; Schwartz, 2004). These studies used some kind of survey instrument to assess teachers' and scientists' understandings of NOS. Only Glasson and Bentley used field observations and interviews to explore scientists' views on NOS. Schwartz used both open-ended questionnaires and interviews to explore scientists' views. Thus, we can conclude that there is a gap in the research that looks more in depth at scientists' understandings of NOS by employing qualitative techniques, such as interviews. This study attempts to close this gap in the research. The result of this investigation will enable researchers in science education to see how some science faculty who teach introductory science courses understand NOS. Science faculty do not share the same definition of "science" in their practice, and thus, they may teach science in diverse ways that need to be better understood, so their impact on future science teachers can be examined.

Questions and concerns discussed above form the foundation of this study. The theoretical framework that guided this research is based on the works of several research studies and summaries of research. The summaries of research by Lederman (1992) and Abd-El-Khalick and Lederman, (2000), and research studies by Durkee and Cossman (1976), Glasson and Bentley (2000), Irez (2006), Karakas (2008, 2009, 2010), Kimball (1967, 1968), Pomeroy (1993), and Schwartz (2004) contributed in developing working conceptions for this study. These studies argue that teachers cannot be expected to teach about NOS if they do not really understand it, and that simply possessing the necessary knowledge does not guarantee its effective communication to students. This study argues that because scientists are considered to be doing real or authentic science, it is important to look at what they say about science and NOS. Prospective science teachers will encounter numerous variations in science instruction in their introductory science courses, prior to taking any science methods classes; therefore, the language used by the faculty could be very important in shaping future science teachers' views of NOS. Introductory science courses are especially important, because these classes are the first science classes taken by future science teachers at the undergraduate level as they could potentially lay the foundation for better understanding of science and NOS in their more advanced science courses. Having instructors who teach in accordance with NOS objectives and who use "precise language" in instruction, might help future students in laying the foundations for "adequate" conceptions of NOS.

Researcher Context

I am a researcher from Turkey. I entered this research project interested in questions that explored teaching NOS in science classrooms. That interest started in one of my first science methods classes. I read an article by Clough (2000) who made a great point that we should teach the rules of the game (in this instance the rules of doing science) before we start teaching science. This point made great sense to me, because I experienced this kind of problem when I first came to the United States. I was not able to enjoy the fun of U.S. football and baseball, because I was not aware of the rules of these games. So I wondered what people found interesting in these seemingly boring games. Now that I have learned a little bit about the rules of U.S. football, I can enjoy some of the fun of this game, but I still do not know the rules of baseball and I am still bored by this game. So my point is that if we, as educators, do not teach our students about NOS (the rules of the game) we cannot expect them to enjoy doing and studying science and take pleasure in what they are doing in science classrooms. That is how I got interested in this topic and why I explored how professors who teach introductory science courses view NOS.

Methodology

Participants

The study involved seventeen participants. The participants were from five different institutions, one Ivy League university (three males), one private research university (four males and one female), one state college (three males), one private college (two females and one male) and one community college (two males and one female) in the northeastern United States. I sent e-mails to total of 30 science faculty members who taught introductory chemistry, physics, biology, and earth science courses at these institutions asking for their permission to be interviewed. Of those participants, 17 responded positively and were included in the study. The most commonly stated reason for not participating in the study was time constraints. I obtained institutional permissions (IRB) from my university and from participants' universities. All participants gave their consent to participate in the study. I arranged the interview times according to participants' schedules via emails and via visiting some of the participants in their offices. Depending on the institution they came from, some participants were practicing scientists who were doing their research at the time or had done research for many years but now were only concentrating on teaching, and some faculty were instructors who had done some research, but mainly were concentrating on teaching. I conducted one in-depth individual interview with each of the participants during the fall semester of 2004 and spring semester of 2005. The interview times ranged between 25 minutes and one hour and 30 minutes; the average interview time was approximately 50 minutes. I gave pseudonyms to all participants in the study to keep their identity anonymous. I conducted all the interviews in person in each scientist's office, except one, Don, who came to my office. All but two of the interviews were conducted in a single session. Jack and Pat's interviews were conducted in two sessions, because of time constraints. Table 1 summarizes the sample, grouped by discipline areas.

Table 1. *Summary of scientists grouped by disciplines*

Discipline	Number of participants	Average years of teaching experience	Number of male participants	Number of female participants
Biology	4	5.25	3	1
Earth science	3	13	2	1
Chemistry	4	19	2	2
Physics	6	21	6	0
Total	**17**	**15.2**	**13**	**4**

Data Collection

I employed qualitative methods, and particularly the interview aspect of ethnographic research design, in collecting data. Ethnographic designs, as Creswell (2002) describes them, "are qualitative research procedures for describing, analyzing, and interpreting a culture-sharing group's shared patterns of behavior, beliefs, and language that develop over time" (p. 481). As such, by using in-depth interviews, in this study I explored the "culture-sharing" behaviors, beliefs, and language among college science faculty. The study focused on how science professors' views emerge. The in-depth/open-ended nature of interviews, as Bogdan and Biklen (1998) write, "allows the subjects to answer from their own frame of reference rather than from one structured by prearranged questions" (p. 3). Also, I used loosely structured interview guides (see Appendix A), as recommended by Bogdan and Biklen , in order to "get the subjects to freely express their thoughts around particular topics" (p. 3). In this study, the topic was an understanding of NOS. However, sometimes I faced some problems during the interviews. While I was aiming to only use open-ended questions during the interviews, sometimes unconsciously and sometimes consciously I used some yes/no and either/or questions, such as "do you think science is objective or subjective?" to get more responses. Such yes/no questions are leading questions and might force informants to say what the interviewer wants, instead of exploring their deep-seated views. Thus, those sorts of questions might have affected the validity of the study.

Lederman (1992) stressed the importance of using individualized interviews to produce accurate representations of respondents' NOS views. Abd-El-Khalick and Lederman (2000) stated that "interviews allow respondents to express their own reviews on issues related to NOS thus alleviating concerns related to imposing a particular view of the scientific enterprise on respondents" (p. 674). Moreover, they continued, "by asking respondents to elaborate and/or justify their answers, interviews allow researchers to assess not only respondents' positions on certain issues related to NOS, but the respondents' reasons for adopting those positions as well" (p. 674). In addition, "the use of interpretive tools such as interviews often reflects the researcher's interest in elucidating and clarifying participants' NOS views rather than simply labeling or judging them" (Abd-El-Khalick & Lederman, p. 674).

Loosely structured interview questions used in this study were developed by the researcher and with the help of some science educators over a period of time of more than one year. Initial development of the questions occurred during a research apprenticeship project in one qualitative research methods class, which sought to investigate six scientists' views on NOS, by looking at various survey instruments measuring students' and teachers' understanding of NOS, such as VNOS – A, B, C questionnaires (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), by consulting with the instructor of the methods class, and by finding and adding additional questions after each interview. The apprenticeship project helped the researcher improve his interviewing techniques and how to get informants to reveal their deep-seeded views on NOS by constantly sharing his short-comings in the field with colleagues. The investigator did not choose to use only the existing survey instruments, because the few questions in them were not enough to fully explicate participants' deep and complex views on NOS; however, he incorporated some of them on the loosely-structured interview guide. Thus, the development of the questions was evolutionary in nature; they evolved over time. I recorded the interviews on a digital voice recorder and later transferred them to a personal computer.

Data Analysis

Present study used qualitative methods in analysis of data. I transcribed the interviews after they all were collected in the summer of 2005 and later coded them according to emerging themes. The first step in the analysis was data organization procedures recommended by Bogdan and Biklen (1998). In organizing the data, I revisited each interview and listened to each audiotape while reviewing the transcripts to ensure the accuracy of data. Each participant's interview transcript was later analyzed according to data analysis procedures described by Bogdan and Biklen, which call for development of coding categories, mechanical sorting of data, and analysis of data within each coding category. Initial codes were supplemented with emergent main categories and sub-codes (Bogdan & Biklen). For example, while reading a transcript, I coded certain views as tentative NOS, creative NOS, empirical NOS, subjective NOS, scientists are cooks, and best science teachers. In average there were identified more then 30 codes for each participant. Later on, these codes were collapsed into categories such as, science faculty's views on the tentative NOS, science faculty's views on the empirical NOS and etc. to align these codes with current NOS aspects.

In this study, I used a realist mode to represent the participants' perspectives through closely edited quotations and interpretations of those quotations (Creswell, 2002; Van Maanen, 1988). Thus, in this study I neither claim to be an arbiter nor assesses the right answers about NOS, but rather I let the participants share their thoughts about NOS and compare these thoughts with the current science education literature on NOS. On the other hand, I share Roth and Lucas' (1997) view that informants' talk about attitudes and beliefs are dependent on context and are highly variable within a given individual. Rather than reflecting individual beliefs, informants' "talk reflects the communities and language games in which they participate, for there are no private languages" (Roth & Lucas, 1997, p. 147). Thus, I make no claims that the data gathered represents informants' permanent and deep-seated views; rather I read them as socially constructed in the moment. While a qualitative researcher intends to tell a story from the view of the participants, he or she can never divorce the words of the participants from his or her interpretations of them and therefore, my "biography, politics, and relationships become part of the fabric of the field" (Bell, 1993, p. 41). Although, I lead the reader regarding what meaning to make from participants' quotations, I try to put as many quotations from the participants as possible for every emerging theme and sub-theme, so that the reader can form his or her own meanings from those quotations and read them from their own background, because they may be different from my interpretations. I present the results as a description of emergent themes that developed through the analysis. I coded and collapsed the interviews into categories. I also grouped the emerging main themes into sub-themes to give more accurate representation of faculty's thoughts about science and NOS as each one of them bring their individual experiences in their specific contexts. It is important to note that the present study is not attempting to align these science faculty with any particular philosophical stance (e.g., relativist, absolutist, traditionalist, positivist, post-positivist, instrumentalist, etc.), because the aim of the study is to portray the views that science faculty hold about science and NOS and not to judge them according to their views. On occasions these perspectives might be used to compare participants' views with the current science education literature and where they stand in that literature.

Results

In this section I make comparisons of faculty's beliefs on the seven aspects of NOS. The results of the research are presented as a description of the emergent themes that I developed through the analysis of data. The interview data were coded and collapsed into categories as recommended by Bogdan and Biklen (1998). The categories were then grouped and reduced to the following set of descriptions and themes:

- How college science faculty define science
- Science faculty's views on the tentative nature of science
- Science faculty's views on the empirical nature of science
- Science faculty's views on the subjective nature of science
- Science faculty's views on the creative nature of science
- Science faculty's views on the social and cultural nature of science
- Functions of and relationships between scientific theories and laws
- Differences between observation and inference in science

The main themes that emerged were also each grouped in sub-themes to give more accurate representation of faculty's thoughts about science and the nature of science, as each one of them brings their individual experiences in their specific contexts to the table. A quotation used as an example for one emerging sub-theme may also be used and seen as an explanation and example for another emerging theme.

Through detailed verbal responses, undergraduate science instructors revealed conviction in their views, supported with examples from their research. These responses demonstrate connections between individual authentic experiences and these faculty's views of science and NOS. However, instructors' views are not necessarily consistent with any particular philosophical position about science and NOS. It is important to note that the present study is not attempting to align these science faculty with any particular philosophical stance (e.g., relativist, absolutist, traditionalist, positivist, post-positivist, instrumentalist), but the aim is to portray the views science faculty hold about science and NOS and not to judge them according to their views. On occasion, these perspectives are useful to portray how the views in this study may be described and compared. Furthermore, these perspectives might be used to compare participants' views with the current science education literature and where they stand in that literature.

How College Science Faculty Define Science

Science faculty gave various descriptions of science and the main description that emerged from these definitions is that science is an experimental way of exploring nature. Other definitions that science faculty used were: science is an understanding that explains the reality, science is an inquiry and asking the good questions, science is a way of knowing and understanding the world, science is explaining what you see around in a logical way using the scientific method, and science is problem solving.

Science is empirical and experimental. Most participants defined science as "a process of learning about and understanding nature and the natural processes through empirical means, through experimentation, and observation," as Liam expressed. Jack further explained "anything else if they cannot be tested and re-observed, and can't be tested by someone else is not science, period." Other participants' definitions fell within these lines; they believed that scientific claims should be supported with experiments and observations to be valid and accepted by the scientific community. These views are in line with the empirical NOS.

Science explains reality. Rich, Donna, and Tina who said "science is a way of explaining reality by doing experiments over and over again to make sure that your conclusions are valid," believed that science explains reality. This view supports the traditionalist and relativistic philosophy of science, which is not advocated in current science education literature and is against the tentative nature of science. However, all three of them also believed that science is experimental and therefore saw the empirical aspect of science. For example, Donna said:

> I would define science as a way of understanding reality that involves observations and formation of hypothesis and testing hypothesis and reevaluating (pause). Science is a way of understanding the reality that involves testing hypothesis, evaluation of evidence and changing ones' understanding when one receives new evidence. (Donna)

These views show that they hold contradictory views about some of the aspects of NOS advocated in current science education literature (Lederman et al., 2002; Schwartz, 2004; Schwartz, Lederman, & Crawford, 2004).

Science is an inquiry and asking the good questions. Josh believed that science is "a process of inquiry, of asking questions, seeking answers, developing hypotheses, testing those hypotheses" in every field, which can lead to "unexpected chance discovery." This view was further explicated by John:

> I- How do you define science? What is science for you?
> John – Ah science for me is inquiry, science for me is teaching a student how to ask good informed questions about things that they observe, whether it be in nature, intrapersonal. Psychology, I think, is fantastic science when it comes to that. Sociologically, I believe science is integrated into all of these. It is asking the good question.

These views fit with the empirical nature of science. Also, John's view that science is integrated into all aspects of society fits with the social and cultural aspects of NOS.

Science is a way of knowing and understanding the world. Lena, Peter, and Ron believed that science is a way of knowing and understanding the world, "a building block and a way of thinking as well" (Ron), and "just sort of accumulating knowledge and refining" (Lena). Tom supported this view in more detail and thought that it might be due to the desire to control the world, which might be "a Western perspective":

> I- How do you define science? What is science for you?
> Tom – Science, ah (pause) that is a good question, science for me, I guess science is a way of explaining the world around us. And to some extent and I don't know if it is a Western perspective on science or something, but it is a way of taking control of the world in certain way, not so much in terms of using the world resources. Of course that happens, but I guess what I mean is that with science comes technology and innovation and science is something that allows human kind to make the world the way they want it to be as opposed to just to be a part of it. And that can be a good thing or bad thing I suppose. It can be a positive thing or destructive thing. So, I guess there are those two sides of this. There is a search for knowledge and information and that is part of science, but also it is an attempt to control our lives in situations through science.

These views fit more with the social constructivist theory, which supports the social and cultural aspect of NOS advocated in current science education literature (Lederman et al., 2002; Schwartz, 2004; Schwartz, Lederman, et. al., 2004).

Science is explaining what you see using the scientific method. Frank believed that science "is a systematic, rigorous investigation of the world around you using mathematical principles and the scientific method of hypothesis and testing and rejection and retesting." This view reflects a more absolutist and traditionalist understanding of science and portrays science as static and an absolute body of knowledge that cannot be changed over time. Believing that there is one "the scientific method" in doing science is in contrast with current research literature, which calls for conveying to students the idea that there are multiple ways of doing scientific research. This view was affirmed by Pat too:

> I- So, how would you define science?
> Pat – Ah, I think the best way to define it is: science makes an effort to explain what you see around you in a logical way and science is all about summarizing something in a hypothesis or a guess and then testing whether your guess is right or wrong and that whole scientific method is really the basis of science. So the way I define science is just what I was saying, you are using the scientific method something that you can use it on.

Science is problem solving. Max and Joel believed that science "is just working to solve problems that are interesting in terms of description of nature" (Joel). The fact that they both saw science as problem solving endeavor may be due to them being theoretical physicists, who try to solve mostly theoretical physics problems. Again this view is not recommended in the current literature, because it portrays science as a static, number crunching endeavor.

Science Faculty's Views on the Tentative Nature of Science

Fourteen participants believed that science is tentative in nature and all highlighted this aspect either explicitly or implicitly all throughout their interviews in various different parts. This theme is relevant to science education because it shows that majority of the participants in this study were thinking in line with science education literature's calls for portraying science as tentative in nature. For instance, Don believed that "scientific knowledge is something that evolves," but did not believe that process of doing science is evolving. He said:

> I am not aware of any change in methodology (of doing science). And again this may be kind of coming from my sort of point of view, I mean, science is what works, if you think something is true you go check it and if it turns out doesn't behave the way you expected then you will say forget it. And that to me kind of seems to be ultimate basis of how science makes progress. And I don't, I can't think of any particular change in that. (Don)

Tom also believed "science is always changing" and further expressed his views on tentative NOS by explaining what he wants his students to know about the research process in science:

> I want them to know that, in just about every field, scientific research is still really active, nobody has all the answers. Whatever it says in the textbook, probably almost every page there is something in there that is still in dispute to some extent, or still being investigated further. And I want them to see the information as valuable by time. You know sort of simple facts, there is always another level, but below that the research is still going on. (Tom)

However, Tom said that in a lot of cases he just doesn't have the time to go into all that and says "here is what the current state of the opinion about this is" and he talks about it. Josh said "there is something that evolves" in science, but believed, like Kuhn (1970), that it is revolutionary and:

> There is a logic and structure to it and every once in a while you get a big surprise, wow dark energy or you got something inspirational, like the idea that black holes aren't just black holes they are dark energy stars. That is the sort of revolution that gets all the way back to the concepts of the words and the connection between the words and the concepts and what all of that means. That is, I think, science at its best, you got a discovery and what to make of it. (Josh)

Rich believed science in “its frontiers is tentative” and thought that one of the major problems in teaching science was that there is “so much to learn that at the level of introductory courses it is very authoritarian and static” and believed that this is the level where “at least such experiences are important” for the students, but further explained that:

> It cannot, almost cannot be otherwise in the introductory course and the only way to get the students to do is to tell them a million times that it is provisional and at the frontiers there are many of things, but that is not the impression of the introductory course. (Rich)

Rich proposed a “very special course, a case studies course, a course with strongest historical component” to overturn this problem in undergraduate education, because, he continued, “very few courses in this country give students an idea of what science is in at least first two years of education of science, in that sense my own personal experience was like that” (Rich). Pat explained that “if as scientist we are not open to the possibility that we are wrong then we are missing something.” And when asked how her students perceive this NOS aspect she explained:

> They might not like it. I mean, they like to know that they are learning a fact and that is always goanna be the way it is, but it is not the truth of it. It is just not the way it works and whether they like it or not it is a fact of science that you are always testing and retesting what you have done. (Pat)

When asked about how she portrays this aspect of science in her classes Pat added:

> I go back and talk about, well things like transition state of a chemical reaction and just talking about how once upon a time you didn’t know that they were there, but there were some clues, rates of reactions, the whole idea as minimum energy for a reaction to occur, they gave as this idea that there were something called transition state. Now we have technologies that are fast enough that we can actually visualize what is going on in a transition state. Does that mean we are right? Maybe, but as technology gets better and better maybe we will find out that that is not all there is to it and I comment about this, but I don’t know if they could get the impact or the importance of this. So, you do your best.

Lena believed that science is “not static” and “continually improving”, but did not believe in the postmodern view of science being “just relation of scientists,” meaning that science is not just an intellectual exercise. There were three scientists who had mixed views on the tentative NOS. Here is an excerpt from Jack’s interview that portrays this confusion:

> I – So do you think that science is tentative and that science is changeable?
> Jack – Absolutely not, it is exactly what it is, what has always been and it will never be anything else and it doesn’t matter whether it is here or in

> the state of Mars or the surface of Titan. Right, when they built a device in this world and sent it to Mars, it works the same way in Mars as it works here. The laws of science, the laws of physics are the same everywhere and that is the way it should, it is not a question of how it should be that is the way it is. I keep am open mind if something worth the change, I will be willing to say "OK, may be there is something different about Mars," this device works inaccurately, so I would consider the possibility of equipment malfunction, but I would always keep an open mind. You have to keep an open mind that is one of the most important things about science. Even for things that are like the conservation of mass, the conservation of energy. I am not going to, it is going to be hard to convince, but in the end, in other words without even checking I won't say no. I will just say not likely that you are going to convince me. Would you like to make a bet of money first, so that I can pick your money.

Science Faculty's Views on the Empirical Nature of Science

All of the participants in this study held views that expressed the empirical, experimental, and testable nature of science, and that scientific knowledge is derived from observations of the natural world. Participants pointed out this aspect of NOS either explicitly or implicitly in their interviews in various different parts. This theme is relevant for science education because it shows that almost all of the participants in this study were thinking in line with science education literature's calls for portraying science as empirical. For example, Tina believed you have to design an experiment to get scientific data and that "you have to have variables that you control, that there are always variables that you cannot control easily with current technology, that there are conclusions that you can draw that are wrong, that sometimes you can't draw conclusions at all, and that science is a process not an end point" (Tina). Tom believed science "begins with questions and observations" and John confirmed this view by saying that something is science "if we can ask good questions about things that we observe." John continued "a lot of people tend to put psychology, or sociology, or anthropology, in these soft, quote end quote, soft sciences. I don't agree, I think that anything where you make observations that lead to good questions or hypothesis that are testable, that is all science" (John). Max also believed that science starts with "well posed question" and exploration of that question by "constant pushing to test the ideas and coming up with possible experimental test." Don portrayed his view of the empirical nature of science by comparing science and religion, and how he sees religion as "being pre-science" and where "what one might do if one has no data and no information." He continued:

> I – How would you compare science and religion?
> Don – Well, the obvious difference is religion is typically not tested to see if it works. And so, for example, normally there are not know test of the efficacy of prayers and I don't know the details of these. And that don't interest me that much, but I presume you can take a group of thousand people and split them in half and some of them pray for what they want and some of them don't pray for what they want and then you can see how

> many (laughter) do what they want and do the comparison. But religion has different levels. Also, one can take religion in a way that it does not overlap with science at all, but that is not typically the case. Typically, people, I think, in pursuing their religious goals or being involved in religion tend to use it to motivate actions or justify actions in a way which bring it into confrontation with science. And so ultimately I see religion as, if you like, being pre-science, what one might do if one has no data and no information and doesn't know, then one is free to believe that.

Jack believed "science is this: goes directly to the question of what are the things that you can directly verify by experiment, by checking it out, by observation and anything that doesn't go in that is not science." Peter said "science is process by which you go from observation to assessment and conclusion" and Liam affirmed by saying that "science is a process of learning about and understanding nature and the natural processes through empirical means, through experimentation, and observation." Liam's views on the empirical nature of science, like Don's, were further confirmed in his answer to comparison of science and religion question:

> How would I compare science and religion? I think they are polar opposite. Religion is faith based approach to understanding the world. Science is empirical and knowledge based approach to understanding the world. (Liam)

Science Faculty's Views on the Subjective Nature of Science

Science faculty's views on the subjective nature of science can be grouped in three sub-themes: a) scientists are subjective, but science itself is objective, b) qualitative methods are more subjective than quantitative methods, and c) science is not subjective. Participants' views on this aspect of NOS were sought either explicitly by asking them whether they think that science is subjective or objective, or implicitly by looking at their answers to different questions in their interview transcripts.

Scientists are subjective, but science itself is objective. Fourteen participants stated scientists personally can be biased, but science as a discipline in general tries to reach objectivity by the means of peer review control mechanisms. However, none of the participants stressed the "theory–laden" nature of science in their interview data (Schwartz, 2004). Thus, we cannot say that participants think in total accordance with literature's call for portraying science as subjective. For instance, Donna believed "individuals are always subjective to a certain extent and scientists at least have some subjectivity," but also said "scientists do science by seeing them interacting with one another, evaluating evidence, and by seeing them interact close in print and in person and again evaluation of evidence" to eliminate the subjectivity each one of the scientists bring to their research. Don affirmed this view by stating that "individual scientists bring their own individual personalities very, very strongly and sometimes that being too glory and some times that being bad try." He gave as an example Rutherford "who was unable to accept, the science in the early 1800's." Don continued:

> Certainly personality plays a role. And I think survival of scientists and their place in the history sometimes sort of depends upon their personalities as much as their mental capacities. And ah yeah, there is much nonsense which is produced along the way and gets sort of filtered out. (Don)

Here Don means that scientists bring their biases to their research by their personalities and their ambitions to be known or publish first some new findings that might not be totally correct and sometimes using false data. However, Don kept his faith in science by saying that such false claims get caught by other scientists and science sort of cleans itself from such false claims and remains objective. Tom very eloquently portrayed his views on this theme. He saw the gender and cultural differences scientists can bring to their research. Below is his lengthy answer:

> I – So do you think that science is subjective or objective?
> Tom – Ah, I think it is certainly a bit of both. I think the conventional stand on science is that it is objective. That it is just factual information that is being looked for and presented when it is found, but I think in practice there is a subjective element to it. Based on my own background, and upbringing and history I will naturally come up with certain types of questions and pursue the answers to those questions in certain ways and if we had a women here she would do it differently just because of the gender differences. And I don't think necessarily either of us would do it right or wrong, but we would do it differently or we might ask different questions and then when we got an answer we both might interpret that answer slightly differently. And the same would go, if we had a scientist from another part of the world or who had been trained may be even in a different university or may be in a different laboratory. So, there is that amount of subjectivity to it, I suppose. If then, if all those scientists start communicating and are using methods that can be compared or evaluated among the scientists then that subjectivity can be an asset, because I might find that another researcher has come up with a way to pursue something that I would have never thought of, but now that I have seen him do it, I can apply it to my research. It is strength for science.

Josh thought the questions scientists seek are the subjective part in science, and the other steps, such as data collection and hypothesis testing, are more objective, because the peer-review mechanisms prevent any filtration of subjectivity. Lena also believed the step of formulating questions in science is more subjective then other steps, and scientists "bring their own histories to what they do all the time." She said:

> I – So do you think that science is objective or subjective?
> Lena – Oh, that is interesting I don't think it is; I mean I think everybody wants it to be purely objective, but it never is, people can't be completely, purely objective on things. We would like to be, but we can't be. So I mean, people bring their own histories to what they do all the time, their

> own ways of perceiving. But I think to some degree there are certain, I guess, set of rules by which we all have to play if we goanna be scientists. So I think, in the minimal we all have to kind of follow the rules (laughter), in doing processes or doing science. Ah, but yeah our perceptions are going to be part of it, and certainly our biases are going to come into it. And hopefully that is not so much in the way we interpret the data as the way we formulate questions and pose hypotheses, but it probably is (laughingly) the way we interpret it too.

Ron believed that "we have our biases" and groups "like the National Science Teachers Association (NSTA) sometimes have underlying biases in some things and you have to recognize that." He continued "we always whatever we look at we look at with biases. And I try to make sure that whatever we look at has a minimum of biases in terms of how I look at that type of thing. I got to believe that the end is going to be objective." Rich though that scientists are "more subjective then they think" they are. Peter believed that scientists try to be objective as much as possible, but once they receive "some specific training" or "have been studying one specific field for a long time," it is easier for them "to lose objectivity." Peter also said "as long as your tests are set up in a rigorous fashion there is not a lot of cutting, if you get a certain results, there are certain possibilities to find that results might be fault and you go back and do it again, if it is potentially again a different result then along the scientists' subjectivity is getting in a way" (Peter). Joel captured the essence of this sub-theme: "personally people are subjective but I think that the net result is become objective." He said:

> Scientists are people and they are subjective in some way especially influencing their own career and so they are no different from everybody else in that sense so it is just that in terms of subject matter you can easily be proved wrong. Working in field where some one is making measurements and you predict 2.97 and the answer is 2.58. Well you are not quite wrong, but you are not right either.(Joel)

Max believed science "is very personal," but also that "there is a lot of peer review, people get to talk, and people have to write a proposal, they get a lot of feedback. So unless someone is really isolated, which case is not likely to happen as much anyway, if they go off they will quickly get pulled back" (Max). Chris thought that "scientists sometimes are not as scientific as you would think" and that "there are a lot of subjective values involved, opinions" involved, but believed that "in general, if you take the scientific community as a whole it is objective."

The majority of the participants in this sub-theme did not see the influence of current scientific theory and paradigm in directing scientific research, and failed to recognize the theory-leaden nature of observations and investigations within a research context as was the case with Glasson and Bentley (2000)'s report. These participants overwhelmingly expressed the view that personal subjectivity, such as variances in taking measurements, is part of science, but emphasized that science itself tries to achieve objectivity by the means of peer review control mechanisms. This view is in contrast with recommendations of science philosophers and educators who advocate for a deeper understanding of the theory-leaden nature of science.

Qualitative methods are more subjective than quantitative methods. Two participants, Tina and Frank, stated that qualitative methods are more subjective than quantitative methods and that numbers are important to categorize something as scientific and objective. Tina believed scientists "tend to be more objective when they are analyzing their data or try to design an experiment, but they can be subjective if their data is not quantitative, but instead qualitative." Frank said:

> Are there numbers, if there aren't any quantifiable quantities, if there aren't any measurements it is not science. I don't care what they say; it is just somebody's opinion. If there aren't any numbers associated with it, it is not science. That is it, it is cut and dry, there is no question about it, if there aren't numbers it is not science. So who is talking about it and is it quantifiable and testable.
> I – So, what makes something science?
> Frank – What makes a scientific problem is if it can be measured and quantified, if you have an explanation that can be tested, and if it is repeatable, of course, if it is repeatable. I think things like sociology and economics, you can measure things and you can have ideas about how they work. It is not really testable ideas in many of these circumstances and certainly not clearly repeatable. So, I would call things like sociology and economics not really science. It is close, but we are not there yet, you can't do experiments, you can't tests your ideas very well. So, it has to be testable, measurable, and repeatable. (Frank)

The fact that only two of the participants, one chemist (Tina) and one physicist (Frank), considered there to be more subjectivity in qualitative approaches as compared to quantitative, and where they describe quantitative as involving numbers, is in contrast to the findings of Schwartz (2004) who found that chemists as a group were more inclined to view qualitative approaches as subjective then the quantitative, as compared to physicists. However, the very few numbers of participants stressing this point reduces the reliability of these findings, and the ability to draw any general conclusions from these results or to dispute Schwartz (2004)'s findings. The views expressed in this sub-theme are in contrast to the suggestions of science philosophers and educators who stand for a deeper understanding of the theory-leaden NOS.

Science is not subjective. Only Jack expressed the view that science is not subjective and that scientific type a person must be objective, must trust the numbers, and that most scientists are capable of separating their professional and non-professional lives. Below is a combined excerpt from his interview that highlights these views:

> Anything you must take on faith is religion or something else, but it is not science. I teach that in the class, I teach the non-science majors and the very important aspect in the whole course is to know the difference

> between science and everything else, because that is the difference between objectivity and subjectivity.
> I – So do you think that most scientists are objective or subjective?
> Jack – When they do science, most scientists are capable in both, not all of scientists are created equal, but most scientists are capable of separating their lives between the two things professional and non-professional… when people get to be somewhere around seven or eight grade that is where you can tell, they are going to be a scientific type of person, an objective type of person, bottom line type of person. There are lots of clichés for it, but you know some people show me the money. They want to know the number, how much is this costs, how much is this, but this, but that, how I will get that, is an objective person, they give, they don't care about any bullshit explanations or sales or anything, all they care about is I got this many apples for that many dollars and that is the bottom line, that is a scientific type of person. (Jack)

This view is more consistent with naïve notions of subjectivity, commonly voiced by learners before explicit NOS instruction (e.g., Abd-El-Khalick & Lederman, 2000; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Schwartz & Lederman, 2002).

Science Faculty's Views on the Creative Nature of Science

All of the participants expressed the view that science is creative in nature, seven by just affirming the creative nature of science and art, five by saying that designing an experiment to a research question is more creative then other steps of science, two by saying that creativity depends on the individual and that the best scientists are very creative, and one claiming that data collection step in science is not very creative. Participants' views on this aspect of NOS were sought either explicitly by asking them whether they think that science is creative and involves imagination, or implicitly by looking at answers to various questions in the interviews.

Affirming creativity. Seven of the participants expressed their views on the creative nature of science by just affirming this aspect in various different places throughout their interviews. For example, Jack believed that science "absolutely, absolutely positively" involves imagination and re-quoted Nabokov's (2002) quote "there is no science without fancy, there is no art without facts." (p. 6)Don believed that there is not "much difference between creativity in science and creativity in art and literature." For him they all "seem to flow from a common pond," the pound of creativity, and that they all are creative endeavors. Rich also believed that "both art and science actually deal as much with creation as with discovery usually people in the sciences are about discovery" and "they both share a curious mixture of selfishness and altruism, to do things for yourself, but you want others to see, but also do things for other people." Ron believed art and science "both are very creative and both try to visualize and look at things around them" and thought "mathematics for some people is a really the difference between the two unfortunately." He continued "I think there are a lot of similarities in terms of creativity and observation and try to convey what you see to others on canvas, or in the classroom or in the lab." Ron believed that scientists sometimes need to get away from their work to be creative. Frank also believed that "science and art are both creative, they both require skill", but thought that "you get a better pay as a scientist usually." He further elucidated his thoughts as follows:

> I – How much creativity is involved in science?
> Frank – It is a very creative. It is one of the most creative endeavors out there, to think about abstract objects that you can't see, or sometimes touch, or get to and try to figure out how they work, it is very creative. I think, astronomy is one of the most creative, because they are just points of life. And you have to build on the ideas that people have previously and you keep embellishing the painting as in order to create the work of astronomy so that whole thing fits together. It is a very creative; it is absolutely creative, inspiringly creative.

Creativity in designing an experiment to a research question. Several participants believed that there is more creativity in designing an experiment to a research question then the other steps in obtaining a scientific knowledge. They expressed this view in different parts throughout their interviews. For instance, Tina believed that "there is a lot of creativity in science when you try to design an experiment that will answer a question that you have." She thought that "you have to be able to think outside the box and bring in other mechanisms may be to answer your question." Pat believed that there is a lot of creativity "in setting up experiments and trying to figure out how do you answer the question" and that "it takes a lot of creativity to design the experiment and so in that respect there is whole a lot of creativity in science." Tom also believed that "the best science is very creative," and thought that "coming up with the question can be a standard process," but believed that "there is really creative part that a lot of scientists do in devising a way to answer the question or to challenge the little bit of information they have." He said:

> There a lot of people out there, a lot of scientists who are just so curious about the world out there, so they would try again and again and again to get something to work and if that is what it takes to really pursue knowledge you know sort of uncompromising desire to have that knowledge. So, I think the ways of getting at that information is where the creativity comes into it. (Tom)

John believed "the nature of science being inquisitive and the nature of science a lot of time having to come up with new ideas, or new instrumentations, or adaptations of ideas or instrumentations to ask new questions and answer those questions takes a lot of creativity." He thought that "to truly understand science you have to understand the history of it and those who came before you." Liam said "there is a lot of creativity in science when you get to the point of choosing which questions to answer, choosing which data, which observations initially to investigate further," but hoped that "there is not too much creativity in interpreting the data." He explained:

> There is a tremendous amount of creativity that can go into experimental designs and this is what distinguishes great scientists from typical scientists. Hopefully there is not too much creativity in interpreting data, but what distinguishes great scientists sometimes from typical scientist is the ability to look at and may not exactly to expectations and work something from there. (Liam)

Jack also though that there is a lot of creativity involved in choosing which questions to answer and how to design an experiment. He gave an example from his field that portrays the “art at the beginning of doing certain kinds of experiments”:

> At the very beginning of doing certain kinds of experiments, particularly experiments there are usually what we call art at the beginning. Because nobody knows what is important, nobody knows what the all factors that influence the outcome of an experiment are and at the beginning you just trying to find that much about without even understanding the relationship, you just need to know what matters. There are and I am sure there will continue to be into the future as people do more and more experiments in different ways at the beginning there would be what we call art. There is a kind of experiment that people do in spectroscopy, is a thing called novel beam that amounts of a squeezing a gas in a small hole into a high vacuum and the gas comes the other side very cold and people do spectroscopy on the gas. Well, the operation uses beams, when I was a graduate student and to this day really, people call and they say “well, how do you get the coldest beams and how do you get to do this”, it is black right, you don’t exactly understand it, but everybody knows what to do, and you can see that it is written in the literature and what it amounts to is a description, do it this way, do it this way, the hole should be this size, you drill the hole this way. And if you do it that way you get the right answer, you get reproducible results. That is why we publish. And then we can argue what it means and all that, and we can argue later about why you have to do it that way. (Jack)

Depends on the individual, the best science is very creative. Few participants believed that creativity depends on the individual and that the best science is very creative. For example, Donna believed that creativity “depends very much on the individual” and further explained:

> Some people who do the best science are very creative and they are able to look at ideas from a number of different angles and come up with really clever ways of testing their ideas. A lot of science is not very creative and is just following a pattern. Well, I test this just last week, and I am going to test this next week in a very similar manner without really coming up with any new view points or particularly new ideas. So, the best science is very creative, but a lot of science is kind of well (pause) rot (laughter). (Donna)

Peter believed "the better scientists are extremely creative and not only do they have the ability to think in a high level and to connect things in a high level, but they can come up with the more creative solution to the problem or by bringing in things that they understand from beyond the narrow focus of the project, they can essentially get to better solutions to better interpretations." Lena affirmed this view:

> Creativity, ah I think a lot of the more important discoveries are coming from people. Ah there are couple of different things involved, one of them is luck, pointing at right things, if you recognizing things. But also creativity, I guess, because you have to know what questions to ask and that is a hard thing to come up with. So, I think people that are more creative and willing to think outside the box, often times are more likely to stumble across things that weren't expected or maybe are really goanna make change the way to think about things. Creativity is important if you do any kind of lab based science. Lots of times you come up with things, solutions with equipment or something that don't exist today, get creative and think about how to address these things. (Lena)

Data collection is not creative. Josh believed that data collection step in science is not very creative. He said:

> I – How much creativity is involved in science?
> Josh – Depends on the kind of science you do, if it is a matter of data collection and making a laboratory goal that sort of thing, it is not necessarily much creativity and incentive to make your laboratory work better and get work done faster. The genomics and all of the massive data that he collected and analyzed that is, I mean there is a room for a lot of creativity in making things happen better and faster, developing the technology to assist you. But otherwise in data collection I don't think, if that is objective data collection, is involving whole a lot of creativity. And finally what Thomas Edison said about genius being 99 percent perspiration and 1 percent inspiration. I mean that is what is going on in the laboratory. And you have a good idea and then you pursue it. I mean, I think of creativity more as finding new ways of looking at things and trying to looking to relate different areas.

Science Faculty's Views on the Social and Cultural Nature of Science

The overwhelming majority of the participants believed that society and culture in which science is produced affects how and what kind of science is done. One participant had a mixed view about this aspect of NOS and believed that science is universally applicable, but there are some personal cultural influences to it. Only one participant believed that science is universal and there should not be any social and cultural influences to it. Another interesting side theme is science is everywhere in our lives. Participants talked about this aspect of NOS either explicitly or implicitly in different places in their interviews. This theme is relevant to science education because it shows that majority of the participants in this study were in agreement with science education literature's, such as AAAS (1989), NRC (1996), Lederman (1992), and others, calls for portraying science as socially and culturally embedded endeavor.

Society and culture effects how and what kind of science is done. Most of the participants emphasized the view that society and the culture in which science is done effects how and what kind of science is done in that society. This view is further divided into several sub-themes according to what they emphasize and they are: a) political and social pressures on how science is done; b) pressure of funding determines what science is done; and c) scientists' personal upbringing and background influence how science is done.

Political and social pressures on how science is done. Several participants said political and social pressures affect what and how science is done. Tina believed scientists' "cultural background would effect" how and what kind of science they do, and "if you come from a society where everybody is expected to be creative then your method of approaching science is goanna be different then someone who comes from society where everything is dictated from your boss." Don gave the example "of biology in Russia in the 1940's and the 1950's" as a way to "sway" science for political reasons. However, he didn't think "the culture has a great influence on the outcomes, necessarily." He continued:

> It might influence the questions one is interested in. It might influence how you want to approach something, but ultimately what you understand either works or not, and that is very, very strong constrain. It sort of speak to there be an ultimate physical reality, as we don't create our own reality. But people from quite different backgrounds seem to have consistent experiences when they go to test it, aspects of reality so to speak. And different cultures, they are I think driven to the same common understanding in that respect. (Don)

Josh "absolutely" believed that scientists' cultural background or society plays an important role in what they do and what questions they ask. He further explained:

> Well, I mean a lot of research is driven by potential for actual applications. So there it is you better have a relationship with the larger society. And I mean also in more general sense you want to do work that is contributing to society, field industries, and to the culture, and also to education. It is bringing others into the knowledge making discovery or whatever it is, all scientific process. (Josh)

Liam believed there probably is social and cultural "influence in terms of what types of questions people are interested in acting, interested in answering," but thought "there should not be cultural influences on the interpretation on data." He further emphasized "certainly in terms of what choices people make in terms of what to pursue there would be cultural influence." Pat said scientists' cultural background or society "in a practical sense" affects the way they do science.

Pressure of funding determines what science is done. Several participants believed that pressure of funding determines what science is done. Peter believed that following the scientific method "is actually something that is pretty important in terms of science from the stand point of getting funding, because nowadays you really have to have a good proposal to get funding from National Science Foundation." He continued "you have to have a scientific question that is set up in terms of scientific method," because "reviewers view that as being important phase" in scientific investigations. Josh confirmed these views by stating:

> You can get money if you can think of a good reason to collect data and you're goanna need graduate students and post-docs, there is something that you can get a couple of people if you want, and there is something that the university will be very happy to have (laughingly), bringing all of the money to support all over there. And I think that had a real impact on what people think of what is to do with science, because it provides a lot of the financial whereabouts if you actually do science. (Josh)

Jack believed pressure of funding determines what science is done and thought scientists bring their cultural background in their research "only in their explanations when they talk to people and try to get money, and try to get acceptance," because "in a capitalist society you don't make any money unless you sell something, you don't generate the capacity to do more science until you sell something and give the people the benefactor for what they do." Jack continued:

> So when you do sales, you look at the customer, the person who is buying and you explain in terms that they understand it and they appreciate it. And if you don't they won't come and do what you want them to do. And so most people are not actually telling what they want. They are telling what, if they are successful, they are telling what the other guy wants to hear. And they have to, because that is what works. Generally speaking that is sales. (Jack)

Joel believed scientists "go in a direction where they can get research support" and clarified:

> People roughly pursue problems they are interested in, some of it is conditioned on research support, some of it is cultural. People can do science because they are part of an administrative position and they feel that they can make money influencing that position so that could become possibly a dominating factor, but obviously there are people and a lot of factors into it. It is a question of doing something that you want to do and not be supported or doing something that you will be supported, a lot of

> people will chose to do it. It is just a survival and everyone has to survive in society and scientists are no different. (Joel)

Scientists' upbringing and background influence how science is done. Several participants pointed out that scientists' background and the culture in which they are brought up influences how and what kind of science they do and what kind of questions they probe. For example, Donna believed that scientists' cultural background "almost has to" affect their way of doing science, and that their "personal world view is going to affect the inference" they are making. Don also believed that "individual scientists bring their own individual personalities very, very strongly and sometimes that being some too glory and some times that being some badly try" and thought that the "survival of scientists and their place in the history sometimes sort of depends upon their personalities as much as their mental capacities." Tom pointed out that "people with certain backgrounds will ask certain types of questions, which will create certain types of answers" and said that based on his "own background, and upbringing and history" he will "naturally come up with certain types of questions and pursue the answers to those questions in certain ways." Frank also believed that "the background of the scientist, the background knowledge, his or her background knowledge or cultural bias" will influence his scientific inferences. He further emphasized that "two people can observe the same thing but infer different meanings." Lena was also "sure that people's background influences the way that they see the world and so it certainly influences what type of questions they goanna ask and may be the way they will interpret some of the results that come out of things."

The participants' responses outlined in this sub-heading, overall revealed that scientists' background and the culture in which they are brought up influences the questions they ask and pursue, and the inferences they make after their observations. This view is in agreement with science organizations' (AAAS, 1989 NRC, 1996; NSTA, 1982) advocacy for portraying science as socially and culturally embedded endeavor, and hopefully the scientists in this study will be able to integrate this aspect of NOS in their instruction.

Science is universal, but there are some personal cultural influences. Rich had mixed views on the social and cultural embeddedness of science. He believed scientists' cultural backgrounds do not play any role in how and what kind of science they do. Rich explained that science "is a Western European invention not an American one, but as any good invention it is transferable to other cultural backgrounds." He also believed science is universally applicable and "it is clearly shared by the vast majority of world cultures to success at doing science by people from very different cultural backgrounds." However, Rich pointed out that there could be some personal and cultural influences to it, and said "the sort of the creative energy that people bring to these things are to some extend culturally determined." This view is not in total agreement with the NOS aspect advocated by science educators, and therefore, Rich might have trouble portraying this aspect of NOS to his students.

Science is everywhere in our lives (scientists are cooks and mechanics). Four participants expressed the view that scientists are cooks and mechanics and that everyone who knows how to cook or repair something is doing kind of science, which means they believed that science is very much integrated in people's lives, and that science is part of the social life and culture. For instance, Tina believed that she does science "all the time," and continued "you always trying and doing something to see that it will work, even people who aren't scientists. They are going to change the recipe on their brownies; they are going to see if the seed is growing in that area, their garden. So people are always doing science." Don didn't see "a great distinction between doing science and fixing broken cars." He further explained:

> You basically have something in front of you, which you don't understand, which is poking your arms. And I think that the car mechanic probably works by hypothesis. The car doesn't start, it might be ignition is not in line, does some appropriate checks and sometimes comes with surprising conclusions and revelations. And really seems science not to be much different of this, different kind of experience. I understand that it would be very naïve and may be kind of pragmatic view of science, but I don't see it in practice to be much different then car fixing. I fixed cars and I have also done research, and I don't, I can't see the difference between the two. (Don)

Peter believed "everyone is a scientist" and "scientists are not special people" and "science is something that everyone dose and works in any problem solving whether it is in the kitchen or whether it is in the garage." Pat said that scientists "cook" and "cooking is chemistry, cooking is a lot of things, but one of them is chemistry." She didn't think "on a day to day basis" that scientists' life is "any different then anyone else."

Functions of and Relationships between Scientific Theories and Laws

Participants overall expressed mixed views on this NOS aspect. Some believed that there is a hierarchical relationship between scientific theory and law and that those theories become laws with sufficient time and repeated testing. Others acknowledged that theories and laws are different kind of scientific knowledge, but still believed that there is some kind of hierarchical relationship between the two. And some expressed the view that scientific theory and law are different types of scientific knowledge and that there is no any hierarchical relationships between the two. This finding is relevant to science education, because it show that even scientists who have better training in scientific investigations and who are involved with scientific research on day to day basis are still confused with this aspect of NOS, as much as students and teachers are. This shows that scientists in this study might have problem in explaining the differences between the scientific theory and scientific law to their students. And also the language they use in instruction may portray theory and law as hierarchical.

Hierarchical relationship: Theories become laws with sufficient time and testing. Several participants believed there is a hierarchical relationship between scientific theories and scientific laws and that theories become laws with sufficient time and repeated testing. For instance, Tina pointed that "law is something that has been proven and theory is something that can be tested with experimentation." She continued "I think theories can become law, but it is also true that the word theory is just used because it is convenient and something that is really has been proven beyond a doubt, may be never becomes or called a law though in fact it is one." Liam said "I probably should know what precisely law and theory is, because that is essential part of why some people have issues with evolutionary theory" and explained "as I understand it a law is something that can be proven and a theory is something which is not absolutely proven true or false," which implies that with sufficient time and repeated testing theories can become laws. Chris defined scientific law as "something that has to be already established and well very fine" and theory "has not necessarily been tested," and that "in ideal case theory should be law, but sometimes theory is not a law." He gave as an example the difference between the theory of general relativity and string theory. Chris said:

> The theory of general relativity has some support, has some experiments, so you can speak of the laws of general relativity. On the other hand, we have string theory, which has no experimental support whatsoever, so still remains a theory, so we cannot talk about of the laws of string theory. (Chris)

Don expressed the view that certain theories are "purely hypothesis" and certain theories are "absolutely solid" depending on their centrality to the field and acceptance through repeated confirmations. He believed that "theory is almost a meaningless term" and that "this is a great problem of course, because of the evolutionary theory." Don explained:

> I mean evolutionary theory, the word theory there means something which is well established, well founded and universally accepted among knowledgeable people, but people who don't like evolution will use evolutionary theory in the sense of theory as being someone's idea. And it is very, very difficult because of that. Law, on the other hand, I think is not such an unrestricted word, but rather normally as accepted to mean something which is pretty well established and firmly tested. And but again Newton's law of gravity has its limitations and so long just with in whatever sphere of applications appropriate to super seated by Einstein's theory of gravitation except which is another law, which may be super seated some day also. (Don)

Mixed views on the relationships between scientific theories and laws. Lena had mixed views on this aspect. She believed that scientific theories and scientific laws "are not all that different really." Lena said "in a scientific sense theory is something that is an idea about how something works or how happens, that has been tested over and over and has not yet been disproved" and "is pretty close to the way things work." She continued:

> Law, I think, is just take it one step further, but is basically the same kind of thing. I think natural law is just something that you just have to expect as an old theory or something. I mean natural law isn't variant. You just have to accept that there are no boundaries in order to be able to do science, because if you acknowledge that natural law might not be operating all the time then you are outside the realm of science. The gravity works most of the times, but not all the time. It doesn't work, so you have to accept that before you can start the scientific process. (Lena)

Lena also believed that "probably to some degree" there is hierarchical relationship between scientific theories and scientific laws, because "gravity started out as a hypothesis" and now it became a law. Max acknowledged that theories and laws are different kind of scientific knowledge, but still believed that there is some kind of hierarchical relationship between the two. He explained that "law is some kind of description of how the natural world works and the theory is the whole process where you explore what are the implications of laws, sort of predictions of laws, sort of if there is consistency of a set of laws" and thought that "theory is more general." However Max believed that:

> The traditional scientific method is you have some theoretical model and as long as it has these internal self consistencies and explains the real world you continue to push on it, to expand its frontiers, to see how robust it is, and the more it survives those tests the more it becomes a kind of dogma, and the dogma is usually what we call a law. It is a well tested set of principles. (Max)

Different types of knowledge, not hierarchical. Four participants expressed views that were consistent with science philosophers' and educators' definitions of scientific theory and scientific law. This is relevant, because it shows that these participants might be able to teach and portray appropriately the functions of and relationships between scientific theories and laws to their students if they want to or intend to. For example, Frank thought that "rigorously speaking a theory is something that is well proven and scientific theories are one of the kind of rock, solid pieces of a foundation of science as the theory of gravitation, the theory of evolution, the theory of motion." And then he defined laws as "also rigorous pieces of scientific truth, things that always seem to be true," but that they "tend to be smaller in scope" and that "a law would apply to a certain situation, whereas theory is broader, it can include many laws." Pat said "theories and laws are different" in the sense that "a law is a concise way of explaining something that happens, but theory tries to explain why it happens." She further explained "a law says this is the way it is and the theory says here is why we think it is the way it is" and said that "it is difficult thing when you try to teach the students the difference between the two." Donna felt "very uncomfortable with law as a concept in science" and thought that "the idea of law being something immutable is to a certain extend a way for scientists to interact with the public on the subject of science to say that we are really, really pretty darn sure about this, because most people who are not scientists don't understand the strength of the concept of a theory." She felt "more comfortable talking about the idea of a theory," because she thought "it is one of the wonderful things about science is the openness to reevaluation on getting new evidence." Donna believed theory is "holding open the possibility that there is something new," whereas "the idea of a law is a little tin bridge for people to understand a truly scientific view point." Jack believed theory and laws are "completely different things." He said "theory is just someone's explanation for why a certain part of the physical world is the way it is, or just a description within some theoretical framework." Law on the other hand, "the truly scientific law is immediately grounded in the empirical." Jack explained "theory is just like these religious laws and human laws, they come and go like air, like wind." He further explained:

> The Newton's laws of motion really, thermodynamics for sure, the three laws, those things are actually just statements of empirical facts. We needed worth to make those statements and so one might think that those things have something to do with a theory. In actual fact they don't, all they are just a statement of an empirical fact and tells you how to define that fact, so that you can measure it, see it, show it, it is never ever violated. And so, you can chose different words, you can chose a different paradigm in which to state these facts, but they still would be the same basic empirical facts, you would do the same basic experiment to test them. And then you would find that they are never broken. So, the words you chose, the situation, the paradigm that is a theory that can change, like I said like a wind, but the empirical facts that is a law definitely. (Jack)

Jack did not think "so much" that "theory turns into law", he clarified that "what happens is that theory gets to a point where it allows us to restate the same empirical truths that we had before, but in a different paradigm so that it seems to contain a greater understanding of the world around us, but they are still the same laws, they are ultimately the same laws." Later on he gave the definition of the distinction between theory and law in science, as recommended by science education literature, he said "I guess I would like to think that law has something more to do with the way the world really is and theory has more to do with the way we look at it."

Difference between Observation and Inference in Science

Most participants expressed the view that science is based on both observations and inference, and that observations are gathered through human senses or extensions of those senses and inferences are interpretations of those observations. Participants also pointed while inferring scientists' may bring their biases to interpretation of an observation. This is relevant for science education, because it shows participants in this study could teach and portray appropriately the difference between observation and inference in science if they wanted or intended to. For instance, Tina believed inferences are "conclusions that you are drawing based on your data" and "observations are what you are seeing from your experiment, measurements that you are taking, growths that you are seeing, color changes and inferences are what you concluded to be true, because of your observations." Don believed that observation is "you see something, it is basically a fact and that includes the possibility of miss-seeing here or miss- recording or whatever, but the idea of observation is it happened, there it is." Inference on the other hand, he believed, "would be a logical conclusion which follows, in practice probably from almost anything; ideally it would be a logical conclusion which follows from observations and possible theories also leading to further conclusions." He also pointed that inference "is synonymous with deduction and conclusion, inference may or may not be true, it should be checked obviously."

Pat explained that in observation "you observe it and you can record it. To infer something is taking a little bit of a leap, you can assume that it means something, but whenever you do that kind of inference you should always be doing a little check and saying is this a logical jump" (Pat). Frank said that "an observation should be a measurement, something that you record, it might not necessarily be a number, it could be a color" and believed that in an observation "two independent observers observing the same thing should agree on their observation, there should be no question, there should be no difference within the error of admission." An inference, he thought, "is an interpretation based partially on the observation and probably partially on where the scientists, the background of the scientist, the background knowledge, or cultural bias, so, two people can observe the same thing but infer different meanings." Donna also believed "personal world view is going to affect the inference you are making." Jack further affirmed by stating that "an inference is not necessarily reproducible, but you can do the same experiment twice get exactly the reproducible results and show it to two different people and get two different sets of inferences with the same exact set of facts, so, observations are fully reproducible, inferences are not necessarily," and that "observation is a statement of the empirical truth." Lena believed "observation is the data" and "you can make an observation and hopefully that is not goanna be particularly ambiguous or subjective observation," whereas an inference "is more about what I mean, what I am telling, what that observation that set of observations is telling you." Chris and Max, said boundaries between observation and inference in science are not clear, and sometimes scientists mix these two terms. Chris said inferences and observations are "pretty closely related, sometimes the boundaries are very fuzzy." He gave examples from his field, he said:

> By definition you cannot see a black hole, because it doesn't emit light, so the only way you have to observe a black hole is through some sort of inference, so from some observations you won't see the black hole directly, but with some other hints you might infer that there is a black hole there, so it is quite difficult to say that you have seen a black hole. Because by definition you can't see them, so sometimes to explain the difference is very fuzzy, and we tend to may be mix them. Sometimes we say this has been observed, but hasn't really been observed. Another example is with dark matter, so we haven't seen dark matter, but we infer its existence from say gravitation forces of galaxies. (Chris)

Liam expressed no clear view on the difference between observation and inference in science. He said "well the definitions of those words have obvious differences, and I think that observation is something that is absolutely objective as the physics."

These findings show that majority of the faculty hold views on this aspect of NOS that are in agreement with views recommended by science educators. Most can clearly distinguish between scientific observation and inference. These findings are consistent with results of others (Durkee & Cossman, 1976; Schwartz, 2004).

Discussion

Data reveal that participants generally viewed science as experimental way of exploring nature, and in some instances their views were in line with the views promoted by science educators about teaching NOS, and in other instances their views were more mixed and traditional. For example, they viewed science as tentative, empirical, experimental, and testable in nature and saw the importance of empirical data in development and justification of scientific knowledge, most clearly distinguished between scientific observation and inference, and saw science as creative in nature, but did not recognize the creativity in the interpretation and analysis of data.

Views of the tentative NOS were consistent with the findings of Durkee and Cossman (1976) and Schwartz (2004) who reported that majority of their participants viewed the scientific knowledge as inherently tentative in nature. Consistent with the findings of Behnke (1961) and Glasson and Bentley (2000), only three participants had absolutist and mixed views of scientific knowledge. This shows that, overall, the participants in this study primarily affirmed that scientific knowledge is subject to change. They recognized that there are areas of science that are more certain than others, and yet some viewed science as progressing toward external reality.

All of the participants in this study agreed upon the importance of empirical data in the development and justification of scientific knowledge. These results are consistent with the findings of others (Bell, 2000; Glasson & Bentley, 2000; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Schwartz, 2004). This shows that participants in this study held "adequate" views about the empirical nature of science, as recommended by science education literature. And making observations, conducting experiments, asking the important questions was seen as a part of science and scientific process by the faculty in this study.

Although, all of the participants said science is creative in nature, which is in agreement with the science educators' recommendations for teaching NOS, they were missing the very important component of creativity involved in science and that is use of creativity in interpretation and analysis of data, as recommended by AAAS (1989), NRC (1996), Lederman (1992), and Schwartz (2004). Participants expressed the creativity in science by just affirming the creative nature of science and art, by saying designing an experiment to a research question is more creative than other steps of science, by saying creativity depends on the individual and that best scientists are very creative, and by claiming that data collection step in science is not very creative. Particularly, creativity was seen as a part of the process of science in general, but not necessarily as a part of developing solid claims. There was a division between doing and justifying. However, the extent to which these participants saw this division is not determined from the interview excerpts. These results are in agreement with the findings of Schwartz who found that even though the scientists in her study "considered creativity and inference to be important to their work, few could actually explicate the use of creativity in making meaning of data" (p. 369). This may be due to the fact that some participants, as Schwartz points out, did not recognize the role of creativity in making meaning of data, because of the grey lines between doing science and being in the profession of science.

The majority believed that the society and culture in which science is produced effects how and what kind of science is done, but did not recognize the reasoning processes involved with how the science itself is conducted, and therefore, the socio-cultural influences were seen as primarily external. Also majority of the participants stated that scientists themselves personally can be biased, but science itself as a discipline in general tries to reach objectivity by the means of peer review control mechanisms, and therefore failed to acknowledge the influence of current scientific theory and paradigm in directing scientific research, and did not recognize the theory-leaden nature of observations and investigations within a research context.

The fact that the majority of the participants emphasized the importance of funding, the influence of political and societal pressures, and the personal upbringing and background of scientists, influences the direction and continuation of scientific research, is in agreement with science educators' recommendations for teaching NOS. However, again there is a missing point in these influences and that is these influences are generally seen more directed toward what questions get asked more so as than on the reasoning processes involved with how the science itself is conducted. In this way, the socio-cultural influences are seen as primarily external by the scientists. These findings support Schwartz (2004), who wrote scientists in her study also reported "having to tailor their research programs toward the agendas of funding agencies" (p. 371). Politics and society "establish standards and direct research through funding decisions, and are recognized feature of scientific-social dynamics" (Knorr-Cetina, 1999; Ziman, 1995, as cited in Schwartz, p. 370). However, as Schwartz points out, this feature is "typically overlooked in the context of science education. Through contacts with scientists in practice, students and teachers might learn about the pressures of acquiring funding, but recognition of such requirements may also lead to recognizing the theory-leaden aspect of NOS" (Ryder, Leach, & Driver, 1999; Schwartz, Lederman, et al., 2004, as cited in Schwartz, 2004, p.371). Because grant writing process itself mandates work to be framed within current theory and directed toward worthy goals that fit within the visions of current scientific process (Schwartz).

Participants overall expressed mixed views on the functions of and relationships between scientific theory and law. Some believed that there is a hierarchical relationship between scientific theory and law and that theory becomes law with sufficient time and repeated testing. Others acknowledged theories and laws are different kind of scientific knowledge, but still believed that there is some kind of hierarchical relationship between two. Some expressed the view that theory and law are different types of scientific knowledge and that there is no hierarchical relationships between two. These findings show that participants held varying views on functions of and relationships between scientific theory and scientific law. Overall, as it was the case in Schwartz (2004)'s study, "half of them reported hierarchical views that theories develop into laws with repeated testing and or sufficient time, however, it should be noted that, unlike typical naïve views, most of these hierarchical views maintained laws as tentative" (p. 373). A typical naïve view states “laws are theories that have been proven true through repeated testing” (Lederman et al., 2002, as cited in Schwartz, 2004, p.373). Very few of the participants used “proven true” terminology to describe the transition from theory to law. Participants, as it was the case with Schwartz’s study, tended to “use the idea of a consistently established theory and a historical use of the terminology” (p. 373). Consequently, participants’ hierarchical views are not typical to teachers’ and students’ naïve views (Abd-El-Khalick & Lederman, 2000; Lederman et al., 2002, Schwartz). These findings are in agreement with the findings of Schwartz (2004) who also reported such results; participants’ views of theory and law were consistent with their views of tentativeness. Some participants believed laws to be more certain than theories, and this certainty depends on the discipline they are in (Schwartz). Those disciplines that have fewer variables, as Schwartz points out, are “more controllable and predictable, are more likely to have established laws, and thus, have more certainty attached to them” (p. 373).

The findings show that participants’ views of science and NOS are complex, mixed and naive. For instance, one participant may hold deeper and more sophisticated view on one aspect of NOS, but have more traditionalist and absolutist views on another aspect of NOS. Therefore, it is hard to categorize their views as informed in one of the philosophical school of thoughts (e.g., rationalist, traditionalist, positivist, post-positivist, instrumentalist, and absolutist). These results are in agreement with the findings of Schwartz (2004) who reported that scientists’ “epistemological views of science are complex and sophisticated, ‘informed’ in some areas, but not necessarily” (p. 1), and Glasson and Bentley (2000) who found that it is difficult to label a scientists as positivist or post-positivist based on their perceptions of their work, because the use of terminology is an issue of interpretation. However, these results were in contrast to the findings of Pomeroy (1993), Durkee and Cossman (1976), Kimball (1967, 1968), Schmidt (1967), and Behnke (1961) who reported either their participants held “adequate” understandings of the most aspects of NOS, or held more traditional “inadequate” views of the most aspects of NOS. This shouldn’t be surprising, because Schwartz and Glasson and Bentley used qualitative techniques in collecting their data, such as one on one interviews with their participants and field observations, and therefore it was easier for them to explicate the gray areas in the scientists’ line of thoughts. In contrast, the rest of the studies employed quantitative methods, such as survey instruments, and therefore it was hard for them to see these grey areas. Furthermore, it is hard to point out any significant differences in the views about science and NOS among the participants from the different higher institutions in this study. Being an instructor in an Ivy League institution or in a local Community College does not mean that the instructor from the former institution has a better or more sophisticated understanding of the aspects of NOS than an instructor from the latter institution. The years of teaching experience also did not show any significant difference in the views about science and NOS among the participants. Science faculty with more then 30 years of teaching experience can have varying views about the aspects of NOS as a science faculty with four years of teaching experience. Therefore, it is hard to report any note worthy differences in the views about science and NOS among the participants in this study based on gender, years of teaching experience, and on the type of higher institution.

Science, as a way of knowing, is different from other ways of knowing because it values particular kind of logical approaches to gathering empirical data. In order for teachers to guide their students in understanding the characteristics of science and NOS, teachers themselves need to understand these characteristics. In order to gain this knowledge, they must have opportunities to learn about NOS in both their content and pedagogy courses throughout their education. Thus, science professors' understanding of NOS, who teach the content courses, becomes crucial in shaping these views. I think that in order for science teachers to teach about NOS, they need instruction that explicitly addresses the history, philosophy and the workings of science not only in their pre-service science methods courses, but also in their undergraduate introductory science courses. Incorporating NOS aspects into undergraduate science courses would help students and future teachers to better understand how science as a discipline operates, and provide them with an example of how to better teach science to future generations who then can become scientifically literate citizens. However, the findings support the results of Schwartz (2004) who claim that "engaging in an authentic scientific inquiry, as a member of the scientific community, is not necessarily sufficient in and of itself to ensure informed conceptions of NOS or conceptions same as others within the scientific community" (p. 392). Engaging in authentic scientific inquiry may or may not help in developing epistemological views of science and NOS aligned with positions for scientific literacy as pointed out in the current reform documents relevant for K-16 science education (Schwartz).

These findings add an important contribution to the existing third category of research on NOS and that is the attempt to understand teachers' conceptions of NOS. Examples, quotations, and results from this study may be useful for teacher educators and faculty who teach introductory science in their efforts to portray contemporary science in instruction. However, the intent of this research is not to provide generalizations to all scientists. Such claims would extend beyond the scope of the research design.

There are several areas for future study. Longitudinal research studies exploring relationship among faculty members' beliefs, their classroom practices, and student beliefs are required. Only such studies will be able to reveal the true interaction between instructors' beliefs, their classroom practices and student understanding. There is little question that the study would have been stronger had its design included systematic collaboration with others. Collaborative research designs stand to improve the quality of data analysis and generate important dialogue about understandings of science and NOS. Further investigation of scientists' authentic science practices and their relations to epistemological views could be helpful. This can be explored through direct observation of scientists in their research setting to investigate the extent to which what scientists do compare with how they really practice. Observations of scientists in practice should be done prior to exploring their epistemological views. This approach would enable for more objective descriptions of their practice because the researcher's observations would not be influenced by knowing their views a priori.

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Appendix A

In my interviews I asked my participants questions, such as the following:
Where are you from?
Where did you finish your elementary, middle, and high school education?
What type of school did you go to (public, private, home schooling etc.)?
Where did you go for undergraduate education?
Where did you go for master's education?
Where did you go for PhD education?
Do you have post doctorate?
How long have you been teaching this course?
Did you teach science classes anywhere else, different from this institution?
Looking back at your high school or college years how would you describe the best science teacher or teachers you had? Why was he/she so good?
Can you describe her/his or their best qualities?
What interested you in science?
How do you define science?
Why did you choose this particular field of science?
How did your family affect you in pursuing science?
How did your educational experience prepare you to understand science?
What kind of science books do you read for enjoyment?
What scientific controversies have you followed?
How do you know something is science or scientific?
How do you see scientists do science?
How would you describe the role of creativity in science?
How would you compare science and religion?
How would you compare science and art? How are they similar and different?
How would you compare theory and law in science?
How are inferences and observations in science different and how are they similar?
What goals do you have for your students?
What do you want your students to know about - science?

- research process?
- generation and verification of knowledge?

How do you see your students' understanding of science before they came here?
What kind of strategies do you use to teach about nature of science?
How do you or do you incorporate the history of science in your instruction?
How do you or do you incorporate other cultures' contributions to science?

How do you or do you use nature of science examples as explanations in your introductory science course?
How do you assess your students' understandings of NOS?
How do you think we can make students more aware of how science works?
How do you think we can make students more scientifically literate?
What role do you see yourself playing in teacher preparation with regard to future teachers' understanding of NOS?

I also asked them probing questions during the interviews when I saw it as necessary. Probing questions such as: Can you elaborate more on the issue? How exactly is that? What do you mean by that? Can you explain?

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