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Prospective Science Teachers' Understanding of the Nature of Science

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Abstract

This descriptive study explored 130 prospective science teachers' understanding of the nature of science in some main points. Data were collected through the question form that has eight open-ended questions. Analysis revealed that many participants held contemporary views on scientific knowledge that scientific knowledge may change in the future because of the reinterpretation in the light of new discoveries. And also most of them stated that hypotheses, theories and laws are different types of ideas and statements. Another result of this study is that cultural differences shaped view on influence of society on science and technology. And many participants hold traditional views on following scientific method for scientific inquiry that many participants thought all scientists followed the same scientific method. Results of the study also indicated that most of the prospective science teachers had a consensus on the possible positive effects of school science.

Keywords: Prospective science teachers, Nature of science, Scientific knowledge, Scientific method, Teacher education program.

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INTRODUCTION

Throughout the history of science education, the main goals of science education for students are to teach something about the body of scientific knowledge, about the process by which knowledge is generated, and about the manner in which knowledge is socially constructed (Bybee & Ben-Zvi, 1998). To all these perspectives, an understanding of the nature of science is an essential aspect of any education in science. Matthews (1995) stated that:

> Science affects styles of thinking and reasoning in society; it influences the acceptable modes of rational and reasonable debate; it contributes to public intelligence by instilling a concern for evidence and its rational and open appraisal. For all its faults, the scientific tradition has promoted rationality, critical thinking and objectivity. It instills a concern for evidence, and for having ideas judged not by personal or social interest, but by how the world is (p. 2).

According to Kuhn (1970), since the goals and problems of the society change, scientific knowledge also changes continuously. Due to the recent developments and improvements in science, science education reform brought scientific literacy into the central point of the goals of science education. It is widely believed that understanding of the nature of science education curricula, intended to promote scientific literacy, and enhances the ability of a person to observe events perceptively, reflect on them thoughtfully, and comprehend explanations offered to them. In addition, these abilities can provide the person with a basis of making decision and taking action. Students are the future citizens that will run the country and make the important decisions affecting many lives. Therefore, they must be aware of the nature of science.

The development of an adequate understanding of the nature of science continues to be advocated widely as a desired outcome of science teaching. Many contemporary science educators agree that encouraging students' understanding of the nature of science, its presuppositions, values, aims, and limitations should be the central goal of science teaching. They also support the idea that rather than discussing the definitions, the nature of science should actually be taught in science education programs. Scientific historians, philosophers and educators share the same opinion that some elements of nature of science should be taught to individuals. These elements are determined as; scientific knowledge is not precise and that it is based on experiments, it is subjective and it is a product of human creativity and imagination, and that it is established socially and culturally. It also explains the relationship between law and theory and the difference between observation and deduction (McComas, Clough & Almazroa, 1998).

It is clear that science teachers are the key factors to increase students' understanding of the nature of science and their scientific literacy. For this reason, researchers must pay careful attention to what they say and do in the classroom and to the kind of classroom climate they establish (Lederman, 1992). Although an understanding of the nature of science is considered to be one of the primary goals of science education for many years, previous studies show that students have inadequate conceptions about the nature of science (Akerson, 2003; Palmquist & Finley, 1997; Shiang & Lederman, 2002). Unfortunately, gaining the ability to understand the natural and designed world is getting more attention; many students see little connection between what they learn in the classroom and real life (Resnick, 1987). Yager (1991) stated that even students who score well on standardized tests often are unable to successfully integrate or contrast memorized facts and formulas with real-life applications outside the school. Therefore researchers argue that the main reason for students' inadequate conception is the inadequate conceptions of science teachers who are the responsible people to develop such an understanding in their students.

In Turkey, understanding of the nature of science as one of the most important aspects of science teaching has not been investigated enough yet. For that reason, the purpose of the present study was to determine the understanding of the nature of science of prospective science teachers. The understanding of the nature of science had been explored following the main points: (1) understanding of scientific knowledge, (2) the view on the influence of societies on science and technology, (3) the view on the influence of science and technology on society, (4) the view on the characteristics of scientists, (5) the view on the following scientific method for scientific inquiry, and (6) the influence of school science on society. According to the findings of this study, current science teacher education programs may be modified in the direction of enhancing science teachers' understanding of the nature of science.

METHODOLOGY

This research has a simple descriptive survey approach. This simple descriptive survey approach is one-shot survey for the purpose of describing the characteristics of a sample at one point in time apart from the other approaches of survey research namely cross-sectional and longitudinal (Mertens, 1998, p. 108). In this research, simple descriptive survey is conducted for the purpose of describing prospective science teachers' understanding of the scientific knowledge, characteristics of a scientist, the influence of societies on science and technology, the influence of science and technology on society, scientific method, and the influence of school science on society.

Participants

Participants are prospective science teachers of a faculty of education at a state university in one of the cities located on the west of Turkey. Purposive sampling is used to select the participants. In purposive sampling, it is assumed that the people chosen possess the necessary information about the target population (Franklen & Wallen, 1996). This study was conducted with 130 volunteered prospective science teachers who had already completed the 3rd grade and passed to the 4th grade. These prospective science teachers have already completed the basic science courses, science laboratory courses, nature and history of science course and, one of the science teaching courses (Special Methods of Science Teaching I).

Data Collection

The data were collected at the end of the first semester of 2010-2011 academic year from the pre-service science teachers through an open-ended questionnaire. The question form was used to collect data from a sample of 130 prospective science teachers in this study. In a class time of 60 minutes, participants wrote about the questions on Table 1, prepared by the researcher in accordance with the research questions and related literature. These eight questions assess the same issue; they were asked in order to get access to pre-service teachers' views on the understanding of the nature of science.

Table 1: Subscales of the Items Used in the Instrument

Main Points of Nature of Science	Questions
Understanding of the Scientific Knowledge	What do you think scientific knowledge is? What do you think about a group of scientists in the world in terms of their research on atom? Do they examine the atom in a basically same way and use the same approach or not? How do you explain the difference between a theory and a law?
The Influence of Society on Science and Technology	How is science and technology affected by the society?
The Influence of Science and Technology on Society	How is society affected by science and technology?
Characteristics of Scientists	What do you think about the characteristics of a scientist? (in terms of gender, personality, and daily life)
Following Scientific Method for Scientific Inquiry	Do you think that scientists follow the same scientific method or not for their scientific inquiry?
The Influence of School Science on Society	How is society affected by school science?

All questions were examined by three instructors of science education and then revised accordingly. In addition, the questions were piloted on another group of 10 prospective science teachers for clarity and comprehensibility. Initially, the pilot participants were asked to read and answer the questions by themselves. Afterwards, the researcher interviewed each of the pilot study participants on what they think each question means and suggesting ways of rewriting the questions if they are unclear. At the end, the final revisions on the questions were accomplished.

Data Analysis

Since the research questions in this study are general and reflect the intention of finding out the views of prospective science teachers' on the understanding of the nature of science, qualitative approach was

used. The prospective science teachers answered the questions by filling out the question form at the end of the nature and history of science course, which they enrolled in on the sixth semester. The analysis of prospective science teachers' written responses was based on forming general categories according to their responses showing their views on their understanding of the nature of science. All of the responses for each question were analyzed in turn. In the analysis, the structures towards particular meanings, concepts and relations were tried to be figured out where it is necessary to establish these structures over the categories with the codes identifying them (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz ve Demirel, 2008). Therefore, the answers were examined to draw comparisons and distinctions according to their meanings in order to identify the coding categories.

Firstly, prospective science teachers' written responses were examined by the researchers independently. Next, the researchers came together and decided on the final form of the coding categories. Then, each researcher worked individually in order to group these coding categories. These categories were compared, and the final form of the categories was constructed. An inter-rater reliability of this questionnaire was done by two experts of science education. Each coder separately analyzed the data that was randomly selected from the prospective science teachers' filling out the question forms under six main categories as, *the understanding of the scientific knowledge, the influence of the society on science and technology*, the *influence of science and technology on society*, the *characteristics of scientists, following scientific method for scientific inquiry, the influence of school science on society*. Pearson correlation was used to determine the inter-rater reliability and the value r was found 0.89. This value indicates a high level of agreement.

First category, the understanding of the scientific knowledge, includes prospective science teachers' thoughts about the characteristic of scientific knowledge and their thoughts about the differences among hypothesis, law, and theory. Second category, the influence of the society on science and technology, involves prospective science teachers' views on the effects of society and culture on science and technology. Third category, the influence of science and technology on society, involves prospective science teachers' views on the effects of science and technology on society in terms of productivity, comfortable life, being an independent and rich country. Fourth category, characteristics of the scientists, includes prospective science teachers' thoughts about the gender of the scientists, scientists' daily life, and their personality. Fifth category, following scientific method for scientific inquiry, includes prospective science teachers' thoughts on the ways of scientific methods. Final category, the influence of school science on society, involves prospective science teachers' views on the effects of school science on society.

RESULTS

Scientific Knowledge

Three questions were asked about the scientific knowledge. The understandings of the scientific knowledge with codes were presented in Table 2.

Table 2: Understanding of the Scientific Knowledge

Scientific Knowledge	**f**	**%**
Hypothesis, Data, Observation, Experiment	107	82%
Changeable	116	89%
Unchangeable	2	1%
Subjective	115	88%
Objective	22	17%
No comment about the scientific knowledge	23	18%
Theory		
What nature does under certain conditions?	104	80%
Law		
How nature works.	104	80%
Theories become laws.	9	7%

*Teacher candidates stated more than one statement.

It is seen that, most of the prospective science teachers had some phenomena based on their understanding of the scientific knowledge. Besides, nearly 82% of the participants define scientific knowledge as inference and hypothesis on the grounds of experiments and observations. In addition to these, 18% of the prospective science teachers did not define scientific knowledge. Most of the participants (89%) showed the belief that scientific knowledge may change in the future because of the reinterpretations in the light of new discoveries. According to these participants, scientific facts can change. While just few of the respondents (1%) stated that scientific knowledge cannot change, about 9% of the prospective science teachers did not have any comment on it. Most of the participants (88%) responded that the subjective structure of the observations may lead changes in scientific knowledge. This is because they thought that the interpretation depends on the individual scientist's point of view or on what the scientist already know. On the contrast, about 17% of respondents stated that scientific knowledge is objective.

In order to see whether prospective science teachers regarded hypotheses, theories and laws as a sequential set of statements or as different types of ideas and statements, they were asked about the relationships between theory and law (Table 2). Most of the respondents (87%) advocated that theories cannot become laws since they are different types of ideas. In addition to these, 13% of the prospective science teachers did not define theory and law. Most of the prospective science teachers (80%) defined theory as an explanation for "what reasons of observable phenomena are" and "why it happens", and also they define law as an explanation for "how descriptions of relationships among observable phenomena are". The study showed that only few prospective science teachers (7%) have misconceptions about that.

The Influence of the Society on Science and Technology

One question asked about the influence of the society on science and technology. The influence of society on science and technology with codes is presented in Table 3.

Table 3: Views on the Influence of Society on Science and Technology

The Influence of the Society on Science and Technology	**f**	**%**
Society affects science and technology	114	88%
- Cultural differences (religion, custom, cultural believes)	77	59%
- Needs of society	54	41%
No comments	16	12%

*Teacher candidates stated more than one statement.

Most of the prospective science teachers (88%) claimed that science and/or technology are affected by the society and its culture in which it is constructed. Besides them, 12% of the participants did not say anything about it. Although the participants accepted the effects of society and its culture on science and/or technology, they explained that with two different reasons. While 59% of the prospective science teachers stated that science and/or technology are shaped by cultural differences (religion, custom, cultural beliefs) of the society in which they develop, according to 41% of them, science and/or technology are shaped by the needs of the society.

The Influence of Science and Technology on Society

One question asked about the influence of science and technology on society. The influence of science and technology on society with codes is presented in Table 4.

Table 4: Views on the Influence of Science and Technology on Society

The Influence of Science and Technology on Society	**f**	**%**

Positive Effects	56	43%
Negative Effects	-	-
Positive and Negative Effects	44	34%
No comment	30	23%

*Teacher candidates stated more than one statement.

Most of the prospective science teachers (77%) thought Science and Technology have some influence on society. Unfortunately, 23% of the participants did not give any comment on it. A big portion of them (43%) stated that science and technology have a positive effect on society, because they mentioned that science and technology bring greater efficiency, productivity, and progress. In addition, they believe that the more science and technology develop, the more the society and its economy will develop. On the other hand, 34% of the respondents advocated that science and technology have both positive and negative effects on society. As an example for the positive effects of science and technology, medical developments is given; as an example for the negative effects of science and technology, production of nuclear weapons is given by the participants.

The Characteristics of Scientists

One question asked about the characteristics of scientists. The characteristics of scientists with codes are presented in Table 5.

Table 5: Views about the Characteristics of Scientists

Characteristics of the Scientists	**f**	**%**
Gender		
Male	12	9%
Female	-	-
No gender differences	117	91%
Personality		
Curious	108	83%
Explorer	79	61%
Observer	51	51%
Creative	42	32%
Problem Solver	39	30%
Suspicious by Nature	38	29%
Critical Thinker	26	20%
Patient	24	18%
Neutral	21	16%
Daily Life of a Scientist		
Same as everyone but…	85	65%
- relate everything to science and use more scientific method	36	28%
- doing much more inquiry	65	50%
- find many different solutions to problems	31	24%
Different from everyone	32	25%
- anti-social life	20	15%
- study hard	38	29%
- get little sleep	15	11%
No comment	13	10%

*Teacher candidates stated more than one statement.

Most of the prospective science teachers (91%) claimed that there was not a difference between males and females. However, few of the participants (9%) said that males were higher in numbers because they believed that society generally supported male scientists' more than female scientists. Therefore, participants claimed that males were luckier than females.

When asked about the personality of a scientist, respondents attributed many features of them. Prospective science teachers primarily mentioned two features of scientists; they are curious (83%) and they are explorers (61%). Besides these features, prospective science teachers emphasized observer

(51%), creative (32%), problem solver (30%), suspicious by nature (29%), critical thinker (20%), neutral (16%), and patient (18%) as the other important characteristics of scientists.

While 13% of the prospective science teachers did not say anything about the scientists' daily lives, 65% of the participants thought scientists' daily lives were the same with the other people. Even though their daily lives are very similar to other people, scientists relate everything to science and they use scientific method while solving problems (28%), they will do much more inquiry (50%) and they will find many different solutions to the problems (24%) in their daily lives. However, 25% of the participants thought scientists' daily lives were different from other people. About one fifth of the participants (15%) stressed that the scientists had anti-social lives and 29% of the participants stated that a common feature of scientists is that they are people that studied-hard during their daily lives and 11% of the participants thought scientists got little sleep.

Following Scientific Method for Scientific Inquiry

One question asked about following scientific method for scientific inquiry. Following scientific method for scientific study with codes were presented in Table 6.

Table 6: Views about Following Scientific Method for Scientific Inquiry

Following Scientific Method for Scientific Inquiry	**f**	**%**
Every scientist follows a scientific method for their inquiry	123	95%
- Every scientist follows the same scientific method	100	77%
- Scientists do not follow the same scientific methods	19	15%
- No explanation about it	4	3%
No comment	7	5%

*Teacher candidates stated more than one statement.

To the question asked about following scientific method for scientific study by scientists, most of the prospective science teachers (95%) answered in the same way as they thought that every scientist followed scientific method for their inquiry. On the other hand 5% of the participants did not answer this question. Although 95% of them claimed that there was a method followed by scientists during the scientific investigations, 3% of the prospective science teachers did not mention whether scientists followed the same method or not. 77% of the participants thought all scientists followed the same scientific method and this method is the method most science books wrote; observations, hypothesis, experiments etc. On the contrary, 15% of them thought that scientists did not follow the same scientific methods and they believed that every scientist followed their own scientific method.

The Influence of School Science on Society

One question asked about the influence of school science on society. The influence of school science on society with codes was presented in Table 7.

Table 7: Views of the Participants on the Influence of School Science on Society

The Influence of School Science on Society	**f**	**%**
Positive effects of school science	120	92%
- being a scientifically literate person	43	33%
- developing higher thinking skills	23	18%
- relating science learning to their daily lives	34	26%
- arousing curiosity	9	7%
- presenting job opportunities	5	5%
Negative effects of school science	10	8%
- the abstractness of the school science prevents its positive effects	10	8%
- it is hard to relate school science learning to daily lives	6	5%

*Teacher candidates stated more than one statement.

Most of the prospective science teachers (92%) advocated the positive effect of school science. 33% of the participants stressed that students will be scientifically literate people through school science, and that they can use scientific process skills to solve daily problems. Besides, 18 of them believed that science teaching helped students to develop higher thinking skills that enabled the students to solve the problems and discover new meanings and understandings. Some of the participants (26%) stated that school science was a link between science and daily life and thanks to school science students could relate the science they had learnt to their lives. While a small percent of the participants (7%) believed that school science arouse students' curiosity, another percent of them (5%) emphasized that school science presented job opportunities for the students. On the other hand, 8% of the prospective science teachers thought that the negative effects of school science were more than the positive effects of it on society. These participants (8%) stated that the abstractness of the school science prevented its positive effects. In addition, a small percent of them (5%) thought that it was very hard to relate school science learning to daily life because it was separated from the real life.

DISCUSSION

This study aimed to investigate the prospective science teachers' scientific thoughts through their written answers reflecting the nature of science which would be their subject of teaching in the near future. The results are discussed below in order to conclude the profile of the prospective science teachers regarding their understanding of scientific knowledge, the influence of society on science and technology, the influence of science and technology on society, characteristics of scientists, following scientific methods for scientific inquiry, and the influence of school science on society.

When we look at the results in general, they may indicate that a majority of the prospective science teachers' awareness of scientific knowledge is changeable and they define scientific knowledge as data, hypothesis, and observation. Results of the study also indicated that some of the participants thought that scientific knowledge is consistent and provable. In contrast to the traditional view, most of the prospective science teachers thought that the subjectivity of the scientists in their work was strongly important because they thought that the interpretation depended on the individual scientist's point of view or on what the scientist already knew.

In addition, a consensus was observed about the explanations of law and theory of the prospective science teachers. Concerning the nature of scientific knowledge, interestingly, most of the prospective science teachers thought that hypothesis, theories and laws are different constructs. Only few participants expressed that hypotheses became theories, and theories became laws depending on the availability of the supporting evidence. This result was very different from the studies of Ryan and Aikenhead (1992), Yakmacı (1998), and Yalvaç, Tekkaya, Çakıroğlu, and Kahyaoglu (2007). Since the elementary and high school science textbooks that students use in Turkey include many misleading assumptions about the nature of science, this result was unexpected for us, too. In general, these textbooks advocate a simplistic hierarchical relationship among hypotheses, theories and laws. Hence, it is possible that many prospective science teachers' previous science learning experiences might have shaped their understanding of the nature of science. After enrolling in the science teacher education program, the prospective science teachers have to take many basic science courses, pedagogy courses, and nature and history of science course during the preparatory program. Especially the differences among hypotheses, theories and laws will be explained through several activities about the nature of science and some assignments on nature and history of the science course. In addition, prospective science teachers will watch several science videos and discuss them during the course. It is possible to say that these applications might develop their understanding of the nature of science.

One of the interesting findings of this research was that most of the prospective science teachers stated their opinions on the effects of society and culture on science and technology. Most of them thought that a society's culture and world view influenced scientific research, and that this influence became greater when a research area contradicted society's cultural and world view. Most participants thought that culture, which differed from one country to another, influenced the conclusions scientists

reached at the end of their investigations. Besides them, they stated that religion, cultural beliefs, custom and society influence scientific research. These results are very similar to the study carried out by Kahyaoğlu (2004), Yalvaç and Crawford (2002). On the other hand, the other findings of this research show that many prospective science teachers believe that science and technology have positive effects on society and science and technology brings economical well being, productivity, comfortable life, being independent and a rich country. Participants' views might have been influenced by the scientifically and technologically developed countries' success in terms of economy, politics and culture.

Another finding of this study is that most prospective science teachers stated that there was not any difference between males and females in terms of discoveries. In addition, a majority of the respondents stated that scientists had a daily life as other people. The only difference is, scientists always think about everything all the time and they always investigate something and they are so creative that they can find many different solutions to the problems in their daily lives. In contrast to the studies of Can (2005), Finson (2002), Kahyaoğlu (2004), and Muşlu (2004), just a small portion of the participants thought scientists were anti-social people. According to these participants, scientists have isolated lives, they work hard and they do not sleep much. The reason of this belief on the anti-social lives of the scientists may come from the belief that scientific and technological studies need hard working.

One of the other important findings of this study is that most of the prospective science teachers participated in this study thought that scientists followed scientific methods; questioning, hypothesizing, collecting data, and concluding, in their investigations. These findings are similar to the results reported by Abd-El-Khalick and BouJaoude (1997), Erdoğan (2004), Haidar (1999), and Tairab (2001). On the other hand, only a small percent of the participants thought that the methods followed by the scientists do not have to be same with the other scientists' methods. These findings are not surprising because as in many other countries, the scientific method is taught at schools with a hierarchical relationship in Turkey, too. Although the chapter one of most science textbooks includes a five-step or seven-step scientific method that describes how to do science, epistemologists have generally agreed that there is no such thing as scientific method (Ryan & Aikenhead, 1992). In general, teachers, textbooks, and teaching methods, as well as the evolution system enforce students to memorize the steps of scientific method, recite, and follow it as a recipe for success. However, the visions of reform are quick to point out that there is no single fixed set or sequence of the steps that all scientific investigations follow. The contemporary view of scientific inquiry advocated that the questions guide approaches and the approaches vary widely within and across the scientific disciplines and fields (Lederman, 2004).

The results of the study also indicated that most of the prospective science teachers had a consensus on the possible positive effects of upbringing and the importance of education given to students on the use of science and technology in their life. In the light of this idea, much more scientific and technological studies would be done in Turkey in the future. It is possible to say that this idea may increase the support given by the whole society to be a scientist and it will also give the opportunity to the well-educated citizens to consciously decide on scientific and technological issues.

Conclusion and Implication

One of the important goals in the newly improved elementary school science curricula in Turkey is to train scientifically literate individuals for a healthy and developing society. To achieve this goal, science teachers, who have a great role in shaping the students' views of nature of science, must be scientifically literate and have a good control of scientific knowledge in the first hand. Therefore, science teachers must possess contemporary views about the understanding of scientific knowledge, the influence of science and technology on society, and the influence of society on science and technology. In order to achieve a scientifically literate society, science teacher educators and science teachers should work hard.

This study gives insights about the views of prospective science teachers on these points. According to the results of this study, it may be concluded that the understanding of nature of scientific knowledge profile of the prospective science teachers drawn by this study is not heartening. It may be possible to say that the applications of the nature of science of these courses in this teacher education program are very successful and the learning environments, offered to the prospective science teachers, are working well. At this program, the courses such as "nature and history of science" and "science

teaching methods" that are based on the discussions of the issues are also trying to address the science that students face outside the school. Obviously, these applications help us to improve the prospective science teachers' understanding of the nature of science. As an educator, we keep in mind that students should be prepared to decide on socio-scientific issues during their education life. Therefore, this kind of classroom activity should be a part of the education at all levels.

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