A STUDY OF UNDERGRADUATE STUDENTS' PERCEPTIONS ABOUT NATURE OF SCIENCE

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Abstract. Present study examines undergraduate students' understanding of nature of science (NOS). The researcher analyzes survey data collected from 52 undergraduates (mostly freshman) at a Private Research University in Northeastern U.S., who were enrolled in a Biology course. Present study reveals that there is no significant difference of the understanding of NOS among science majors, non-science majors and undecided group of undergraduate students and that they hold contemporary views about some aspects of NOS and traditionalist views about other aspects. This study calls for improving the teaching of NOS in high school and college classrooms.

Keywords: nature of science, college science teaching.

Introduction

Teachings in ways that help students understand nature of science (NOS) has long been central goal of science education (Voelker & Wall, 1973). There has been a long tradition of theoretical writings concerned with establishing the cultural, educational, and scientific benefits of teaching about NOS, and of infusing epistemological considerations into science programs and curriculum: Schwab (1945, 1958) `s writings in the 1940s and 1950s, the article of Klopfer (1969) and the book of Robinson (1968) in the 1960s, and more recently the paper of Lederman (1992), the thesis by Abd-El-Khalick (1998), and a number of others (Lawson, 1999). All these indicate that if we want students to learn and become competent in science, then they must be taught something about nature of science (Lawson, 1999).

However, in spite of a general and long-term philosophical commitment to this goal, the vast majority of research forces the conclusion that the goal has been largely unfulfilled. Part of the problem can be attributed to a justifiable confusion about just what science and nature of science is (Lawson, 1999).

In response to the question: “What is science?” there is no adequate definition, but the remark of Edwin Hubble is perhaps as good as any of the attempts: “Equipped with his five senses, man explores the universe around him and calls the adventure science” (Hubble, 1954, p.6), or in short by science people attempt to understand the universe. Typically, nature of science refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). These characterizations nevertheless remain fairly general, and philosophers of science, historians of science, sociologists of science, and science educators are quick to disagree on a specific definition for NOS (Lederman, 1992). Such disagreement should not be surprising given the multifaceted and complex nature of the human endeavor we call science (Lederman, 1992). Moreover, similar to scientific knowledge, conceptions of NOS are tentative and dynamic: these conceptions have changed throughout the development of science (Lederman & Abd-El-Khalick, 1998).

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 that fully describes all scientific knowledge and enterprises (Schwartz & Lederman, 2002) and there is always likely to be an active debate at the philosophical level about NOS (McComas, 1998). However, at the level of helping individuals understand the basic of science in order to promote an effective science literacy, there is an agreement (even though not complete) about the aspects of NOS among science educators that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded (Lederman et al., 2000). Also two additional important aspects are the distinction between observations and inferences, and the functions of and relationships between scientific theories and laws (Lederman et al., 2000).

Abd-El-Khalick (1998) and Lederman et al. (2000) in their critical review of literature state that results from several studies (Aikenhead, 1973;

Broadhurst, 1970; Lederman & O'Mally, 1990; Rubba, 1977; Tamir & Zohar, 1991; Wilson, 1954) were consistent, regardless of the assessment instruments used in the individual studies, that students have not acquired adequate understanding of NOS. For instance, students thought that scientific knowledge was absolute, that scientists' main concern was to collect and classify facts in order to uncover natural laws, and that hypotheses can be proven true (Lederman et al., 2000). Additionally, students had inappropriate conceptions of the role of creativity in science, the role of theories in guiding the scientific research, the difference between experimentation, models, hypotheses, laws, and theories, as well as inadequate conceptions of the interrelations and interdependence of the different areas of science (Lederman et al., 2000). Even the most capable students and those most interested in science showed lack of knowledge of the aspects of science (Lederman et al., 2000). Researchers therefore argued that science curricula were not successful in improving such knowledge (Abd-El-Khalick, 1998).

As seen from the above summary of literature there is confusion about NOS even among science educators, then how we can expect students to have appropriate understanding about NOS. It is expressed in the writings of Cobern (1993) that one can pass exams and still not have had appropriate understanding about NOS. Furthermore, Lederman (1999) writes that "teachers' conceptions of NOS do not necessarily influence their classroom practices." All these writings suggest improving teaching of NOS.

This study attempts to explicate undergraduate students' perceptions of nature of science, and more specifically tries to figure out if there are any significant differences about the contemporary views of NOS among science majors, non-science majors, as well as a group of students who have not decided their major yet. Such information should provide useful data to increase our understandings of NOS's perception among undergraduate students. In addition, results of the present study should provide ways to improve our instructions in high school and college level.

Methods

Subjects

The population of the present study came from undergraduate students of a private research university in Northeastern United States who were taking BIO-123 course in Fall semester of 2001. The present sample ($n = 52$) consists of science majors, non-science majors, as well as undecided group of students.

Science majors comprise 30.8 % (n = 16), non-science majors 50.8% (n = 29), and undecided group comprise 13.5 % (n = 7) of the population. Male participants comprise 19.2 % (n=10) and female students comprise 78.8% (n=41) of the population. The distribution of class level of the population was as follows; freshmen were 55.8% (n=29), sophomores were 28.8% (n=15), and juniors were 13.5% (n=7). Age of the population was as follows; 50% (n=26) were 18 years old, 26.9% (n=14) were 19 years old, 15.4% (n=8) were 20 years old, and 2% (n=2) were over 20 years old (one 21 and one 22 years old).

Procedures

Questions on the questionnaire were constructed by the author based on relevant previous literature about NOS (questions were prepared based on the questionnaires previously made by Lederman & O'Malley (1990); Lederman et al. (2002); Bell et al. (2000); and Alters (1997). Then the researcher consulted with the instructor of BIO-123 course about the questionnaire. As a result of this consultation some changes were made on the questionnaire and a questionnaire of nine questions (*cf*. Appendix A) was prepared. Five of these questions were Yes / No questions and the remaining four were open-ended questions, which require writing of participants' opinion. A total number of 100 questionnaires were given to the instructor of BIO-123 in the Biology department at the Private Research University to be distributed to his students. Questionnaires were distributed and collected by the instructor. A total of 52 questionnaire forms were returned and then analyzed by the researcher.

Analysis of Results

Responses to the questionnaires were analyzed according to the contemporary views of NOS, which were presented as follows by Abd-El-Khalick (1998):

1) *Tentativeness* – Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge;

2) *Empirical basis* – Scientific knowledge is based on and/or derived from observations of the natural world;

3) *Subjectivity* – Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal

subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work;

4) *Creativity* – Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of natural world;

5) *Social and cultural embeddedness* – Science is a human endeavor and, as such, is influenced by the society and culture in which it is practiced. The values and expectations of the culture determine what and how science is conducted, interpreted, and accepted;

6) *Observations and inferences* – Science is based on both observations and inferences. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientists guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations;

7) *Theories and laws* – Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

Each of the above mentioned contemporary aspects of NOS were analyzed separately, by looking of undergraduate students answers to each question, because each question was representing one of these contemporary aspects of NOS.

Results

Analysis of the demographics data shows that subjects weren't equally divided into science majors, non-science majors and undecided group. Big portion of the subjects were females, which shows that the study is mainly representing female undergraduates' views of NOS. Majority of the participants were between 18 and 20 years old, which is the age of undergraduates, who graduated from high school and attended the college without interruption of their education and have fresh experience with high school curriculum. Table 1 reveals the valid and missing points in demographics data.

Table 1.

Statistics

N	Valid	52	51	51	50
	Missing	0	1	1	2

In what follows analyses of responses of every subject group (science majors, non-science majors and undecided) to each of the questions in the questionnaire are presented. To question number 1 in the questionnaire that represents the tentativeness of science students responded as follows (Table 2):

Table 2. Percent of Affirming and Non-Affirming Answers to Tentativeness of NOS

Major	**Affirming**			**Non-Affirming**
	N	**(%)**	**N**	**(%)**
Science	**13**	**81.3**	**3**	**18.8**
Non-science	**21**	**72.4**	**8**	**27.6**
Undecided	**5**	**71.4**	**2**	**28.6**

As seen from Table 2 science majors showed slightly higher understanding of the tentative nature of science than non-science majors and undecided. In general all students showed very good understanding of the tentative nature of science, which may lead us to believe that this aspect of NOS is well thought in high school.

To question number 2 in the questionnaire that represents the subjectivity of science students responded as follows (Table 3):

Table 3. Percent of Affirming and Non-Affirming Answers to Subjectivity of NOS

Major	**Affirming**			**Non-Affirming**
	N	**(%)**	**N**	**(%)**
Science	11	**68.8**	**5**	**31.3**
Non-science	**17**	**58.6**	**12**	**41.4**
Undecided	**5**	**71.4**	**2**	**28.6**

Table 3 shows that between science and non-science majors there is a decrease in the understanding of the subjectivity in science compared to the understanding of tentativeness of science. The undecided group showed the same understanding as the previous one. In general students showed that they understand the subjective nature of science, but again science majors showed higher understanding than the other groups.

To question number 3 in the questionnaire that represents the involvement of creativity in science students responded as follows (Table 4):

Table 4. Percent of Affirming and Non-Affirming Answers to Creativity of NOS

Major	Affirming			Non-Affirming
	N	(%)	N	(%)
Science	13	81.3	3	18.8
Non-science	21	72.4	8	27.6
Undecided	5	71.4	2	28.6

Table 4 shows that student gave the same responses as in question 1, which means that science majors showed slightly higher understanding of the creative nature of science than non-science majors and undecided. In general all students showed very good understanding on the involvement of creativity in science, which suggests that this aspect of NOS might be appropriately taught in high schools.

Question 4 represents the social and cultural embeddedness of science and students gave the following responses (Table 5):

Table 5. Percent of Affirming and Non-Affirming Answers to Social and Cultural aspects of NOS

Major	Affirming			Non-Affirming
	N	(%)	N	(%)
Science	7	43.8	9	56.3
Non-science	15	51.7	14	48.3
Undecided	3	42.9	4	57.1

There was a big decline in the understanding of social and cultural embeddedness of science compared to previous questions. This might suggest that this aspect of NOS is not appropriately taught in schools. However, there was a change of the previous tendency; non-science majors showed slightly higher understanding of this aspect of NOS than science majors. This might be due to their involvement with more social studies subjects. Question 5 in the questionnaire represents the empirical basis of science to which students responded as follows (Table 6):

Table 6. Percent of Affirming and Non-Affirming Answers to Empirical aspect of NOS

Major	Affirming			Non-Affirming
	N	(%)	N	(%)
Science	10	62.5	6	37.5
Non-science	18	62.1	11	37.9
Undecided	4	57.1	3	42.9

As seen from Table 6 all subject groups showed similar tendency to this aspect of NOS. In general students' understandings of the empirical basis of science were adequate, but not enough to say that this aspect of NOS is taught well in schools.

Question 6 in the questionnaire represents the difference between theory and law in science. Students responded as follows (Table 7):

Table 7. Percent of Affirming and Non-Affirming Answers to Difference between Theory and Law

Major	Affirming			Non-Affirming
	N	(%)	N	(%)
Science	2	12.5	14	87.5
Non-science	2	6.9	27	93.1
Undecided	0	0	7	100

In Table 7 nearly all of the students responded non-affirming to this question. This should not be surprising, because most of the textbooks written in science say that theories with accumulation of substantial supporting evidence become laws, which is not in consistency with the contemporary understanding of NOS. This means that legislators should take urgent actions to force publishers to write new textbooks in accordance with the contemporary understandings of NOS. Question 9 tries to evaluate the understanding of the difference between observation and inference in science (Table 8).

Table 8. Percent of Affirming and Non-Affirming Answers to Difference between Observation and Inference

Major	Affirming			Non-Affirming
	N	(%)	N	(%)
Science	9	56.3	7	43.8
Non-science	17	58.6	12	41.4
Undecided	4	57.1	3	42.9

Table 8 suggests that all subject groups have similar tendency to this aspect of NOS. In general students' ability to differentiate between observation and inference in science were adequate. Question 7 tries to evaluate whether students hold a conventional belief that to achieve scientific knowledge scientists always do experiments (Table 9).

Table 9. Percent of Affirming t and Non-Affirming Answers to Question 7

Major	Affirming			Non-Affirming
	N	(%)	N	(%)
Science	4	25	12	75
Non-science	6	20.7	23	79.3
Undecided	1	14.3	6	85.7

Table 9 shows that majority of students in all subject groups responded non-affirming to this question, which means that science teachers should reconsider their way of conducting experiments and find ways to show students that scientific knowledge can be achieve with abstract reasoning of mind too. Question 8 aims to evaluate whether students could differentiate between religion and science (Table 10).

Table 10. Percent of Affirming and Non-Affirming Answers to Question 8

Major	**Affirming**			**Non-Affirming**
	N	**(%)**	**N**	**(%)**
Science	8	**50**	**8**	**50**
Non-science	**15**	**51.7**	**14**	**48.3**
Undecided	**4**	**57.1**	**3**	**42.9**

All subject groups showed similar tendency in Table 10, which is that half of the students can differentiate and half cannot differentiate between religion and science. The difference between religion and science was analyzed in the basis that they are completely different systems of believe and way of acquiring knowledge.

Analyses of total mean scores of the contemporary understandings of NOS for each subject group are indicated in Table 11.

Table 11. Total mean scores of the contemporary understandings of NOS for Majors

Major	**N**	**Mean**	**(SD)**
Science	16	**.5347**	**(.1634)**
Non-science	**29**	**.5057**	**(.1961)**
Undecided	**7**	**.4921**	**(.1260)**

Note. Higher scores indicate greater understanding of NOS. The measure is coded from (0)=Poor understanding of NOS to (1)=Appropriate understanding of NOS. Standard Deviations (SDs) are in parentheses.

As seen from Table 11 mean scores of science major students are slightly higher than both non-science majors and undecided group of students. This suggests that students who made up their mind in high school to study science in college are more likely to have appropriate understanding of the contemporary views of NOS than students who did not made up their mind or did not chose science us their major in college.

Analyses of the mean scores of contemporary understanding of NOS for each particular question for science majors, non-science majors and undecided group of students are shown in Table 12.

Table 12. Mean Scores of Understanding of NOS of Majors for each particular question

MAJORS		Question No. 1	Question No 2	Question No 3	Question No 4	Question No 5	Question No 6	Question No 7	Question No 8	Question No 9
Science Major	M	.812	.688	.812	.438	.625	.125	.2500	.500	.563
	N	16	16	16	16	16	16	16	16	16
	SD	.403	.479	.403	.512	.500	.342	.4472	.516	.512
Non-Science Major	M	.724	.586	.724	.517	.621	.069	.2069	.517	.586
	N	29	29	29	29	29	29	29	29	29
	SD	.455	.501	.455	.509	.494	.258	.4123	.509	.501
Undecided	M	.714	.714	.714	.429	.571	.000	.1429	.571	.571
	N	7	7	7	7	7	7	7	7	7
	SD	.488	.488	.488	.535	.535	.000	.3780	.535	.535
Total	M	.750	.635	.750	.481	.615	.077	.2115	.519	.577
	N	52	52	52	52	52	52	52	52	52
	SD	.437	.486	.437	.505	.491	.269	.4124	.505	.499

Note. Higher scores indicate greater understanding of NOS. The measure is coded from (0)=Poor understanding of NOS to (1)=Appropriate understanding of NOS. SD's stands for Standard Deviations.

Table 12 indicates that mean scores of science majors' understanding of each aspect of NOS are higher than non-science majors and undecided group. Science majors' understanding of NOS ranges from .125 for question no. 6, which is concerned with the differences between theory and law, to 812 for question 1, which deals with tentativeness in science. When we compare non-science majors with undecided groups we see that, except for question no. 2, which deals with subjectivity of science, non-science majors' mean scores of understanding of NOS is higher than undecided group. It is important to note that all three groups showed very poor understanding of differences between theory and law in science, respectively 0.125; 0.069, and 0.00 for science majors, non-science majors, and undecided group. This suggests that the differences between theory and law in science are very poorly taught in schools. None of the students (Mean=0.00) from undecided group has correctly responded to that particular question. This result poses a challenge for teachers to better teach the differences between theory and law in science.

Two sets of independent t-test analyses were conducted using continues and categorical variables to see if there are any significant differences in understanding of NOS between science and non-science majors, and also science majors and undecided group. The difference in understanding of NOS between science majors and non-science majors are shown in Table 13.

Table 13. Difference in Understanding of NOS between Science and Non-science Majors

Independent Samples Test

		t-test for Equality of Means			
		t	df	Sig. (2-tailed)	Mean Difference
Understanding of Nature of Science	Equal variances assumed	.502	43	.618	2.898E-02
	Equal variances not assumed	.530	36.1	.600	2.898E-02

The final results of this t-test revealed no significant differences in understanding of NOS between science and non-science majors $t= .502$ (df=43, $p=.618$). In this situation we are not able to reject the null hypothesis, which indicates that there is no significant difference between the two participant groups.

The second analysis of independent t-test was conducted to see if there are any significant differences in the contemporary understanding of NOS between science majors and undecided group of students. The results are shown in Table 14.

Table 14. Difference in Understanding of NOS between Science Majors and Undecided Group

Independent Samples Test

		t-test for Equality of Means			
		t	df	Sig. (2-tailed)	Mean Difference
Understanding of Nature of Science	Equal variances assumed	.613	21	.547	4.266E-02
	Equal variances not assumed	.680	14.9	.507	4.266E-02

Results of the t-test from Table 14 indicated no significant differences in understanding of NOS between science majors and undecided group t=.613 (df=21, p=.547).

Discussion and Conclusion

Present study revealed that there is no significant difference of the contemporary understanding of NOS among science major, non-science majors and undecided group of undergraduate students. However, the validity of this study is suspicious, because the sample group was small and not equally divided. Also, the questionnaire could be improved and its validity could be tested in a pilot study. Thus, a future study with bigger and equally divided subjects groups is suggested. Nevertheless, the study revealed that some aspects of the contemporary understanding of NOS, such as the difference between theory and law, socially and culturally embeddedness of science, and ways of acquiring knowledge are poorly taught in high schools and should be improved. The best understood aspect of NOS among all groups (science, non-science and undecided group) was the tentativeness of science. Another interesting result from the study was students' understanding of the difference between religion and science; half of the students were able to differentiate between religion and science, but the other half weren't able to differentiate. This result shows that this controversial issue needs to be addressed not only in schools, but in society as a whole. This is a societal issue and has to be discussed openly in the media and in the family. In general, this study suggests that teachers should improve their teaching of NOS in their classroom, because the NOS are the rules of the game (in this case the rules of playing science) and we cannot expect students to play well the game without teaching them the rules (Clough, 2000).

This study supports some and contradicts some of the finding of studies such as, Aikenhead (1973), Broadhurst (1970), Lederman & O'Mally (1990), Rubba (1977), Tamir & Zohar (1991), and Wilson (1954). For instance, students from these studies thought that scientific knowledge was absolute, that scientists' main concern was to collect and classify facts in order to uncover natural laws, and that hypotheses can be proven true, but majority of the students in the present study thought that science is tentative and subject to change. Additionally, students from above mentioned studies had inappropriate conceptions of the role of creativity in science, while majority of the students in the present study said that science is creative. However, majority of the students in the present study also had hard times in figuring out the role of theories in guiding the scientific research, the difference between experimentation, models, hypotheses, laws, and theories, as well as inadequate conceptions of the interrelations and interdependence of the different areas of science, as the students from above mentioned studies.

Appendix A

VIEWS OF NATURE OF SCIENCE QUESTIONNAIRE

Name: Gender: **M /F** (circle one) Date: / /

Class level: **Freshman / Sophomore / Junior / Senior** (circle one) Age:…..

Instructions: *The following questions are related to science and scientific investigation. Please answer each of the following questions. You can use back of the page if you want to comment more specifically about the questions.*

1. Can scientific knowledge claims be proven absolutely?

Yes ***No*** ***No comment*** (circle one)

2. Do you believe that scientific knowledge is subjective?

Yes ***No*** ***No comment*** (circle one)

3. Do you think that to generate a knowledge claim scientists?:

(*circle one opinion* (**a** or **b**) *with which you agree*)

a. add something extra: creative insights, hunches, inspiration or a strong personal commitment to an idea;

or

b. strictly follow the rules of scientific methodology.

4. (*circle one opinion* (**a** or **b**) *with which you agree*)

a. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced;

b. Other claims that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

5. Briefly explain the difference between scientific knowledge and opinion?

6. Briefly explain the difference between a scientific theory and a scientific law?

7. Scientists must do experiments to achieve knowledge?

Yes ***No*** (circle one)

Briefly explain your answer.

8. Briefly explain the difference between religion and science?

9. Briefly explain the difference between observation and inference in science?

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