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What Went Wrong? Literature Students are More Informed About the Nature of Science than Science Students

Sözel Bölüm Öğrencileri Bilimin Doğası Hakkında Sayısal Bölüm Öğrencilerinden Daha Bilgilidir; Eğitimde Yanlış Giden Nedir?

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Abstract

The purpose of this study was to investigate science-math (SM) and literature-math (LM) branches of high school students' views on NOS and to compare their beliefs about NOS. The study's sample consisted of 120 Turkish 11th grade students (60 in the science-math branch and 60 in the literature-math branch). Some significant differences were found between science-math and literature-math students' conceptions of NOS. The results indicate that compared to science-math branch students, literature-math branch students seemed to be more informed about the tentativeness of scientific knowledge, arriving at scientific knowledge, differences in scientific knowledge and scientific opinion. The results of this study introduce one of the reasons why science-math students enroll in courses on history of science and philosophy of science during high school.

Keywords: Nature of science; high school students; scientific literacy, philosophy of science, science education

Öz

Bu çalışmanın amacı, 11. sınıf Fen-Matematik branşı öğrencileriyle Türkçe-Matematik branşı öğrencilerinin bilimin doğası hakkındaki kavram(a)larını karşılaştırmaktır. Çalışmaya 60 Fen-Matematik, 60 Türkçe-Matematik branşından toplam 120 öğrenci katılmıştır. Sonuçlar Türkçe- Matematik bölümü öğrencileri, fen (Fizik, Kimya, Biyoloji) derslerini çok daha az almalarına rağmen, Fen-Matematik bölümü öğrencilerinden bilimin doğasının, bilimsel bilgi, deney ve gözlemlerden elde edilmiş kanıtlara dayanır, bilimsel bilginin değişebilirliği gibi bazı özelliklerinde daha bilgili bakış açısına sahip olduklarını göstermiştir. Bu sonuçlar doğrultusunda, bilim tarihi ve bilim felsefesi derslerinin, bilimin doğası hakkındaki kavramların öğretilmesi için lise döneminden itibaren verilmesi gerektiği önerilmektedir.

Anahtar Sözcükler: Bilimin doğası; lise öğrencileri; bilim felsefesi, bilim okur-yazarlığı; fen eğitimi.

Introduction

Many national and international reform documents state that the most important objective of science education is to promote scientifically literate citizens with intellectual resources, values, attitudes and inquiry skills. Scientific literacy is commonly defined as the

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development of a deep understanding of major scientific concepts, processes of scientific inquiry and the nature of science, as well as the development of the ability to make informed decisions regarding science and technology as they relate to personal and societal issues (AAAS, 1990; NRC, 1996; Bell, Blair, Crawford & Lederman, 2003). Therefore, many science educators view the cultivation of scientific literacy, which is a *magic concept* in the context of curricular efforts and reforms, as the educational solution to many of the economic, social and environmental challenges of the next century.

This current of thinking has motivated countries all over the world to work to improve students' understanding of the NOS through curricular efforts and reforms (AAAS 1990; Millar & Osborn, 1998; Ministry of Education (Taiwan), 1999; National Center for Educational research and Development (Lebanon), 1997). Similarly, Turkey needs to develop consciousness around the interactions between science and technology, as in the most *developing countries*. Thus, producing scientifically and technologically literate individuals has become the central goal of science education in Turkey, with a newly developed science and technology curriculum whose implementation began in 2004 (Ministry of National Education, 2004, Turkey).

The NOS has been defined in numerous ways. Abd-el-Khalick, Bell and Lederman (1998, p. 418) state, "Typically, the nature of science has been used to refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge." According to Lederman (1986), the NOS most commonly has to do with the values and assumptions inherent in scientific knowledge. For example, it is based upon such concerns as whether scientific knowledge is moral or amoral, whether it is it tentative or absolute and whether scientific knowledge is a product of the human imagination or not. Individual responses to such questions can be presumed to constitute individual conceptions of the NOS (Lederman, 1986).

The literature shows that scientifically literate individuals possess a wide variety of attributes, one of which is an adequate understanding of the NOS. Abd-El-Khalick and Lederman (1998) have acknowledged that no consensus exists on the NOS among philosophers of science, historians and science educators. Such disagreement, however, should not be surprising or disconcerting given the multifaceted and complex nature of science. Nevertheless, science educators generally refer to the NOS as a way of knowing or the values and beliefs inherent in the development of scientific knowledge (Lederman, 1992). Furthermore, like scientific knowledge, aspects of the NOS and concepts related to it are tentative and dynamic. These concepts have changed through developments in science and in systematic thinking about the nature and workings of science (Abd-El-Khalick & Lederman, 1998).

Science research around the world has consistently shown, however, that kindergarten through 12th-grade students have not attained the desired level of understanding of the NOS (e.g. Rubba, Horner & Smith, 1981, Tamir & Zohar, 1991; Aikenhead 1987; Fleming, 1987; Solomon, Scott, & Duveen, 1996, Abd-El Khalick, 2002). Like studies of other countries, Turkish studies have shown that almost all participants—teachers (Yakmacı, 1998; Irez, 2006; Tasar, 2006) and students (Kiliç, Sungur, Çakiroglu &Tekkaya, 2005; Dogan, & Abd-El-Khalick, 2008)— hold inadequate views about fundamental *aspects* of the *nature of science* and have struggled to understand the nature of science for many years

In considering the importance of cultural factors in science education, some researchers (Haidar & Balfakih 1999) contend that background, religion and culture influence students' understanding of the epistemology of science. They explored the views of sixteen hundred United Arab Emirates high school science students about the epistemology of science. They noted that most of the Emirate high school students held uninformed views about the nature of science. Their studies on high school science students' views regarding the NOS revealed that curriculum designers should consider religion, culture, history, society, and the environment in developing science curriculum.

The relationship between students' religion, culture, history, society, different branch affiliations and development of NOS concepts and the influence of NOS knowledge on science learning is worth investigating. On the other hand, the focus of the lesson is history, philosophy, with students helped to develop their conceptions of the nature of science as a by-product. As Russell (1981) has stated, *'If we wish to use the history of science to influence students' understanding of science, we must...treat this material in ways which illuminate particular characteristics in science' (p. 56)* (as cited *in* Bell, 2001).

Exploring literature-mathematics and science-mathematics students' views about NOS reveals possible way to understand the influence of different courses (philosophy, history, physics, chemistry, etc.) and culture on students' views regarding NOS. That process will also shed light on ways to improve the high school science curriculum in Turkey and in other developing countries.

One goal of my study has been to explore the views of high school students from science-math (SM) and literature-math (LM) branches on the NOS. Although there have been many studies about college students and teachers in different branches, only a small number of studies have examined high school students' views of the nature of science (e.g., Rubba & Andersen,1978; Rubba, Horner, Smith,1981;Aikenhead, 1987; Fleming, 1987; Lederman & O'Malley, 1990; Moss, Abrams, & Robb, 2001; Ryan, 1987; Haidar, & Balfakih, 1999; Tao, 2003; Kang, Scharmann & Noh, 2005).

To date, only one researcher investigated the relationship among the students' epistemological beliefs with respect to gender, grade level, and fields of the study. She studied with sixth, eighth, and tenth grade Turkish students (Kurt , 2009). The results showed that tenth grade students' epistemological beliefs on Justification dimension differ in terms of the fields of the study. The students attending to math-science had more sophisticated beliefs than the students attending to literature-social sciences. On the other hand this study reported that it was found statistically significant between mathematic-science field, literature-mathematics field and literature-social science field but small effect of the fields of the study on students' epistemological beliefs. She suggested that the national curriculum should be arranged to improve the epistemological beliefs on the different field of students. This previous study' context was different from the current study. Furthermore, this study is important because it is the first study focusing on NOS views of 11th grade of Anatolian high school from different branches. It would be interesting to conduct this study with other grade level and different high school students to compare their epistemological beliefs with respect to grade level, and different branches of the study.

A second goal was to better understand how LM and SM students' branch affiliations affect their own concept of the nature of science. Science educators know that many factors contribute to students' construction of scientific knowledge, such as society, culture, religion, the media, museums, etc (Haidar and Balfakih 1999). Understanding high school students' learning process in the science context and exploring how their branch affiliations affect their NOS conceptions is very important: science educators around the world should know how students' different branch and cultural affiliations affect their views of the NOS if they are to teach science properly. Furthermore, science curriculum developers in Turkey need proof of weakness and strengths in the present high school curriculum with respect to nature of science because of the national high school curriculum reform efforts that are already underway in Turkey.

Methodology

The purpose of the present study

The principle aim of this study has been to explore the views of science-math and literature-math 11th-grade students regarding scientific epistemology. In examining this distinction, we sought to compare the students' perspectives about NOS in Turkey.

Participants

The curricula in all 9th grades at Anatolian high schools are comprised of common courses like physics, chemistry, biology, mathematics, literature and the history of Turkey, and they apply the same weekly timetable. These are compulsory courses. All students shared the same classroom and the same curriculum through the 9th grade. 9th grade is an important transition period in terms of students' selection of a branch of study, which in turn affects the opportunities that they enjoy with regard to college. When students finish the first year (9th grade), they have to choose their branch: mathematics–science, literature-mathematics, literature-social sciences, foreign language, etc. 10th, 11th, and 12th grades are comprised of branch courses and elective courses. These courses correspond to the branch to be selected.There were several reasons for the focus on eleventh-grade students and this particular school. First, this school offers high-level LM and SM branches to prepare for university entrance exams. Second, these students populate the high school science courses that are targeted in the current Turkish curricular reform efforts. Third, twelfth-grade students devote time and energy to preparing for university examinations. In total, 60 of the students were from the SM (35 female and 25 male), and 60 of them were from the LM branch (38 female and 22 male).

Instrument

The instrument used in the study is the Turkish version of Perspectives on Scientific Epistemology (POSE), the open-ended questionnaire developed by Abd-El-Khalick in 2002. The translated POSE items were used as a pilot study with a different sample of 60 eleventh-grade students in three different types of Turkish high schools in Ankara (public science, Anatolian, and general high schools, as well as a private high school). After the pilot study, a final check was conducted on student understanding of the wording of the items and viewpoints.The items on the POSE questionnaire were used in a previous study (Khishfe & Abd-El-Khalick, 2002) that investigated changes in NOS views among 6th graders. Content and face validity have been established through the input of experts and pilot testing.

The POSE questionnaire includes open ended questions specifically addressing the following components of the nature of science: "Creative/Imaginative"; "Tentativeness"; "Empirical"; "Scientific Theories and Laws"; "Observation & Inference"; "Social and Cultural Embeddedness"; and the distinction between scientific data and scientific thought (Appendix A).

Procedure

The questionnaire was administered by the teacher to the students and took approximately 30 to 40 minutes to complete (Appendix A).

Data Analysis

In a qualitative study such as this one, it is important to increase validity. To make the data more meaningful, two additional researchers helped to analyse the data and categorise it as indicating a naïve, uncategorised or informed level of understanding. The researcher and two science education researchers analysed the data independently using a blind round of analysis. There was a *high* degree of consensus *among* the researchers for the analyses. A few differences appeared in approximately 10% of the answers, and these differences were resolved by further examination of the data. The results were compared and contrasted to increase the internal validity of the study. The data analysis included two phases. The first phase involved generating data by categorizing each participant's views on the six emphasized aspects of NOS as *naive, uncategorized* or *informed*. This phase involved conducting several repetitions of the category stage and verification stage. In the second phase, the percentages of students in the different categories (naive, uncategorized and informed) for each NOS aspect were used to compare the two groups. Through this scoring procedure, an answer expressing as an appropriate view was categorized as "informed." For instance, one student's explanation of the tentativeness of scientific knowledge is given below that we categorized as "informed".

Everything is changing. Of course, scientific knowledge changes with new technology and new interpretation. For example, in atom theory, in the past it is said that atoms cannot be broken into pieces, but now it is an idea that there is small particles than atom. I want to give another example is once again "atom". Since structure or models of atom has been changed from past years. Finally I think that modern atomic theory is used now…

Coding was categorized as "naive" if it expressed a view that was inappropriate or illegitimate. On the other hand, alternatives that were categorized as "naive" reflected views supported by logical positivists (Ryan & Aikenhead, 1992).

For instance, one student explained her creative and imaginative view of scientific knowledge; We categorized this view as "naive":

Scientists must not use imagination. An artist must be creative, but scientist must not. It makes the science subjective. This is my idea. For example to use for his, his countries or his regions profit makes it subjective. Science is based on facts and does not accept imagination.

Coding was categorized as "uncategorized" if it expressed a view that was complex or difficult to clarify. For instance, one student explained the social and cultural embeddedness of scientific knowledge. His view is given below:

I still do not have an idea. I don't think the cultures are affected. Maybe religion and ethical values are affected by science. Actually, it is must be universal. It is not affected if it is a law; if not, it is the opposite. This is my idea.

Table 1.

The context for assessing the six emphasized NOS aspects

NOS Aspect	POSE Items
Creative/Imaginative	1,7,8,9
Tentative	2,7,8
Empirical	2,3,7,8
Scientific Theories and Laws	4, 5, 6
Observation & Inference	1,4,5,8,9
The Social and Cultural Embeddedness	7, 8, 9

Results

SM students' and LM students' views on the nature of science are very different from one another. The percentages of students in the different categories (naive, uncategorized and informed) for each NOS aspect are given below.

Table 2.

Numbers and percentages of students having informed, naive and uncategorized views of the six target NOS aspects.

NOS Aspect	LM Students (N / %)			SM Students (N / %)		
	Naïve	Informed	Uncategorised	Naive	Informed	Uncategorised
Creative/Imaginative	41(68.33)	17(28.33)	2 (3.33)	50 (83.33)	7 (11.66)	3 (5)
Tentative	-	60 (100)	-	9 (15)	51 (85)	-
Empirical	18 (30)	38 (63.33)	4 (6.66)	10 (16.66)	46 (76.66)	4 (6.66)
Scientific Theories and Laws	60 (100)			60 (100)		
Observation and Inference	21 (35)	36 (60)	3 (5)	15 (25)	43 (71.66)	2(3.33)
Social and Cultural Embeddedness	39 (65)	18 (30)	3 (5)	43 (71.66)	15 (25)	2 (3.33)

Aspects of the Nature of Science (NOS):

Creative and Imaginative Nature of Scientific Knowledge:

An artist is someone who draws; paints pictures; or creates sculptures, novels, poems or films. "Scientist" is an occupation like an artist. Creativity and imagination are crucial to the work of a scientist. However, most of students thought that scientists do not use creativity or imagination in their work.

Some of the SM students' answers are given below:

SM Student: Scientists produce scientific knowledge based on what we need by using scientific method. They do not use imagination or creativity. God just uses creativity.

SM Student: Scientific knowledge is produced by long and tiring scientific studies... Scientific knowledge appears after comprehensive information gathering. Because scientific knowledge is cumulative, especially what happened to Newton (Gravity) is, infect, and outcome of knowledge accumulation with helping the God rather than divine assessments.

Some SM students thought that God helped them to make scientific discoveries. Culture and religion play important roles in their beliefs about scientific knowledge. In particular, it is not surprising to observe that SM students believed in some sort of spiritual force. Indeed, similar findings were found in studies conducted in Muslim countries (Haidar, 1999, p. 808).

Most of the students held naïve views of this aspect of NOS, as demonstrated in Figure 1. Although creativity and imagination are the most important components of scientific knowledge, most SM and LM students did not think that scientists use their creativity or imaginations to invent or produce scientific knowledge. LM students were more informed than SM students (28.33% and 11.66%, respectively) about the imaginative and creative aspects of NOS. Only two LM students noted that imagination is the most important thing in science and that each truth is first an imagination. It is important to point out that one LM student referenced Jules Verne's book as an example of imagination in science.

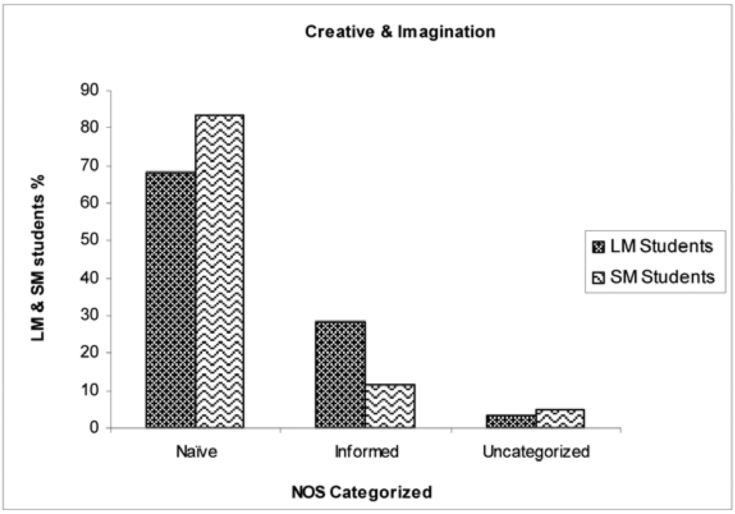

Figure 1. Percentage of students with naive, informed and uncategorized views of the creative/imaginative aspects of NOS.

In addition to this, SM students emphasized that science is a cumulative process, although scientists use the scientific method instead of imagination for this process.

One of the LM students' answers is given below:

LM Student: For example, Jules Verne's book is named "Journey to the Moon." The book was written in 1865, approximately 100 years before the first trip to the moon, and it was impossible to do this trip with the technology then. But today, to do this journey to moon is an ordinary activity. Scientist starts with his/her imagination. And then, to prove this, experiments and observations will help them.

Tentativeness aspects of NOS:

"Tentative" is a negative adjective that, for many fields, is used to mean instability. This is inconsistent with what we have generally used it to mean in science. Tentativeness is an inevitable objective in scientific knowledge. Scientific knowledge is constantly changing, so we do not ever say that there is a "final word" in science. Understanding the tentativeness of science is important because the tentativeness of scientific knowledge makes it different from other forms of knowledge and prevents it from becoming dogmatic.

The majority of SM students (51%) and LM students (60%) held informed views about scientific knowledge being tentative; this is the most encouraging result of the study (Figure 2). Most of the students expressed the notion that scientists will find new things with new technologies. Besides this, theories may change in the future because of the effect of technology. Laws, on the other hand, are absolute. All participants agreed that laws do not change with time. It is interesting that LM students' views regarding the tentativeness of NOS are more informed than SM students' views.

Some of the students' answers are given below:

LM Student: Scientific knowledge is of course going to change. Science looks like a skin (for example snake's skin) which renews itself. The bottom of the new knowledge gets ahead by throwing out the old one. Science is developing. Every second, newer knowledge is found. Science gains momentum for reaching accuracy as technology improves.

SM student: Science is a field that is developing cumulatively. Nowadays we perceive that an accepted norm may not be true. For instance it is understood that Pluto is not a planet now.

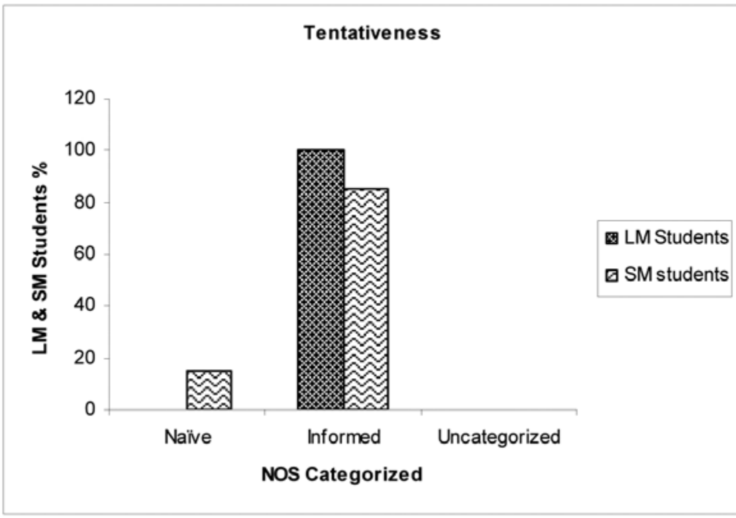

Figure 2. Percentage of students with naive, informed and uncategorized views of the tentativeness aspect of NOS.

Empirical aspects of NOS:

Science and scientific knowledge are based on observing nature. Scientists gather information by observing the natural world and conducting experiments.

Observations and explanations build on each other to generate scientific explanations of natural phenomena. Undoubtedly, science is a cumulative activity. Observations and experiments repeated again and again produce more accurate and extensive explanations that describe nature (AAAS, 1990). Most of the participants (76.66% of SM students and 63.33% of LM students) exhibited more informed views with respect to the empirical basis of NOS. SM students were more informed of the empirical basis of NOS than were LM students. Although they had informed views on empirical basis aspect of NOS, some of the SM students did indicate that scientific knowledge should be verified or disproved through experimentation (Figure 3). Additionally, some students stated that whether scientific knowledge is accepted or unaccepted depends on empirical evidence. Furthermore, they stated that principals of science are based on experimentation. They stated that they cannot distinguish accurate or inaccurate information without experiments. This view belongs to Francis Bacon, who used experiments to examine scientific knowledge in the 16th century. For Bacon, experiments were more important than observations in proving scientific thought and certainty. Experiments are a basic part of scientific knowledge, and the existence of truth depends on the empirical approach. Some scientists believe that "natural circumstance is created in all situations to test hypothesis" (Perez-Ramos, 1998). Now, however, the meaning of an experiment is "a set of actions and observations, performed in the context of solving a particular problem or question, to support or falsify a hypothesis or research concerning phenomena". Most of the students expressed the idea that experiments and curiosity are cornerstones for scientific investigation.

Some of the students' answers are given below:

SM student: Of course I consider. All scientific knowledge is obtained as a result of curiosity. Scientific knowledge is produced by doing experiments.

SM student: Of course I consider. I do not hesitate to do an experiment if it is going to be helpful for humanity. I also recommend it to everyone if it does not have a side effect.

One of LM students stressed that experiments may be harmful for living things and nature. This student's answers are given below:

LM students: I do not think to do these experiments. I do not desire that anything in our life will flourish with the help of scientific reasons or unnaturally. Besides I know that it may be harmful due to being contrary to the nature. For example, genetically modified organisms, cloning, and added hormones in meat, dairy and plants. Probably, if people will consider of science and technological applications and use them to truly benefit human beings in the near future, it can be used, but not now.

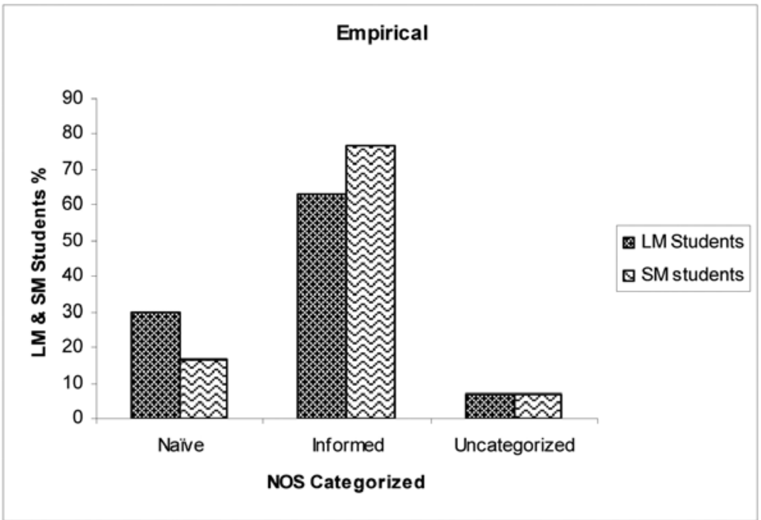

Figure 3. Percentage of students with naive, informed and uncategorized views of the empirical aspects of NOS.

Scientific Theories and Laws:

None of students demonstrated informed views with consideration to the differences between definitions of theories and laws (Figure 4). Theory and law opinions of SM and LM students were categorized into three groups. First, all of the students noted that theory is not absolute fact, whereas laws are absolute fact. Secondly, if a theory subjoins more worldwide evidence then becomes a law. Third, theory and law have different levels as verified many times. According to that view, a law is on a higher level than a theory. Furthermore, most of the students stress that while the design of a theory is based on imagination, law is attained with accuracy and evidence. For that reason a theory is simply disproved, while a law is impossible to refute.

Some students expressed a situation with the examples as follows: the same event is explained by two different theories. One is theory of creation, whereas the other is theory of evolution. The law of gravity, however, is exclusive and obvious.

Some of the students' answers are given below:

SM student: A theory is accepted by small group. Theory is refuted simply; however, law is an impossible fact to disprove. For example gravity is a law.

LM student: A theory is at first based on imagination and we need to investigate these ideas because we won't be sure about accuracy without proving it.

SM student: *A theory is a theory because it is not* absolute truth *100%. Therefore, a theory can change over time.* If scientific *study is done with methods of mathematics, it will command our mind. A law is proven with the formulization of a mathematical method. Therefore, it cannot change.*

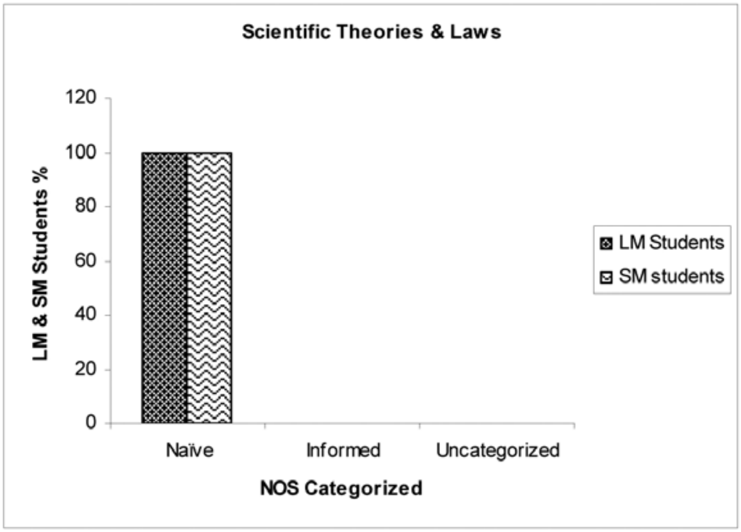

Figure 4. Percentage of students with naive, informed and uncategorized views of the scientific theories and laws aspects of NOS.

Observation and inference aspects of NOS:

Observations and inferences play an absolutely essential role in scientific investigation. Observations are obtained using the human senses or with the help of various tools. The results obtained are the interpretation of these observations. The observations and conclusions of inferences guide today's perspective of science and scientists. Multi-faceted perspectives and inferences will contribute to a valid observation. Direct observations obtained with the senses of natural phenomena can be deceptive in this case. However, a consensus may be reached by reducing the relativity of observations.

Most of the students (71.66% of SM students and 60% of LM students) have more informed views with respect to the observation and inference aspects of NOS (Figure 5). With regard to the nature of observations, LM students generally held more naïve views than SM students (35% of LM students as opposed to 25% of SM students). This should be no *surprise given that* LM students take fewer science courses than SM students. In this context in which *they* try to produce scientific knowledge, observation is more important than experimentation in thinking. It is truly amazing, however, that a fourth of SM students held the naive point of view. Some of students' answers are given below:

SM student:

At the beginning, scientists have theories about a subject in the nature or about phenomena. Then they observe and do experiment by obtaining necessary data. After the experiments, they come to a conclusion if there is no information to disprove their findings…

LM student: Scientist never hesitates to do experiments and make observations because they are curious, open to innovation and live in suspicion. Every innovation urges them to do more experiments and observations.

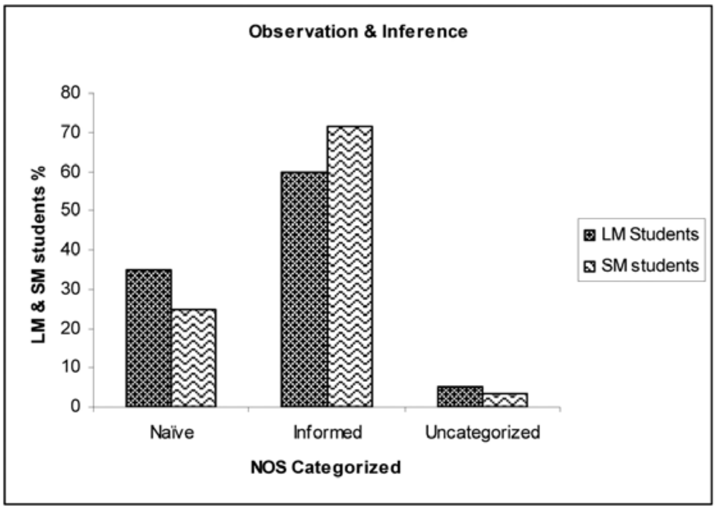

Figure 5. Percentage of students with naive, informed and uncategorized views of the observation and inference aspects of NOS.

Social and cultural embeddedness aspects of NOS:

Science has progressed through the impact of the scientific theories and laws adopted so far. The investigation of the data obtained from the development of the questions and the new filtrate of the theory of scientific knowledge contributes to the progress of science. The review of the first-hand evidence with the perspectives of the new information leads to changes in the science. The subjectivity, perspectives, beliefs and the previous work experience of scientists will determine how and in which ways scientists will administrate their works. Hence, science, a human activity, is affected by applied society and culture.

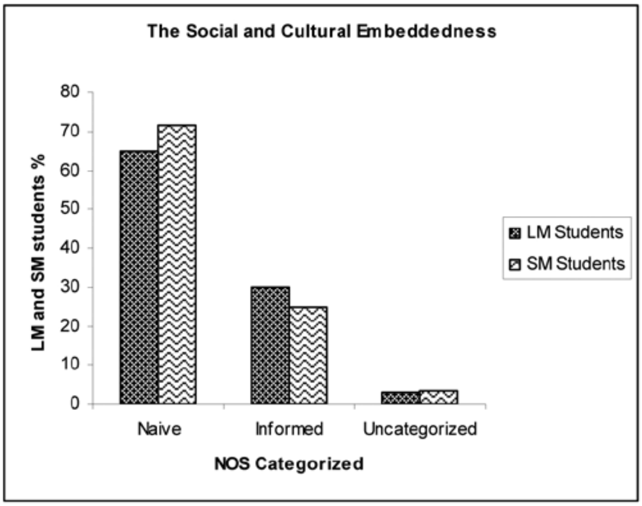

Figure 6. Percentage of students with naive, informed and uncategorized views of the social and cultural embeddedness aspects of NOS.

Most of students reported that science is universal and independent from society (SM students with naïve views=71.66%; LM students with naïve views=65%). SM students explained that the term "scientist" is objective, and their inventions are not affected by their culture or society (Figure 6).

Some students' views are given below:

SM student: A mind is one way. People think the same everywhere in the world; for example, the basic unit of matter is atoms, and each living things was composed of cells. Therefore, the influence of cultural norms of the science is not concerned.

SM student: It is exactly like solving a geometry questions. Some law all rules but cannot make use of it. Some law very well and perceive the details.

Three of the respondents answered this question differently:

SM student: Science is universal. Although a Christian country of Europe, a Muslim country, and Iran have very different social structures, the same scientific law applies all of them. For example, an apple drops down and water lifts object everywhere. But sometimes, their own interests for the sake of people lead to the wrong information about science.

LM student: Scientific research reflects social and cultural values completely, like in Iran, Iraq, and Saudi Arabia, where strict management science is not very developed. However, in the United States, France, England science and scientists are supported with financial opportunities and appropriate environment so; more progress has been made in science.

LM student: Their beliefs, their characters, their ideology, their freedom, their environment, their race, and their gender may cause them to consider differently. All lived in different places, considered in different ways, and came to conclusion differently. I can claim something else with the same proof.

These results indicate that there are large differences between LM and SM students' responses in some aspects of NOS. It was found that LM students' views about NOS were more informed than SM students' views.

Conclusions and Implications

Over the past 40 years, there have been many studies of students' understanding of and misunderstandings with regard to the nature of science and science in general. Many of these studies have found that students hold NOS concepts that are different than those accepted as appropriate by the scientific community (Mackay, 1971; Rubba, Horner, & Smith, 1981, Tamir &

Zohar, 1991; Aikenhead 1987; Fleming, 1987; Solomon, Scott, & Duveen, 1996; Abd-El Khalick 2006; Irez, 2006; Dogan & Abd-El-Khalick, 2008).

The findings of this study display that both LM and SM students hold naïve views about creativity and imagination, as well as about the social and cultural embeddedness aspects of NOS. With regard to these aspects, however, SM students held more naive views than LM students. LM students had been looking at scientific knowledge from *a broader perspective.* They had not only taken more literature, history and philosophy courses but had also read more books related to these courses and had discussed them with their class. Additionally, LM students had learned about topics in philosophy courses that might be of assistance to them in this realm, including the following: the nature and extent of human knowledge, the existence of god and the status of religious belief, the relationship between mind and body, etc. In my opinion, social science courses such as those in philosophy and history influence developing students' views of the epistemology of science. Most SM students thought that scientists must use the scientific method to ascertain the truth. These findings are compatible with the related literature (Aikenhead, 1973, Aikenhead, Fleming & Ryan,1987; Griffiths & Barry, 1993; Griffiths & Barman, 1993; Abd-El-Khalick & Boujaoude, 1995; Kang, Scharmann, & Noh, 2005). It is likely that the rationale for this view is based on the curriculum, the teachers and biology textbook–the latter because chemistry and physics textbooks do not include a unit on the scientific method and the scientist. These sources may teach that although scientists work in a variety of ways, there is one scientific method used to solve every problem. These arguments seem to be supported by the investigation by Irez (2009). His research revealed that Turkish biology textbook fails to emphasize fundamental aspects of the NOS. Some SM students believed that the imagination and creativity are not used for scientific investigation because only God is creative. They also believed that some scientific discoveries are God's miracles, as in the case of Newton. Although the scientific perspective approaches everything "with a grain of salt," one does not be suspicious of religious knowledge, faith and belief the power of deities. Religion and science are different from each other in many respects, though they may share some commonalities. Perhaps the best approach may to present students with information about both science and religion.

Other findings indicate that almost all participants maintained informed views regarding the tentativeness, observation and inference aspects of the NOS. SM students held more informed views about aspects of observation, inference and empirically-based scientific knowledge. This can be explained by the fact that SM students took more science courses than did LM students after the 9th grade. SM students have the opportunity to do experiments that demonstrate verification using a recipe, as in a cookbook. Furthermore, science classrooms devote considerable resources to giving students more scientific concepts and formulas (instead of giving them the opportunity for practical work and inquiry). Therefore, students thought that experiments were the most important method of determining whether information was accurate or inaccurate.

Another important outcome of this study is the finding that all LM students 100%) understood that scientific knowledge is changeable, whereas 15% of SM students held naïve views on the tentativeness of the NOS. The reason for this difference between the views of the two groups is likely that LM students enroll in more social science courses, like those in philosophy and history, which affect their comprehensive outlook on scientific knowledge. A classroom is an incredible arena for learning how scientific knowledge has developed throughout history. Students should see that scientific knowledge is mostly durable, though it can change.

Accordingly, it seems that students' lack of understanding regarding concepts related to the nature of science has generally originated from the science curriculum, which contains many facts and formulas. Another thing is that Turkish teachers are under a great deal of pressure to prepare students for *university* entrance *examinations while* also teaching the regular curriculum. Inevitably, the effects of the *university* entrance *examination system* have changed the classroom climate to one in which the teachers feel forced to "teach to the tests." Designing such classroom climates without the anxiety of competition might enhance students' beliefs about the NOS.

Hence, when preparing a teaching program and student activities using science concepts, it is very important to include everyday concepts. In teaching science concepts, teachers should organize activities that encourage students to use their prior knowledge and experience. Teachers should also provide students with the opportunity to apply newly acquired concepts in a variety of situations. Research has consistently shown that the explicit approach *has* proven successful in teaching aspects of the NOS (Abd-El-Khalick et al., 1998; Bell, Lederman, & Abd-El-Khalick, 2000; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006).

Finally, the above results, for example, indicate that philosophy, history and literature courses might be effective for the purpose of improving high school students' NOS views *even if they* are *not* as familiar with *science as are* science-math students. LM students know better how to consider problems, discuss issues, read and express their opinions. This result introduces one of the most important reasons why science-math students' need courses on history and philosophy of science during high school. With this in mind, historians of science, science educators and curriculum developers might ultimately need to collaborate and *negotiate,* helping each other confront the challenge of changing students' inadequate views regarding the nature of science when developing the high school curriculum.

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Appendix

Perspectives on Scientific Epistemology (POSE) Questionnaire

1. Scientists produce scientific knowledge (facts, laws, and theories). Some of this knowledge is found in your science textbooks. How do scientists produce scientific knowledge?
2. Do you think that the scientific knowledge found in your science textbooks (facts, laws, and theories) will change in the future?

   Circle one: Yes [Answer part (a) if you circled "yes"]
   No [Answer part (b) if you circled "no"]

   (a) If you circled "yes," explain why you think scientific knowledge will change in the future.
   (b) If you circled "no," explain why you think scientific knowledge will not change in the future.
3. While buying some bulbs at a florist shop, you come by a hand-written note next to some liquid bottles. The note claimed, "Miracle-grow will make your plant grow much faster than it would without this scientific breakthrough: Try it today!" Having grown plants yourself; you are a bit suspicious of this claim. Can you think of an experiment that would allow you to test this claim?
4. (a) What is a scientific theory?
   (b) Give an example of a scientific theory.
   (c) How do scientists produce a scientific theory?
5. (a) What is a scientific law?
   (b) Give an example of a scientific law.
   (c) How do scientists produce a scientific law?

6. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
7. Scientists believe that the dinosaurs lived more than 65 millions years ago.
   (a) How do scientists know that dinosaurs really existed?
   (b) How can scientists tell how the dinosaurs look like (for example, the texture and color of dinosaurs'
   skin, the shape of their eyes)?
   (c) How certain are scientists about the way they believe the dinosaurs look like?
8. All matter is made up of atoms. Atoms are very small: even a single cell is made up of millions and millions of atoms. The atom is shown as having a nucleus in the center with electrons moving around it. Scientists hold different views about this representation of the atom. Some scientists believe that this is a true and exact representation of the atom. Other scientists believe that this representation is just a model since we cannot know whether this representation of the atom is true and exact.
   (a) What is your view on this issue? Why do you hold this view?
   (b) How do scientists determine the representation of the atom shown above?
   (c) Scientists disagree about their beliefs regarding the representation of the atom. How is it possible
   for scientists to disagree? Explain your answer.
9. Scientists agree that about 65 million years ago the dinosaurs became extinct. However, scientists disagree about what caused this extinction. Some scientists believe that massive and violent volcanic eruptions were responsible for the extinction of the dinosaurs. Other scientists believe that a huge comet (or asteroid) hit the earth 65 million years ago and led to series of events that caused the extinction.
   (a) Did you hear about this issue before? Circle one: Yes No
   (b) What, if any, is your view on this issue? Why do you hold this view?
   (c) Does it surprise you that scientists disagree about the cause of the extinction of the dinosaurs? Explain your answer.
   (d) It is known that all the above scientists have access to and use the same set of data. How could it be that these scientists use the same data and still arrive at different conclusions regarding the cause of the extinction of the dinosaurs?