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Cases of Science Professors' Use of Nature of Science

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Abstract Study provides qualitative analysis of data that answers the following research question: how college science faculty teach science and NOS and incorporate aspects of NOS and the history of science into their undergraduate courses? Study concentrates on four cases and more specifically on three introductory science classes and on four instructors who taught those courses. These instructors were chosen as case studies to explore in greater detail what occurs inside introductory science courses in one particular higher institution in the Northeastern United States. Participants' teaching styles are presented through a combined and detailed presentation of interview data and classroom observations supported with examples from their classroom activities. Constant comparative approach was used in the process of organizing and analyzing data. Findings revealed that participants preferred to use the traditional teacher-centered lecturing as their teaching style and whose main concern was to cover more content, develop the problem solving skills of their students, and who wanted to teach the fundamental principles of their subjects without paying special importance to the NOS aspects. The study also revealed that other variables of teaching science, such as large class size, lack of management and organizational skills, teaching experience, and instructors' concerns for students' abilities and motivation are more important for these scientists then teaching for understanding of NOS.

Keywords Nature of science · College science teaching · Science education · Case study

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Introduction

The long history of the advocacy for teaching about nature of science (NOS) in science classrooms is evidenced by the National Society for the Study of Education (1960) and Hurd (1960). These two resources claim the existence of movement for teaching this goal in American schools as early as 1920. However, given science's tentative nature, the specific topics that we should teach about NOS, has changed over time (Lederman 1992). In the beginning of the twentieth century, science educators expressed NOS objectives in terms of increased emphasis on the scientific method (Hurd 1960). In the 1960s, the objective focused on inquiry and scientific process skills such as observing, hypothesizing, inferring, interpreting data, and designing experiments (Welch 1979). In the 1980s, psychological factors, such as the theory-laden nature of observations in science and the role of human creativity in developing scientific explanations, as well as sociological factors, such as the social structure of scientific organizations and the role of social discourse in validating scientific claims, started to appear in the objectives of NOS (National Science Teachers Association (NSTA) 1982). Currently, the National Research Council (NRC) has clearly stated the most recent objectives of science education with the following statement:

> "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." (National Research Council 1996, p. 21)

Additionally, American Association for the Advancement of Science (AAAS) further supported the advocacy for teaching about NOS with the following statement:

> "Education in science is more than the transmission of factual information: it must provide students with a knowledge base that enables them to educate themselves about the scientific and technological issues of their times; it must provide students with an understanding of the nature of science and its place in society; and it must provide them with an understanding of the methods and processes of scientific inquiry." (American Association for the Advancement of Science 1989, p. xii)

Most recently NOS has started to be considered as a critical component of scientific literacy (AAAS 1989; National Science Teachers Association 1982; National Research Council 1996). This was based on the assumption that an understanding of NOS will enable students and general public to be informed consumers of science, so that they can make informed decisions when confronted with scientific issues.

In order for someone to acquire scientific literacy, it is important to understand how scientific knowledge is generated. As indicated earlier, the National Science Educational Standards (National Research Council 1996) explicitly state that helping students develop adequate understanding of NOS should be one of the primary objectives of all science teachers. 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 science methods courses, but also in their undergraduate science courses.

NOS has been defined in many ways in science education literature. In spite of the significant progress toward characterizing science there is no single NOS definition that fully describes all scientific knowledge and enterprises (Schwartz and 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 Irez 2006). However, at the level of helping individuals understand the basics of science in order to promote effective science literacy, there is some basic agreement about the aspects of NOS among science educators. The understanding is 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 1992). Two additional aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws (Lederman 1992; Lederman et al. 2000).

Clearly, science educators (such as, Abd-El-Khalick, and Lederman 2000; Duschl 1985; Kimball 1967–68; Lederman 1992; Saunders 1955 and number of others) and scientists have been persistent in their advocacy for improved student understanding of NOS over the past several decades. The 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 desired outcome of science instruction (Lederman 1992, p. 331).

In line with this advocacy, the present study investigates how four faculty who teach introductory science courses including the fields of chemistry, physics, and earth science understand and communicate NOS to their students. The outcome of this study will help us to better understand the use of NOS aspects in introductory science courses and the extent to which science professors at college level incorporate aspects of NOS into their courses.

Theoretical Framework and Significance of the Study

The existing body of research on NOS has mainly concentrated on K-12 students', teachers', and pre-service teachers' understandings of NOS. The research on pre-service teachers' understanding of NOS has been gathered primarily by looking at their pre-service teacher methods courses. There are very few studies that focus on college science faculty and their views on NOS, and the way they use NOS instances in their instruction. Furthermore, the few existing studies of scientists' views on NOS lack descriptive details. 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; Glasson and Bentley 2000; Kimball 1967–68; Pomeroy 1993; Schmidt 1967; Schwartz 2004).

Consequently, there is a gap in the existing research that overlooks the influence of introductory science courses on science teachers' NOS knowledge development, and more importantly, on college science faculty members' understanding and teaching of NOS. This study will attempt to close this gap in the research. The result of this investigation will enable researchers in science education to see how introductory science courses address the understanding of NOS. College science faculty do not share the same definition of 'science' in their practice, and thus, they may teach about the method of science in diverse ways that need to be better understood, so that their impact on future science teachers can be examined.

Prospective science teachers will encounter numerous variations in science instruction in their introductory courses, prior to taking any science method classes. For instance, Zeidler and Lederman (1989) gave specific attention to the nature of teacher-student interactions and the specific language used in high school classrooms. The researchers hypothesized that conceptions of NOS may be implicitly communicated to students by the language teachers use in presenting subject matter. They found that when teachers used “ordinary language” without clarification (e.g. discussing the structure of an atom without stressing that it is a model), students were inclined to adopt a realistic conception of science (as cited in Lederman 1992). This conception views “scientific knowledge as true, real, existing independently of personal experience, and where some scientific objects (e.g. atoms, light, ions) have the same ontological status as ordinary objects (e.g. chair, table)” (p. 772). On the other hand, when teachers were careful to use precise language with appropriate clarifications, students were inclined to adopt an instrumentalist conception (Lederman 1992). The instrumentalist view is an alternative conception of science in which “scientific description represents statements of practical utility” (p. 772). Such a conception emphasizes “scientific knowledge as a product of human imagination and creativity; it is used in a theoretical fashion to allow us to make inferences and construct arbitrary models to explain the behavior of physical phenomena” (p. 772). This conception does not view “scientific knowledge as a true, real, and dependable account of reality, instead, scientific knowledge consists of man’s attempts at accounting for observations by inventing explanations” (Munby 1976, p. 118). This conception stresses the tentative nature of scientific knowledge.

Although, Zeidler and Lederman (1989) looked at the high school teachers’ use of language, these findings show that the language used by science faculty in introductory classes could be very important in shaping students’ views about NOS. Furthermore, 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 science instructors who teach in accordance with NOS objectives and who use ‘precise language’ in their instruction might help future science teachers to acquire ‘adequate’ conceptions of NOS. This study examines the extent to which college science faculty model this behavior.

Additionally, how we teach is determined largely by how we personally learn best and how we are taught. Thus, having the example of science faculty who teach in line with NOS objectives might help prospective teachers learn the techniques for teaching NOS. Having science instructors who teach in accordance with the NOS aspects explained above, would help science educators attain the National Science Foundation (NSF)’s call for more inclusive undergraduate science education, one that makes science interesting, understandable, and more relevant to all students. Specifically, the NSF argues that:

> “All students [must] have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology (SME&T), and all students [must] learn these subjects by direct experience with the methods and processes of inquiry. America’s undergraduates – all of them – must attain a higher level of competence in science, mathematics, engineering, and technology. America’s institutions of higher education must expect all students to learn more SME&T, must no longer see study in these fields solely as narrow preparation for one specified career, but must accept them as important to every student. America’s SME&T faculty must actively engage those students preparing to become K-12 teachers; technicians; professional scientists, mathematicians, or engineers; business or public leaders; and other types of “knowledge workers” and knowledgeable citizens.” (National Science Foundation 1996, p. ii).

The questions and concerns discussed above form the foundation of this study. 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), Kimball (1967–68), Pomeroy (1993); and Schwartz (2004) contributed in developing working conceptions of beliefs for this study. These studies argue that teachers cannot be expected to teach about NOS if they do not really understand NOS, and that simply possessing the necessary knowledge about NOS does not guarantee its effective communication to students (Lederman 1992). This study argues that prospective science teachers should not only be made aware of NOS and taught how to teach NOS in science methods courses, but should have the opportunity to see appropriate teaching practices about NOS in their introductory science courses.

Methods and Participants

This study provides qualitative analysis of data that explores how science faculty teach science and NOS in their classrooms. The study answers the following research question: how college science faculty teach science and NOS, and incorporate aspects of NOS and history of science into their undergraduate courses. The research studies three introductory level science classes and four instructors who taught those courses. Jack, Max, Chris, and Lena (all names are pseudonyms) were chosen as case studies to explore in greater detail what occurs inside the introductory science courses in one particular higher institution in the Northeastern United States. Results are presented through a combined and detailed presentation of interview data and classroom observations supported with examples from classroom activities in relation to professors' views of NOS, their teaching approaches, student actions, student reflections, classroom settings, teaching rationale, and future suggestions.

Data Collection

One in-depth individual interview with each of the participants was conducted prior to the beginning of the observation in spring semester of 2005 in order to explicate participants' understanding of NOS. Interviews were arranged according to participants' schedules by visiting them in their offices. Interview times ranged between 25 min (Lena's) and 1 h and 30 min (Jack's), the average interview time was 50 min. All participants gave their consent to participate in the study. All interviews were conducted in person in each instructor's office. Three of the interviews were conducted in a single session. Jack's interview was conducted in two sessions, because of time constraints.

Jack, Max, Chris, and Lena were chosen for lecture observations based on their teaching in different discipline areas, and willingness to participate in further research. Follow-up interviews with the each of the observed faculty were conducted in the fall of 2005 in order to further explicate their understandings of NOS and to obtain their rationales for using or not using NOS in their instruction. These interviews were clinical in nature and deliberately covered aspects of NOS and teaching practices identified from the analysis of the initial interviews and classroom observations. Thus interview questions were different for each one of them. Participants for the classroom observations were purposefully selected from the private research university because of travel convenience for the investigator.

This study employed an 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 this research design and utilizing in-depth interviews and classroom observations, the study explored the 'culture-sharing' behaviors, beliefs, and language among four college science faculty. Moreover, the study focused on the process of teaching of the concepts of NOS and how science professors' views of NSO had emerged. The in-depth/open-ended nature of the interview, 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, the present study used loosely structured interview guides (see Appendix 1), as recommended by Bogdan and Biklen (1998), in order to "get the subjects to freely express their thoughts around particular topics" (p. 3). In this study the topic was the understanding of NOS. Loosely structured interview questions used in this study were developed by the researcher and with the help of few science educators in a period of more than one year.

The initial questions for the interviews developed through several processes:

- Research apprenticeship project in one qualitative research methods class, which sought to investigate six scientists' views on NOS.
- Looking at various survey instruments measuring students' and teachers' understanding of NOS, such as VNOS-A, B, C questionnaires (Lederman et al. 2002).
- Consulting with the instructor of the methods class.
- Finding and adding additional questions after each interview.

Thus, the questions evolved over time. Interviews were recorded on a digital voice recorded and later on transferred to PC computer and written on a CD.

Classroom observations provided another set of information on the way science faculty structure their lectures and the way they use or do not use instances of NOS in their teaching practices. Classroom observations made visible teacher-student interactions and the specific language used by the instructors, as was the case in the Zeidler et al.'s (1989) study. Interviewing does not necessarily produce a clear understanding of participants' conceptions of NOS, even if they use the appropriate vocabulary for it (Duneier 1999). Thus, observing faculty in classroom environment enabled further explication of their conceptions of NOS.

Observing in a classroom setting requires good listening skills and careful attention to every detail, both visual and non-visual (Creswell 2002). It also requires dealing with issues such as the potential deception by participants being observed and the initial awkwardness of being an outsider without initial personal support in a setting (Hammersley and Atkinson 1995). The researcher tried to control for these disadvantages in the classroom observations by wearing jeans and sweatshirts to blend in more easily with the students, and by sitting in different places during the lectures. The researcher blended very successfully with the students in the classrooms to the point that students will ask him questions about instructors' homework assignments, exams, and the hand writing on the slides.

For the purpose of the study, the investigator took complete records of any chalkboard notes. He obtained class handouts and assignments. He noted the physical environment of the class and took notes on teacher mannerisms and nonverbal cues during the lecture (Zeidler et al. 1989). For example, the investigator wrote down whether the instructor was moving around the classroom and making eye contacts with students.

With each observation the researcher's way of taking notes changed. At the beginning of the observations he was trying to write down everything the instructor wrote on a board or on an overhead slide, but later he started to look for more specific interactions between the instructor and the students, and among the students themselves. Thus, the note taking during the observations was also evolutionary in nature. The general purpose of the observations was to generate a picture of what the instructor and the students did during a given lecture.

Data Analysis

Continuous data analysis was performed as information was collected during the duration of the study. The interviews were transcribed by the researcher on a PC computer using a software program that slows down the interview pace. The first step taken in the analysis of the data was data organization procedures recommended by Bogdan and Biklen (1998). In organizing the data, the researcher revisited each interview and listened to each audiotape while reviewing the transcripts to ensure the accuracy of the data. Each participant's interview transcript was later analyzed according to data analysis procedures described by Bogdan and Biklen (1998), which call for development of coding categories, mechanical sorting of the data, and analysis of the data within each coding category. Each participant interviews' were coded separately according to participant's views on NOS as well as on various emerging themes, and later on repeated themes among the interviews were grouped into coding categories. The field notes were written immediately following each classroom observation, and later coded and grouped based on common themes, such as use of history of science, use of NOS language, class size effect, students' distractions and disinterest with a lecture, and use of Q & A in instruction. The initial codes were supplemented with emergent main categories and sub-codes (Bogdan and Biklen 1998). Analytical memos were written for each observed participant's teaching styles. Teaching styles were described by looking at instructors' interactions with the students and whether their teaching was student-centered or teacher-centered, or whether they used group work.

The constant comparative approach (Glaser 1992) was used in the process of organizing and analyzing the data. The use of constant comparative method results in the saturation of categories and the emergence of theory. Theory emerges through the continual analysis and doubling back for more collection of data and coding (Bogdan and Biklen 1998; Glaser 1992) By this method, each item of the data collected (interview transcripts, participant observation notes, and course documents) were reviewed in search of key issues, recurrent events, or activities in the data that became categories of focus. Initially, categories defined by the theoretical framework were followed, but as more data were collected, new categories emerged and were defined while old categories were redefined. Data for each participant were reviewed multiple times for confirmatory and contradictory statements until data were organized to satisfactory categories and sub-codes to address the research question.

In this study, a realist mode was used to represent the participants' perspectives through closely edited quotations and interpretations of those quotations (Creswell 2002; Van Maanen 1988). The investigator shares Roth and Lucas' (1997) view that informants' talk about their attitudes and beliefs depend on context and are highly variable for a given individual. Thus, the researcher makes no claims that the data gathered represents informants' permanent and deep-seated views; rather he reads them as socially constructed in the moment.

Limitations of the Study

There are several limitations to this study. First, the sample was formed out of volunteers and therefore self-selected. The results are limited to this group of scientists and caution should be exercised when attempting to infer about any of the results with regard to other populations. Second, relevant topics of NOS in K-16 science education guided the development of the interview questions used in collecting data for this study. There may be additional features of epistemological views held by these subjects that were not elicited in this study. Nevertheless, the perspectives pursued and gained through the present study were those deemed most relevant for K-16 science education. Third, the researcher was the main instrument of data analysis. The analyses and results are a product of the researcher's interpretation of the data. The interpretation was based on the researcher's knowledge and experience in science and science education and his social location. Therefore, the theory-laden nature of the investigation is a recognized limitation. However, it poses also as a strength due to lack of interference from other researchers' views.

Table 1 Shows participants background and their interest in science

Features	Jack (Chemistry)	Max (Physics)	Chris (Physics)	Lena (Geology)
Grew up	Miami Beach	New Zealand	Barcelona, Spain	Connecticut
K-12 schools	Public schools	Public schools	Private schools	Public schools
Undergraduate	U. of Chicago	New Zealand	U. of Zurich	Syracuse University
PhD	U. of Illinois	Caltech	U. of Munich	Harvard University
Post doctorate	None	Yale University	U. of Chicago.	U. of Michigan
Teaching years	19	19	1	5
Parental support	Did not guide him in becoming a scientist	Did not guide him in becoming a scientist	Did not guide him in becoming a scientist	No any guidance for choosing geology as her career
First interest in science	Middle school as a self-interest	Elementary school as self-interest	High school as self-interest	Before elementary school “ever since” she “was a little kid
Reads	History books and area journals	Popular science, mathematics, cosmology and superconductivity.	Subject books, area journals, no pleasure reading	Area journals, books on natural history, forensic science, mysteries, and horses
Best science teacher	Enthusiastic, funny, encouraging, and who “explain things in a plain way.”	Challenges students, and asks open questions	Clear, motivating and knowledgeable	Enthusiastic and knowledgeable
Understood how science works in	Nothing in his education was designed to help him understand how science works	Grad school	Grad school	Very late in college

Results

Participants’ Views on NOS

Participants backgrounds are presented in Table 1. Analyses of participants’ first interviews revealed their views on science and NOS. These views are presented below in Table 2 as quotations in their own words.

These views reveal that Jack, Max, and Chris had mixed views on some NOS aspects. They all believed science is an empirical and creative endeavor. Lena, Chris and Max believed that science is subjective and socially and culturally embedded. Jack had mixed views on the subjective and socio-cultural aspects of science. Lena, Chris and Max believed that science is tentative, however, Jack tented to view science as absolute and objective body of knowledge. According to Jack theories and laws in science are different and that there is no hierarchical relationship between them. Lena, Max and Chris also thought theories and laws are different, but they believed that there is a hierarchical relationship between them. Lena and Jack clearly distinguished between observation and inference in science, but Max and Chris had hard times distinguishing between observation and inference in science. Lena had the most contemporary and informed views on the NOS aspects. Her only limitation was that she thought there might be some hierarchical relationship between theories and laws.

Participants Teaching Style

I observed Jack, Lena, Max, and Chris during the spring semester of 2005. I observed Max during the first and Chris during the second part of the semester for two months each. Jack was teaching introductory chemistry for science majors. Max and Chris were co-teaching an introductory astronomy for non-science majors. Lena was teaching an introductory Earth science for non-science majors. I observed Jack in almost all of his lectures, because he held the most traditionalist views of the NOS aspects and he was teaching in a most traditional way, and I was trying to see whether he used any NOS examples, or history of science in his instruction. I observed him in 23 lectures of the 28 total. The ones that I did not observe were either midterm or final exams or review sessions for the exams. There were two sessions of Jack’s course each week, one on Tuesday, and one on Thursday from 12:30 pm till 1:50 pm. I observed Max in 8 lectures, of total possible 14 and Chris in 10 lectures, of total possible 14. There were two sessions of the astronomy course each week one in Tuesday, and one in Thursday at 2:00 pm till 3:50 pm., so I had 10 min to walk to Max and Chris’ course from Jack’s course. I observed Lena in 16 lectures, out of possible 28. There were two sessions of the Earth science course each week one in Monday and one on Wednesday at 10:30 am till 11:25 am. I tried to sit in different places during observations, so that I would have different views of the classroom

Table 2 Participants' views on science and the aspects of NOS

NOS	Jack's views	Max's views	Chris' views	Lena's views
Science Definition	"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"	"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"	"Science is the rigor, the verification, something to test and proof that something is true or not"	"Science is not static, it is continually improving, but it is not just relation of scientists, science as a whole is a different type of endeavor then just an intellectual exercise"
Creative NOS	"Science absolutely, positively involves imagination, there is no science without fancy, there is no art without facts"	"Science is the artistry of smelling the right idea"	"There is a lot of creativity in science"	"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, creativity is important if you do any kind of lab-based science"
Tentative NOS	"The laws of science, the laws of physics are the same everywhere, it is not a question of how it should be that is the way it is, and it doesn't matter whether it is here or in Mars or the surface of Titan, when they built a device in this world and sent it to Mars, it works the same way in Mars as it works here"	"We are always uncovering new questions then the answers to it, there is a lot of new that is happening that is very different from the laws that Newton years ago discovered, but there are a lot of things that are discovered that we don't know, so that it is a dynamic kind of area"	"It changes, at least in my field, I don't think it is going to stop, but say there was a time when we thought that physics could explain everything and that was the end. That was right before quantum mechanics was developed and it changed the whole picture in the physics"	"Science as a whole is a process, it is not static, it is continually improving and adding too, and increasing dimensions of what we know about, so it is continually expanding knowledge"
Empirical NOS	"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"	"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"	"Science is about facts, the scientific method, you have phenomenon, you have a hypothesis, and you make a theory and then the theory should make predictions and you verify those predictions, and test whether the theory is working so far"	"Historical science is sort of different it is not experimental, it is not quantitative in sense of repeating experiments over and over again. Historical sciences are different in terms of the methodology of doing science, you can still formulate hypothesis and test them, but it is in a different way then experimental science is
Subjective NOS	"Science is not subjective, scientific type a person must be objective, must trust the numbers"	"Personalities are involved in science, people are involved, judgment involved, a lot of the things that people don't usually associate with science"	"Scientists sometimes are not as scientific as you would think, so there are a lot of subjective values involved, opinions involved, however in general, if you take the scientific community as a whole it is objective"	"The step of formulating questions in science is more subjective then other steps, scientists bring their own histories to what they do all the time."

Table 2 continued

NOS	Jack's views	Max's views	Chris' views	Lena's views
Social and Cultural NOS	"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	"Science is very personal, but 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."	"What you do in science is influenced so much by the society and the choices they do is determined by the society"	"I am 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"
Difference between theory and law in science	Theory and laws in science are completely different things, 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, 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"	"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, theory is more general, law is a well tested set of principles and a kind of dogma"	"Scientific law is something that has to be already established and well very fine, and theory has not necessarily been tested, and in ideal case theory should be law, but sometimes theory is not a law"	"In 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. Law is just take it one step further, but is basically the same kind of thing, law is an old theory it isn't variant, the gravity works most of the times, but not all the time"
Difference between observation and inference in science	"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, observation is a statement of the empirical truth"	"Boundaries between observation and inference in science are not clear, inferences are more subtle, while observations are data, accurate descriptions of what is going on in some experiment. It takes a theory to define also what things are measurable in the theory, so it can become quite tricky, I mean the distinctions become less clear"	"Inferences and observations are pretty closely related, sometimes the boundaries are very fuzzy, we haven't seen dark matter, but we infer its existence from say gravitation forces of galaxies"	"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 that set of observations is telling you"

activities. I spread out the observations throughout the semester by making at least one observation each week. Jack's course had a lab attached to it, but four graduate Teaching Assistants taught the lab. Lena, Max and Chris' courses did not have labs. The settings were large auditoriums with nearly 300 seats. Emerging themes from the observations are presented below.

Professors' teaching approaches

Jack's instruction was a very traditional, teacher-centered lecture, where he used complex chemical language, or a series of math and chemical formulas in his explanations with little indication of their meaning. Below is an example:

> "The instructor talked about how we measure molecules by looking at spectrum. He said 'I had to say the magical word spectrum. We can measure the hydrogen molecule by look at a spectrum. We can do that with many, many things now.' Then he wrote an example on the projector:
> Calculating average reaction rate for:
> $2N_2O_{5(g)} \rightarrow 4\ NO_{2(g)} + O_{2(g)}$
>
> Then he asked students what they can say about this equation, but no one answered. Then he said 'this gas is what you see during the night at airports. This is the brown cloud after sunset at airports.' He wrote:
> Data: time(s)/1200 concentration O_2 mol/l 0.0036; 0.0048
> $\Delta\ \{O_2\}/\Delta t = \{0.0048–0.0036\}$ mol/l/{1800–1200} sec
> $\Delta\ \{O_2\}/\Delta t = 2.00$
> Then he calculated average concentration for O_2 by putting the numbers on the formula. He said 'this class will kill you with number units. I like numbers. You will see why I like numbers at the end.' He continued 'it is either right or either wrong with the numbers. That is what separates us from other sciences.'" (Obs. # 2 of Jack, 01/20/05)

Jack always stayed in front of the overhead projector and did not move at all around the auditorium. Jack was writing his explanations on the projector and from time to time looked at the students in the front rows. He was explaining a concept or solving a problem in all of the observations I made during the semester. Jack's main activity during the lectures was concentrated on problem solving; he would introduce a new concept and start solving problems related to that concept. Jack incorporated, in few lectures, a question-answer type teaching strategy. Students asked questions both about the explanations of a concept or his hand writing. He had poor hand writing and students had hard time reading what he wrote on the slide. During the semester, several times, Jack emphasized the importance of units, numbers and mathematics in science and said "practice makes it prefect" meaning solving a lot of problems will make students good in the numbers and the units. He realized in few occasions that students became bored with the lecture and used some humor to draw students' attention. In one of the lectures he made students do physical exercise. His attempts were mostly unsuccessful.

Max's instruction combined teacher-centered traditional lecturing, group work, and question-answer type teaching strategy. In the latter, he employed the wait-time (Budd-Rowe 1986) rule quite appropriately. Almost after every question he asked, he waited at least for 15 s. Max also used some group work while lecturing; he set apart 5 min of his lecture time for students to work in groups of two or three, where students answered a question usually from the previous lecture. Here is an excerpt that points out this teaching strategy:

> "The instructor showed a slide 'Question from last lecture' and gave students 5 min to come up with a brief answer or several descriptions to the question of how stars work. Under the slide he asked students to turn to their left or right and work in groups. Some students were working in groups; some were working alone, and some not working at all." (Obs. #3 of Max, 02/17/05)

However, students mostly spent their time of group work talking to each other and not about the problem, and did not work in groups. Sometimes Max used demonstrations while lecturing to explain a concept further, and sometimes he used visual aids such as showing a video of star formation for a couple of minutes to explain a concept. Occasionally, Max used the technology inappropriately by moving very fast from slide to slide and sometimes using tables on the slide, which were quite small to read. Max seldom used complex science language, such as physical units, without explaining their meaning. Few times he used positive language, such as "it is a very good answer", to encourage students when they answered his questions correctly.

The instruction of Chris was again a mixture of teacher-centered traditional lecturing with some use of technology, such as Power Point presentation and use of computer animations to explain a certain concept. He incorporated question-answer type teaching strategy, where sometimes he used wait time. Chris used demonstrations while lecturing to explain a concept further, such as picking up two or more students and bringing them in front of the auditorium to demonstrate the expansion of the universe, and sometimes he used visual aids, such as showing computed animations on the screen while explaining the special relativity theory or showing a video of star formation. He also used examples from everyday life to explain certain concepts, for example, when explaining the special relativity theory he gave examples from moving cars. Sometimes Chris used the technology inappropriately. He moved very fast from slide to slide and used tables on the slides which were quite small to read, and sometimes had problems showing some animations. This could be due to the fact that this was his first year teaching an introductory science course in such a big class. Furthermore, Chris talked very fast which prompted students to complain. He also had a thick accent so some students had hard time understanding him. Some students also complained about the difficulty of the exams. He then changed the grading system of the exams instead of addressing the core issues – the level of difficulty. He no longer reduced points for false answer in the multiple choice exams. On a few occasions he was not able to exert his authority over the students. He believed that they should not go to the restroom whenever they need and he warned them not to go out but the students were still leaving whenever they wanted. In most of the question-answer type instruction Chris was not able to get responses from students, and in most occasions he had to force them to give him an answer.

Lena's instruction represented a teacher-centered traditional lecturing, employing however technology, such as Power Point presentation and visual aids, such as photos and graphic illustrations. She also incorporated, in few lectures, a question-answer type teaching strategy, where she used some wait time, but not always, and where students did not participate willingly. Lena was enthusiastic about her topics; she moved all around the auditorium while explaining the material. On the negative side, she spoke very fast and sometimes moved through the slides quickly. The researcher assumes that this was because she wanted to cover everything about a concept in one lecture time.

Lena also used examples from recent global and local events to explain certain concept; for example, she used photos of people running on streets from an earthquake in Kyoto, Japan, or photos from the tsunami in Indonesia. She also incorporated real life stories and events in her instruction, and in few occasions made jokes to keep students' attention on the lecture. On a few occasions, Lena displayed classroom management skills, she warned students to listen to her when they become noisy during the lecture.

Student-teacher interactions

Jack made eye contact only with the students sitting in the front rows, who were listening attentively. But the students in the back rows after a while usually lost interest with the lecture and started to show signs of disinterest and boredom by talking among themselves in groups of two or three in a low voice, some just looking disinterested with the lecture, some reading the school newspaper or solving a puzzle on it, some playing with their cell phones, some reading a novel or a magazine, some solving math problems for another class, some eating food in class, and some sleeping. The class period was scheduled for lunch time and so some students were bringing lunch to eat it in class. This eating prevented them from concentrating on the lecture. The researcher observed these signs of disinterest and boredom in Max, Chris, and Lena's lectures.

Start of the lecture

Jack usually opened up his lectures with a relaxing talk about recent events in the media, such as the Super Bowl, or made jokes. He always asked students whether they had any questions about anything at all in the beginning of the lecture. Usually students asked questions about the procedures of an upcoming exam. In few lectures he made few announcements about the upcoming exams. Jack usually started with a summary of last lecture. Several times during the semester the teacher had some classroom management problems at the beginning of the lecture. The class atmosphere before the lecture can be inferred from the following observation excerpt:

> "I arrived at 12:20 pm. There were few students in the class, around 40 students. Students were entering a few at a time, some sitting in the front rows and some in the back rows. I sat on the right seventh front row next to the wall in the auditorium. There were few students reading newspapers in the front rows. Students were talking among themselves and students in the back were talking louder than students in front rows. Students were now coming in steadily. The teacher came at 12:30 pm and put his bags on the front desk. The instructor put the overhead projector on the front table and prepared it for class. The first two blinds were closed already. Students were talking loudly and a few more were coming still, some were leaving for the restrooms. The instructor was preparing his notes. A few students in the front rows were still reading the school newspaper. Students were still talking loudly among themselves. The teacher turned off the lights and said 'Hello, how are we doing? It is no Miami Beach out there I can tell you that.' He reminded students that they have an exam next week and said 'Any questions about anything?' A girl asked a question about the seating in the exam and the instructor answered. A boy asked a question about whether he will do a review section

at all. Jack said that he did not plan for that, but he will give them a practice exam today and will answer it next Tuesday, which is the class before the exam. The instructor then said 'Are we good? Any other question of any kind?' there were no question asked from the students. Jack continued, 'Patriots were good. Next year the Dolphins, my team, will do better than this year.' He opened up the lecture with a current event, which was the Super Bowl played on Sunday night, to get the students attention and started the lecture." (Obs. #8 of Jack, 02/10/05)

Max, Chris and Lena usually also started their lecture with a summary of previous lecture, making few general announcements, giving an introduction to the material they will cover for the day, and asked students whether they had any questions about the last lecture.

Lena also used some warm up conversation with the students as Jack did, such as making jokes or discussing Super Bowl. She also gave assignments in the beginning of some of her lectures for extra credits, such as writing one page essays about evolution, listening to visiting scientists and writing their opinions about the presentation, or watching a special movie on Discovery Channel and writing a small paper. Lena was also highlighting the important concepts that will be included in the exams and how to study for them.

Incorporating NOS language in instruction

Jack hardly used any NOS language in his instruction. In two or three lectures, he used history of science in his instruction by giving background information about the development of the equilibrium concept or the life of a scientist, such as Newton. Here are some examples:

> "The instructor stated to explain a new theory from chapter 14.5 on the book. The theory was temperature half rate collision theory or more known as transition state theory. The teacher then explained that this theory started in 1950s and gave a brief history of how this theory developed." (Obs. # 3 of Jack, 01/25/05)

> "Jack gave some example from the history of science he said "Arrhenius did his equation as a dissertation and got the lowest possible grade for it and 15 years later he got the Noble Prize. That shows us that it is not so bad to have multiple-choice exams. That shows us that grading is subjective."(Obs. # 5 of Jack, 02/01/05)

In one occasion he gave an incorrect example of NOS language. He suggested that there is only one kind of scientific method in science and wrote on a slide the so-called steps of the scientific method. This kind of instruction is not recommended by science educators, such as McComas (1998) who says that "this is one myth that may eventually be displaced … in favor of discussion of *methods* of science" (p. 58, italics from the author).

In one lecture he appropriately incorporated the subject of science and religion in this lecture. He devoted nearly 10 min of his instructional time to science and religion. Here is the excerpt from that observation:

> "At 13:33 the instructor stopped the lecture and took time to talk about what he saw on the web last night about the guy who invented the laser and maser. Jack said that the guy who invented the laser won the Templeton award which is $1.6 million dollars and which is given to people who reconcile science and religion. Then he asked the following question: "Do people think that there is some connection between science and religion? Raise your hands if you think so." Five students raised their hands. Then the teacher asked students to raise their hands if they think that there is no any connection between religion and science. Three students raised their hands. The instructor then asked students to raise their hands if they think that it doesn't matter if there is connection or not. Around ten students raised their hands. Jack then started talking about the religion and science connection and said that these people in Templeton awards were crazy to waste their money in something that does not contribute to society at all and asked students for their opinion. A white female said that she is religious person, but also a science major and that she coincides them with no problem at all." (Obs. #15 of Jack, 03/10/05)

Jack hardly showed any signs of enthusiasm about his subject, he spoke in a monotonous voice during the entire semester. On a few occasions during the semester he pointed out the benefits of chemistry to the society. He also sometimes incorporated relevant examples from recent and everyday events to explain chemical concept. Here is an excerpt that highlights his strategy:

> "Jack tried to make students interested in studying science. He gave the example of space ship that landed on the moon of Saturn, which is called Titan. He said 'we placed a ship on the moon of Saturn. If that does not amaze you I don't know what will.' He tried to make the point that science is interesting to study. Then he proceeded with the lecture by describing the velocity of an unknown molecule." (Obs. #1of Jack, 01/18/05)

Max also rarely used history of science as a NOS teaching strategy. He provided background information about some of the scientists he mentioned while explaining a concept, however, he did not explicitly emphasize the NOS aspects. Few times he did not provide background information about some of the scientists he mentioned.

Chris, few times, used inappropriate NOS language, such as emphasizing importance of the units and equations in science. For example, once he said “I am teaching you science, and equations are language of science” meaning that students have to learn how to use the equations in science and once he said “you have to know something about some scientific facts if you want to pass this class”. Although scientific facts belong to NOS, just stating this without clarifying the NOS language undermines the tentative and creative aspect of science. In most of his lectures Chris used history of science as a NOS teaching strategy, he gave background information about scientists and in one occasion he gave a brief history of the beginning of the science of cosmology from early Greeks until now. On the negative side, he also did not elaborate on the names he referred to in his lectures.

Lena used a lot of NOS language in her instruction, almost in every lecture, to point out the tentative, subjective, empirical, experimental nature of science. She used history of science by giving background information about scientists and scientific concepts. In a few lectures she talked about the myths of science and about scientists in their real life laboratories by showing photos of scientists. Lena also devoted entire two lectures of her instructional time to nature of science and how science works, she talked about science versus religion, science versus creationism, what is science and what is not, explained the difference between what is a theory and what is scientific fact. In one lecture Lena raised politically sensitive issues, such as the Kyoto agreement on global warming. Here is an example:

> “The teacher showed a photo of President Bush and said, “you know a little bit now on how science works, you have to make your minds when making political decisions. Ok, I am showing my true colors, I am a liberal (laughingly).” A few students laughed too. Lena showed few more slides explaining global warming at 10:56 and a slide ‘Sea-Level Rise’. The females on back were talking in a little bit loud voice from time to time. The teacher showed few more slides explaining sea level rise and what will happen if sea level rises. Students were quiet, listening and some taking notes. The instructor then talked about Global Climate Models and how they work as computer simulations and showed a slide ‘The Kyoto Protocol’ and talked about how it came in effect and how President Bush, before the 2000 elections, supported it and then changed his mind while in office and his lack of understanding of this issue. A white female left the class angrily after these comments at 11:12 slamming the door, while the teacher was talking about Bush’s policies on Kyoto protocol.” (Obs. #14 of Lena, 04/13/05)

Class size

The class size of all three courses were quite large. It changed from lecture to lecture, but the average size was around 130, some days it was 90 and some lectures, especially during the review sessions, it was near 250. In the beginning of the semester there were usually around 200 students inside Jack’s auditorium, but at the end of the semester the class size dropped dramatically some times to 50 students in attendance. The female-male ratio was in favor of males in Max and Chris’ course and in favor of females in Lena and Jack’s classes. There were very few minority students in all of the courses. Around 30 out of 150 students comprised the minority population. There were a little bit more African American students and slightly more Asian American students in Lena’s class compared to the other two classes. The big class size affected teacher-student interactions, because sometimes instructors did not see students who held their hands up, and missed the opportunity to interact with them.

Student actions

Students in the three classes were usually not in time for the lectures, few students were coming 10–15 min late and few students were coming maybe half or one hour late. Furthermore, students were leaving the classes at random times, usually for the restrooms or to get food from the vending machines outside the auditoriums. They would leave for 5 min and come back again, and sometimes they would leave with their belongings early without waiting till the end of the lecture. In all of the classes there were some students, who showed signs of boredom and distraction from the lecture, such as playing with their cell phones, reading the school newspaper or solving a puzzle on it, eating food, sleeping, and very few playing with their laptops. Students usually showed these signs of boredom in the beginning and at the end of the lectures and were preparing to leave class or became noisy when the time was up for the lecture, even though the teacher was still talking.

All the instructors usually finished their lecture with a summary. Students who were interested in the lecture usually preferred to sit in the front rows and were attentively listening with some taking notes and generally they were the same students throughout the semester. Overall, students in Max, Chris and Lena’s classes were usually attentively listening with some students taking notes.

Students in Jack's class seemed more disinterested and showed more signs of boredom with the lectures compared to the other three instructors. On a few occasions, I saw signs that students did not understand Jack's explanation, as they were talking among themselves and asking students next to them what the instructor was saying.

From the above sub-themes about participants' teaching we can see that Jack has a traditional teacher-centered instruction style, where he is mainly concentrated on problem solving, and Max, Chris and Lena have instruction that is a mixture among teacher-centered traditional lecturing, group work, and question-answer type teaching strategy. Jack, Max, and Chris had an instruction with very little incorporation of history and philosophy of science and very little or no instruction geared towards the various aspects of NOS as recommended by researchers, such as Akindehin (1988); Billeh and Hasan (1975), Carey and Stauss (1968), Jones (1969); Lavach (1969), Lederman (1999), and Ogunniyi (1983). It appears that the critical role and possible influences of other variables of teaching science, such as pressure to cover more content and solve more problems, large class size, lack of management and organizational skills, instructors concerns for students' abilities and motivation, students' disinterest, instructional constrains, teaching experience and lack of recourses and experiences for assessing conceptions of NOS are more important for Jack, Max and Chris than teaching for understanding of NOS. Even though Lena used the same teaching strategies as Chris, Max, and Jack, she used a lot of NOS instances in her instruction, and purposefully incorporated history of science. Lena's teaching strategy was different from theirs, because she held the most informed views on NOS, was very passionate about her subject, focused on teaching creationism versus evolution in schools and thought that students should know the difference between scientific and other ways of knowing. From Lena's instruction we can conclude that even if there were various constrains, such as drive to cover more content, larger class size, and students' disinterest that prevent incorporation of the various NOS aspects, college science instructors still can teach for understanding of those aspects, if they clearly understood its importance.

Instructors' Rationales for their Teaching

Participants gave various explanations of their teaching and provided rationales for using or not using certain teaching techniques in their follow-up interviews. In what follows these views are presented and grouped according to emerging themes.

Class Size Effect

Jack, Max, Lena, and Chris, all emphasized that they encountered various problems when teaching in a large introductory class. Jack said the class size effect "is enormous, it makes all the difference," because it is hard to interact with students in a class of over 100. "It is hard to get students to talk; it is hard to get students to be fully engaged, to have any single back-and-forth." He pointed out peer pressure as a reason not to participate in lecture in such a large class:

> "even if they are concerned about how the professor thinks, they are also concerned very much about how their peers think. Not that they are necessarily either right or wrong about what they are saying, but there are other things that come up. Is this guy a suck up, because he is talking to the professor, is he just brown nose trying to win points, or he is an idiot, or he is really smart, but still is sucking up? Nobody wants to look like an idiot, not because they care what the professor thinks, but because of what that pretty girl over there thinks or that good looking guy over there thinks, or they don't want to look like they are talking to the professor, because they will think that guy over there will think that she is too smart and not attractive. I mean all those weird, strange things come into play." (Jack)

Jack personally believed "classes work best when students have a question or even an idea that can be blurted out at the time, but it is harder to get that to happen in a big class." He thought, "whenever you can have a smaller class it is a better class and it works really well, because it is easier to maintain collective focus of what you are trying to talk about." Max said, it is "difficult to be able to gage how individuals are following," and it is hard to check if students "are doing the readings before hand that they are supposed to do" in a large class. Max further explained:

> "and you tend to be more influenced by maybe the portion of the class that is not following, so you can bore the people who are following; all those kinds of things are more difficult in a larger class, and definitely influence your instruction." (Max)

Chris also said that it is hard to make sure that everybody is following the lecture in a large class. Lena said that "it is hard to do any real interaction with 300 people," it is hard to get "any kind of feedback," and it is easy for students to tune out of the lecture in a large class. Chris and Jack explained that the reason why they have large classes in their university is that they don't have enough professors who can teach those introductory classes.

Use of Technology and Demonstrations in Instruction

All four of the scientists used some kind of technological device when presenting their lecture, such as an overhead projector and Power Point slides. They gave various reasons. Jack said that using overhead projector slows him down and gives the students better chance to take notes. And also "in a very odd sort of way," because his "hand writing is very horrible, students have to struggle to be able to read it, but that means they are reading it, they actually have to figure out" what he wrote. Max said, astronomy is a field that "is rich in visual imagery, you can show a lot of nice pictures, you can show animations, which motivates people" and makes them active listeners. Lena said "geology is a pretty visual thing" and using visual images on Power Point presentation help her "sort of bring the excitement about the subject." Chris said that he uses animations and demonstrations to make some concepts more understandable to students. These explanations show that incorporation of some visual imagery or animation, or making demonstrations helps in motivating students and in their understanding of some science and NOS concepts.

Perspectives on the use of Group Work in Instruction

Chris and Max used group work in their instruction and when asked why Chris said group work helps students to communicate their thoughts in front of someone else and makes them think about the subject. Max said that group work helps students to learn from each other and "sometimes students are less threatened by a fellow student, so they don't mind saying that they don't understand something to a fellow student than they will to an instructor." Jack pointed out that the large class size and pressure to cover content prevents him from utilizing group work in his instruction. He has "an open mind to different modes of instruction, but wouldn't know how to do that with a class that size." These explanations reveal that even in a very large class some group work can be incorporated in a lecture, however instructors should be shown how to do that and if the large class size problem is overcame utilizing group work could be much easier. This in turn could help instructors to incorporate some aspects of NOS in these group work activities.

Use of Sophisticated Science Language

Max, Chris and Jack, at one point in their instruction, used complex sophisticated science language, such as some science units and formulas that can sometimes be hard for students to understand. When asked why, they gave different explanations. Max said "partly the education is about coming familiar with another language, so sometimes we will use that language before all the ideas are there, and then when they see it a second or third time they should think better." Chris said that he used units and equations to help students understand how to "formularize thought relation in an equation." Jack said "the units are extremely important" and that there is an art to them. He also said that units and equations are "the language of chemistry." Jack, Max, and Chris saw using units and formulas as extremely important. On the other hand, Lena did not use units and formulas often in her instruction. This can be due to the fact that she was in a different field, an Earth scientist, as compared to Jack, the chemist, and Max and Chris, the physicists.

Use of Q&A in Instruction

All of the participants incorporated, to some degree, question and answer (Q&A) type teaching in their instruction and gave varying reasons why they did it. Jack said he used Q&A just to keep the lecture "more interesting" for students and that "it is a question of getting information from the students" with the hope to modify the "interface with the students better," but acknowledged that "it is just hard to get students to do it." He pointed that it is a matter of communication skills and that it "is a interpersonal dynamic, a complex thing, some people are very good at it, and some people get better at it as they get older and some more confidence, and some people are never good at it and that is the way it is." Jack emphasized that "people do not get jobs as professors, because they are going to be great teachers", but because they are going to be good researchers with good communication skills who care, which is worrying for science education in general, especially in the introductory classes, where students need the most capable instructors with a good pedagogical background to help them understand the workings of science according to their developmental level. Max uses Q&A to help student to improve their writing and communication skills and to practice for the exams, and tries to incorporate as much as possible Q&A in his instruction. Lena and Chris said they use Q&A to keep students awake enough and engaged enough and to force them to think about the subject and that they start paying attention to the lecture. Clearly Q&A was seen by the instructors, as good instructional strategy that can engage students with the lecture and help them see students' level of understanding of the lecture.

Use of History of Science in Instruction

Max, Lena, Chris, and Jack all incorporated some history of science in their instruction. They all talked about the important scientists relevant to their subjects. Max said he incorporated history of science, because it helps students "to realize that science is done by ordinary people", and because he hopes to "appeal to people interested in the social sciences, and humanities." Max uses history of science when it is relevant to a particular topic and when it clarifies some ideas and explains the complexities about our world. Chris incorporates history of science to put science in a "bigger picture, to give them an historical perspective or who the people are behind the names that appear." Jack also includes history to put "the scientific information, a scientific knowledge in a human context" and to make "something relevant." He uses history of science "every chance" he gets. Lena said that using history in instruction helps students to "identify with those old people" and make science more accessible to students. She uses history when it comes up in the lecture, when she is talking about the "really big concepts." The observed faculty clearly saw use of history of science as an important instructional strategy that can help them to put "the scientific information in a human context" and to make science relevant to students. They incorporate history of science when they see it is relevant and important in a lecture. This shows that if intended instructors can incorporate history of science in their instruction as recommended by various science philosophers and educators.

Use of Problem Solving as a Primary Instructional Tool

Jack was the only one who used problem solving as his main instructional tool. He solved problems after every new concept he introduced. Jack said the reason why he uses problem solving is because "in chemistry that is the way it is done, chemistry is all about solving problems, you live and die by problems, problems are what actually illustrates the concepts, illustrates the mechanics of how you do it." The fact that Jack saw problem solving as the main feature of chemistry contradicts science education literature, because such a priority in teaching science to freshmen students gives a false image of science and makes students think that science is all about mathematics. Also, such a way of teaching science leaves very little room for incorporating demonstrations, relevant examples and some of the NOS aspects in instruction, as Jack said he wants to incorporate.

Use of Assignments

Lena was the only one, who gave students assignments for extra credit. She explained that she wanted to give "students who are interested and engaged another outlet to express what they think," and further said the large class size prevents her from using more assignments in instruction. This compounds the issues with class size explained above and can be another reason for reducing the class size in the introductory science courses.

Reasons for Students Distractions with the Lecture

In all of the classes that I observed, there were various levels of distraction and a number of distractors. Some students were not involved with the lecture at all, some were leaving for the restrooms, some were coming late to class, some were leaving the class early, some were reading the school newspaper, some were solving puzzles, and some were sleeping. Lena said she hardly noticed any of those activities going on in her class. The researcher is assuming that the reason for this is that she was enthusiastic about her topic and fully immersed in her explanations. When asked why students come to class if they are not going to listen, she said that "there is enough guilt involved with not going to class that they figured they better go, but they don't think it is important enough to actually listen." Chris also said he hardly notices any of the above mentioned activities and if he notices he "will do something about it." Jack said as long as students do those activities quietly and "they don't interrupt the students and their friends" and do not disrupt the class he doesn't care. He said, "if it is a small class that is a different matter, because then you can't be disruptive, but in a big class fine." Max said the reasons why students come to class late or leave early are lack of motivation, the failure of private education, and may be because classes are not taught very well by the teachers so the students get bored. Max explained:

> "Many students are actually not paying the tuitions themselves, so they don't realize how expensive one lecture really is (laughingly). So, sometimes I discuss how much they are paying for the lecture. Some of them put themselves through school, but it is usually parents who are paying. I think this is partly the failure of private education, the fact of this sort of buying a degree means that they can decide how they spent their time. And then partly, my guess may reflect on us and they don't want to be there all the time, maybe we just don't teach them well… I am always torn by this, because I think I am not an elementary school teacher, I am not there to hold their hand, they supposed to be motivated in some way, but it is significant enough problem and disrupts enough other students that we try to address it." (Max)

Clearly students' distractions with lecture did not pose a problem for these faculty. This maybe due to the large class size, as pointed out by Jack, because in a large class it was important just to keep the students quiet and not to care whether they listen or not.

What is Good About Teaching Introductory Science Classes in College?

All of the participants said that they enjoy teaching and gave various explanations for that. Max said he enjoys teaching, because he likes to “put back something, be able to change people a little bit, surprise them a little bit to see something in a different way,” and “be around young people,” because “it keeps you younger,” and that is why he likes to “be at the university rather than in industry, where you probably can make more money.” Lena enjoys teaching, because she likes “seeing people get excited about stuff and getting interested in, getting involved, and start to realize why some of these things are important and relevant for them, even in those classes of 200 and 300 to see that it is worthwhile.” Chris enjoys it, because he likes the “feeling that you influence something.” Jack enjoys teaching, because it keeps him fresh and makes him think that he is “doing something positive.” Clearly teaching for these scientists wasn’t a burden. They were highly motivated and wanted to give something back to their students.

Qualifications to Teach Introductory Classes

To the question, what do you think qualifications should be to teach an introductory science class, participants gave a range of answers. Max said the main requirement should be “the willingness to work hard” and “being skilled enough communication wise to reach the right level.” Lena said the instructors “have to like what they are doing” and “be able to bring interest, excitement and enthusiasm” to their instruction, because students “are not going to get excited if you are not excited about it.” Chris said these classes should be “taught by science professors who know what they are talking about.” Jack said “qualifications start with technical confidence, the person must feel completely confident with all the scientific material that needs to be taught,” have some experience, at least four or five years as teaching assistant with more than one professor, and suggested “maybe a person who did have training in education would be better,” because he thought:

> “people who have an education background are more aware of things that pertain to younger students, development rates, what develops first, what develops how, the learning process. They are more aware of that than non-education trained people. I don’t know how important that is when people are mature, as mature as anyone between 18 and 22 sometimes that is not very mature.” (Jack)

Overall, the four faculty wanted people, who teach introductory science courses, to be willing to work hard, know their material well, be enthusiastic, and if possible, professor who are well versed in research.

Problems Encountered While Teaching Introductory Science Class

When asked what problems they encountered while teaching introductory science classes, participants saw the lack of motivation of students and their fear of science, as the main obstacles. Max noted that students often see themselves as “I am not a science person” and “I don’t understand science.” And that they cannot “even make a decent discussion about astronomy with a Greek from 2000 years ago and that idea doesn’t embarrass them.” When Max was asked how we should overcome these problems he said we should “give students some power over their own education, to realize that maybe ultimately what they get out of it is very strongly coupled to how much they put into it” and “to have the instruction continue outside the classroom.” Chris also saw the lack of motivation as main problem and proposed radical solutions, “get rid off the grades” and “science requirements” in colleges, but Chris wasn’t sure about these proposals. Jack’s problems were “getting students to be part of the process, getting students to interact, getting students to do the problem sets” and “the bigger the class the harder it is,” because “when the classes are big it makes it very hard to relate in so many ways.” When asked how we should overcome these problems Jack said “making smaller classes”, making “interesting problems”, making “interesting lectures”, and “try to find a way to motivate students.” Lena saw “fear of science,” disinterest, and students’ lack of mathematical skills as the biggest obstacles to learning science. As a solution she said “try to keep them interested and involved.” Clearly, the lack of motivation by the students and their fear of science were seen as the main obstacles among these faculty.

Suggestions to Improve Introductory Science Classes

Instructors gave several recommendations to improve introductory science classes. Max suggested getting students “to agree to be responsible for some basic knowledge before each lecture, so that we could really focus on what they don’t understand and that is very difficult in these introductory classes.” Jack suggested changing the curricula, but pointed out that “it presents an enormous number of logistical and administrative difficulties.” He also suggested incorporating demonstrations to get students interested, but he himself did not do that in the 23 lectures I observed. Chris gave very brief answer and suggested reducing the class size. Lena also suggested having smaller classes, but pointed that there could be some logistical problems. She also suggested "more hands on individual work, making stuff relevant," having students gain some "fundamental basic math skills", and making "sure you have people teaching the classes that they want to teach." Clearly, reducing the large class size and more hands-on activities were seen as major ways to improve science learning.

Discussion and Conclusion

Findings show that majority of the participants in this study preferred to use the traditional teacher-centered lecturing as their teaching style. Their main concern was covering content, developing problem solving skills and teaching the fundamental principles of their subjects without paying special importance to the aspects of NOS. This is in contrast to the findings and suggestions of others (Akindehin 1988; Billeh and Hasan 1975; Carey and Stauss 1968, 1970; Jones 1969; Lavach 1969; Ogunniyi 1983; and Lederman 1999), who call for an explicit approach to teaching of NOS, where learners are provided with opportunities to reflect on their experiences. This reveals that having incomplete understanding of the aspects of NOS and lack of knowledge of how and when to use these NOS aspects affects the purposeful teaching and incorporation of them in instruction (Shulman 1986). This also shows that other variables of teaching science, such as drive to cover more content, large class size, lack of management and organizational skills, teaching experience, and instructors' concerns for students' abilities and motivation are more important for these scientists then teaching for understanding of NOS, as affirmed by others (Abd- El- Khalick et al. 1998; Brickhouse and Bodner 1992; Duschl and Wright 1989; Hodson 1993; Karakas 2008; Lantz and Kass 1987; Lederman and Latz 1995; Lederman 1999).

On the other hand, the follow up interviews with the instructors reveal that they stated at least one of the NOS aspects as their desired goal for students, when asked specifically, and stated that they talk about history of science in their instruction when they see it is relevant to a particular topic. Lena was the only instructor who purposefully incorporated history of science in her instruction, and who had an instruction geared toward the various aspects of NOS, even though she had the same constraints as Jack, Max, and Chris had. This reveals that instructors still can teach for an understanding of NOS, even with various constrains and provided that they have informed conceptions of NOS. Also, research literature clearly indicates that students, teachers, lay people, and even scientists do not necessarily hold adequate conceptions about many of the NOS aspects (Irez 2006; Karakas 2008; Lederman 1992; McComas 1998; Schwartz 2004). Similarly, this study supports this claim and reveals that majority of the participants in this research also held some inadequate conceptions about NOS. This study suggests that if we have a communication between science educators and faculty who teach introductory science classes, the later can be convinced to incorporate some NOS aspects in instruction, and having better communication between the two will make both of them aware of each others goals and concerns while teaching novice students. Thus, more close collaboration between scientists in art & science and science education departments is recommended in designing curricula, reading and sharing of literature, and establishing workshops and conferences that discuss strategies for reforming undergraduate science education, specifically in the area of NOS.

Another important finding is the need for reducing the size of introductory science classes to allow for more meaningful instruction and incorporation of new, innovative teaching styles where students will have more opportunities to become engaged with the material. This finding suggests that undergraduate science education should be reorganized into small discussion type classes where students can work in groups toward conceptual change in their views about certain science concepts and toward greater understanding on the workings of science. Max and Chris' teaching reveal that even in a very large class some group work can be incorporated in a lecture, however instructors should be shown how to do it and if the class size is reduced utilizing group work could be much easier. This in turn would help instructors incorporate some NOS aspects in these group activities. The problem of lack of professor who can teach these courses, as pointed out by Chris and Jack, could be overcome by hiring adjunct instructors, who are in the last stages of getting their PhD degrees, or by hiring PhD students from the science education departments with the appropriate undergraduate degrees.

Appendix 1

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 evaluate 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?

References

Abd- El- Khalick F, Bell RL, Lederman NG (1998) The nature of science and instructional practice: making the unnatural natural. Sci Educ 82:417–437

Abd-El-Khalick F, Lederman NG (2000) Improving science teachers' conceptions of nature of science: a critical review of the literature. Int J Sci Educ 22(7):665–701

American Association for the Advancement of Science (1989) Project 2061: Science for all Americans. Author, Washington, DC

Akindehin F (1988) Effect of an instructional package on preservice science teachers' understanding of the nature of science and acquisition of science- related attitudes. Sci Educ 72:73–82

Behnke FL (1961) Reactions of scientists and science teachers to statements bearing on certain aspects of science and science teaching. School Sci Math 61:193–207

Billeh VY, Hasan OE (1975) Factors influencing teachers' gain in understanding the nature of science. J Res Sci Teach 12(3):209–219

Bogdan RC, Biklen SK (1998) Qualitative research for education: an introduction to theory and methods, 3rd edn. Allyn & Bacon, Boston, MA

Brickhouse NW, Bodner GM (1992) The beginning science teacher: classroom narratives of convictions and constraints. J Res Sci Teach 29:471–485

Budd-Rowe M (1986) Wait times: slowing down may be a way of speeding up. J Teach Edu 37(1):43–50

Carey RL, Stauss NG (1968) An analysis of the understanding of the nature of science by prospective secondary science teachers. Sci Educ 52:358–363

Carey RL, Stauss NG (1970) An analysis of experienced science teachers' understanding of the nature of science. School Sci Math 70:366–376

Creswell JW (2002) Educational research: planning, conducting, and evaluating quantitative and qualitative research. Merrill Prentice Hall, Upper Saddle River, New Jersey

Duneier M (1999) Sidewalk. Farrar, Straus and Giroux, New York, NY

Durkee P, Cossman G (1976, April) Views on the nature of science among college science faculty. (ERIC Document No. ED131999). Paper presented at the 49th annual meeting of the National Association for Research in Science Teaching, San Francisco, CA

Duschl RA (1985) Science education and philosophy of science twenty-five years of mutually exclusive development. School Sci Math 85(7):541–555

Duschl RA, Wright E (1989) A case study of high school teachers' decision making models for planning and teaching science. J Res Sci Teach 26:467–501

Glasson GE, Bentley ML (2000) Epistemological undercurrents in scientists' reporting of research to teachers. Sci Educ 84:469–485

Glaser B (1992) Theoretical sensitivity: advances in the methodology of grounded theory. Sociology Press, Mill Valley, CA

Hammersley M, Atkinson P (1995) Ethnography: principles in practice, 2nd edn. Routledge, New York

Hodson D (1993) Philosophic stance of secondary school science teachers, curriculum experiences, and children's understanding of science: some preliminary findings. Interchange 24:41–52

Hurd PD (1960) Biological education in American secondary schools, 1890–1960. AIBS, Washington, DC

Irez S (2006) Are we prepared? An assessment of preservice science teacher educators' beliefs about nature of science. Sci Educ 90:1113–1143

Jones KM (1969) The attainment of understandings about the scientific enterprise, scientists, and the aims and methods of science by students in a college physical science course. J Res Sci Teach 6:47–49

Karakas M (2008) Science professors' understanding and use of nature of science. VDM Verlag, Saarbrücken, Germany

Kimball, ME (1967–1968) Understanding the nature of science: a comparison of scientists and science teachers. J Res Sci Teach (5):110–120

Lantz O, Kass H (1987) Chemistry teachers' functional paradigms. Sci Educ 71:117–134

Lavach JF (1969) Organization and evaluation of an inservice program in the history of science. J Res Sci Teach 6:166–170

Lederman NG (1992) Students' and teachers' conceptions of the nature of science: a review of the research. J Res Sci Teach 29(4):331–359

Lederman NG (1999) Teachers' understanding of the nature of science and classroom practice: factors that facilitate or impede the relationship. J Res Sci Teach 36:916–929

Lederman NG, Abd-El-Khalick F, Akerson V (2000) Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. J Res Sci Teach 37(4):295–317

Lederman NG, Abd-El-Khalick F, Bell RL, Schwartz RS (2002) Views of nature of science questionnaire (VNOS): toward valid and meaningful assessment of learners' conceptions of nature of science. J Res Sci Teach 39(6):497–521

Lederman NG, Latz MS (1995) Knowledge structures in the preservice science teacher: sources, development, interactions, and relationships to teaching. J Sci Teacher Educ 6:1–19

McComas W (1998) The principal elements of the nature of science: dispelling the myths. In: McComas WF (ed) The nature of science in science education rationales and strategies. Kluwer Academic Publishers, Netherlands, pp 53–70

Munby AH (1976) Some implications of language in science education. Sci Educ 60(1):115–124

National Research Council (1996) National science educational standards. National Academy Press, Washington, DC

National Science Foundation (1996) Shaping the future: new expectations for undergraduate education in science, mathematics, engineering, and technology. (A report on its Review of Undergraduate Education by the Advisory Committee to the Directorate for Education and Human Resources, NSF Publication No. 96–139). Author, Arlington, VA

National Society for the Study of Education (1960) Rethinking science education (59th Yearbook, Part I). University of Chicago Press, Chicago

National Science Teachers Association (1982) Science-technology-society: Science education of the 1980s. Author, Washington, DC

Ogunniyi MB (1983) Relative effects of a history/philosophy of science course on student teachers' performance on two models of science. Res Sci Technol Educ 1:193–199

Pomeroy D (1993) Implications of teachers' beliefs about the nature of science: comparison of the beliefs of scientists, secondary science teachers, and elementary teachers. Sci Educ 77(3):261–278

Roth WM, Lucas KB (1997) From "truth" to "invented reality": a discourse analysis of high school physics students' talk about scientific knowledge. J Res Sci Teach 34(2):145–179

Saunders HN (1955) The teaching of general science in tropical secondary schools. Oxford University Press, London

Schmidt DJ (1967) Test on understanding science: a comparison among several groups. J Res Sci Teach 5(6):365–366

Schwartz, RS (2004) Epistemological views in authentic science practices: a cross- discipline comparison of scientists' views of nature of science and scientific inquiry. Unpublished doctoral dissertation, Oregon State University, Oregon

Schwartz RS, Lederman NG (2002) It's the nature of beast': the influence of knowledge and intentions on learning and teaching nature of science. J Res Sci Teach 39(3):205–236

Shulman LS (1986) Those who understand: knowledge growth in teaching. Educ Researcher 15(2):4–14

Van Maanen J (1988) Tales of the field: on writing ethnography. University of Chicago Press, Chicago

Welch WW (1979) Twenty years of science curriculum developments: a look back. In: Berliner DC (ed) Review of research in education, vol 7. AERA, Washington, DC, pp 282–306

Zeidler DL, Lederman NG (1989) The effects of teachers' language on students 'conceptions of the nature of science. J Res Sci Teach 26(9):771–783