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Turkish high school students' conceptions of the nature of science

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Abstract

The focus of this study is investigating the extent to which Turkish high school students understand the conceptions of nature of science (NOS). The paper describes the use of questionnaire of NOS and a semi-structured interview. The questionnaire was applied to 162 high school students. After the questionnaire was analyzed individually, six students were interviewed. Interview transcriptions were examined individually. Based on the results, students had some deficiencies on the conceptions of NOS. Students may still hold naive ideas about what data is. Hence, science teachers should implement instruction to help the development of their students' conceptions regarding NOS.

Keywords: Nature of science; science education; misconceptions; interview; questionnaire.

1. Introduction

There is no exact definition of nature of science (NOS), but it can generally be defined as the values and assumptions inherent to the development of scientific knowledge. NOS refers to the epistemology and sociology of science (Lederman, 1992). Conceptions of NOS are tentative and dynamic.

The nature of science has become an essential part of science education research and also is a fundamental component in order to achieve scientific literacy. Moreover, students' understanding of NOS is an important in the teaching and learning process. Lederman, Abd-El-Khalick, Bell, and Schwartz, (2002) developed a new open-ended instrument, the Views of Nature of Science Questionnaire (VNOS), such as VNOS-B, VNOS-C and made individual interviews in order to provide meaningful assessments of students' NOS views. They also outlined the NOS framework that underlies the development of the VNOS; and presented evidence regarding the validity of the VNOS. They stated that NOS has some aspects that are empirical basis, observation and inference, tentativeness, laws and theories, theory-laden NOS, creativity and imagination, and socio-cultural embeddedness.

In order to validate the scientific assertions, scientists refer to observations of phenomena because science is based on observations of natural world. Scientists sort out their perceptions about the observations of nature and

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hypothesize their observations in order to underlie the functioning scientific instruments. Observations and inferences are different from each other. While observations are exactly reachable to the senses, inferences are not exactly reachable to the senses (Lederman, et al., 2002).

Theories are used to clarify unrelated observations in more than one area of research. Theories also have an important role in producing research problems. Moreover, theories guide future research. Scientific theories are supported and validated by indirect evidence since they cannot be directly tested. On the other hand, laws explain the relationships among observable phenomena while theories are inferred statements for observable phenomena. Students think that there is a hierarchical relationship between laws and theories, and also think that laws have a higher position than theories. However, these ideas are misconceptions regarding NOS (Lederman, et al., 2002).

Creativity and imagination are necessary for the development of scientific knowledge. For example scientists used their creativity and imaginations during the development of atom. Therefore, atoms do not reflect the reality (Lederman, et al., 2002).

Some properties of scientists which are prior knowledge, beliefs, training, and expectations affect their research. Hence, scientific knowledge is theory-laden. Scientific knowledge, also, is empirical and involves observations and inferences (Lederman, et al., 2002).

Some social and cultural aspects, for instance religion, politics, socioeconomic factors, affect the development of scientific knowledge and science. Scientists do not follow only one scientific method. Students who get this idea have a misconception since science is influenced by scientists' background, experiences, and biases. Therefore, scientific knowledge is not certain and this knowledge which is facts, theories, and laws is subject to change (Khishfe & Lederman, 2006; Lederman, et al., 2002).

Research on NOS was conducted under the four titles. These were assessment of the students' conceptions of the NOS, the study regarding the curricula designed to develop students' conceptions of the NOS, the study on development of teacher' conceptions of the NOS, the study of the relationship between teachers' conceptions and students' conceptions about NOS (Abd-El-Khalick & Lederman, 2001).

Abd-El Khalick (2005) studied with pre-service secondary science teachers on NOS. Researcher stated that participants had some difficulties on NOS. For instance, some of the participants thought that scientific knowledge is not tentative. They also articulated that there is a hierarchal relationship between theories and laws. Majority of the participants had naïve view during the aspects of NOS.

Bell, Blair, Crawford, and Lederman (2003) studied with students who studied on the grade 10-11 in order to explain the impact of an 8-week science apprenticeship program on a group of high-ability secondary students' understandings of the NOS and scientific inquiry. They used the VNOS-B both the beginning of the study and at the end of the study. They also interviewed with both their sample and the scientists who were mentor of their study. They found that students had some inconsistent ideas regarding the NOS.

Khishfe and Lederman (2006) used open ended questionnaire and semi-structured interviews in order to examine whether students improve their conceptions regarding NOS. They stated that there was an improvement on the conceptions of NOS.

In the literature, many studies have been focused on the students' conceptions of NOS. However, there is a need for understanding the students' conceptions of NOS in Turkey in order to development effective instruction. Therefore, this study explores Turkish high school students' conceptions of NOS. The research questions of this study are presented below:

1. What are the 11^{th} grade students' conceptions of NOS?
2. What are the 10^{th} grade students' conceptions of NOS?

2. Method

The focus of this study is investigating the extent to which Turkish high school students understand the conceptions of NOS. The present paper describes the use of questionnaire of NOS (VNOS-C) and a semi-structured interview protocol designed to investigate high school students' conceptions related to NOS.

The questionnaire was applied to 162 high school students (48 10^{th} grade students, 114 11^{th} grade students) in three high schools in Ankara. VNOS-C is given in the open-ended nature. VNOS-C is composed of 10 questions, but 9 questions were used in this study. Our participants averagely spent 25 minutes to complete the VNOS-C. Each VNOS item is printed on a single page to supply students with sufficient space to write their answers. Respondents were encouraged to write as much as they can in response to any one item, and were provided clarifying examples when asked to. VNOS-C was not used for summative assessment purposes in any manner because such use might interrupt on respondents' answers. Students were reminded that there is no right or wrong answers to any item and that the aim was to elicit their views on some issues related to NOS.

After the questionnaire was administered and analyzed individually, six students were interviewed in order to triangulate data from the written responses. From all sample, six of tenth grade students were randomly chosen for the interview. The reason for this choice was the feasibility and time limitedness. All interviews lasted 20–30 minutes. During the interviews, students were given their questionnaires and asked to give details on their answers. Direct clues were not given and students were encouraged to elaborate, give examples, and explain their ideas. Follow-up questions were sometimes used to obtain participants' ideas. For instance, interviewees explained about theory and laws. However, they did not talk about whether there is a hierarchy between theory and law, and then they were asked, "Is there any hierarchy between theory and laws? Can you give any examples about it?" All interviews were audio-taped and transcribed verbatim for data analysis.

3. Results

During the data analysis, students were placed on their answers in the three categories which are informed, transitional, and naïve (Khishfe & Lederman, 2006). There were nine questions in the questionnaire. Table 1 shows the questions correspond to the aspects of NOS.

Table 1. Questions corresponding the aspects of NOS

The aspects of NOS	Questions
Empirical NOS (EN)	1, 2, 3, 6
Observation and Inference (OI)	1, 2, 3, 6
Tentativeness (Tent.)	4, 5, 6,
Laws and Theories (LT)	4, 5
Theory-laden NOS (TLN)	4, 7, 9
Creativity and Imagination (CI)	6, 7, 8
Socio-cultural Embeddedness (SCI)	7, 9

In order to categorize student' view as informed, for instance, in the aspect of tentativeness, that student must give informed view for all of the questions 4, 5, and 6. If that student gives informed view for some of these questions, then this student is transitional. Finally, if the student does not give any informed view for the aspect of tentativeness, then that student can be classified as naïve (Khishfe & Lederman, 2006). In order to calculate inter-rater reliability (kappa), individually analysis was made for the answers of twenty students and were given points them as 1 (naïve), 2 (transitional), and 3 (informed). At the end of the statistical analysis, inter-rater reliability was found substantial (0.75).

3.1. Empirical NOS (EN)

In the EN aspect, approximately 19% percent of students (9) on the tenth grade had informed view. In addition, 26 of 11th grade students (23%) had informed view about empirical NOS. Table 2 shows that the classification of students as naïve, transitional, and informed in the EN aspect.

Table 2. Students' classification as naïve, transitional, and informed in the EN aspect

EN	Naive(1)	Transitional(2)	Informed(3)
10th.grade	14	25	9
11th grade	28	60	26
Total	42	85	35

27 of 11th grade and 12 of 10th grade students thought that science are different from other disciplines such as religion and philosophy since science represent absolute knowledge and express the events with the certain

judgements. Moreover, 19 of 11th grade and 4 of 10th grade students expressed that atoms can be seen with a powerful microscope. Therefore, they emphasized the accuracy of science. Moreover, five students (11th grade) and 2 students (10th grade) thought that science is concrete discipline, but other disciplines are abstract. One student from 11th grade and the one from 10th grade stated that 'science is a memorized course based on formulas; hence there are no differences between disciplines'. However, one 10th grade participant expressed that 'science is a course based on formulas, thus it is different from other disciplines because science is not based on by rote'. Furthermore, two of 11th grade students indicated that 'science is more logical than other disciplines since it facilitates the life, but other disciplines helps people in their spiritual world'. Two of tenth grade students thought that 'science increases the curiosity of people and it also is more funny and real than other subjects'. Other two students from 10th grade articulated 'science is based on the mathematical processes and uses the numbers'.

Two 10th grade students stated that experiments are not necessary for the development of science. Likewise, two students from 10th grade thought that the development of scientific knowledge does not require the experiments.

One student emphasized the absolute knowledge during the interview. All of them believed the requirement of experiment during the development of scientific knowledge.

3.2. Observation and inference (OI)

Only one student from tenth grade and four of 11th grade students had informed view in this aspect according to questionnaire results. Therefore, many students could not think about observation during the development of scientific knowledge. Two students emphasized the OI during interview.

3.3 Tentativeness (Tent.)

Twelve of 11th grade students gave correct or full answers for the question 4, 5, and 6. Thus, these students had informed view. At the same time, only two of 10th grade students answered those three questions for this aspect. Six students (11th grade) and four 10th grade students believed that scientific theories do not change.

Six students believed that science is developing process and scientific theories change or develop during the interview. However, one student thought that theory does not change, but it develops.

3.4. Laws and theories (LT)

Only two students from 11th grade level and one student from 10th grade level had informed view for the question 4 and 5. Majority of them had common misconception which is a hierarchy between the LT (22 of 11th grade level - 7 of 10th grade level). Likewise, 46 students from 11th grade level and 19 of 10th grade participants stated that laws represent absolute knowledge, but theories are not absolute. Moreover, 19 of 11th grade students thought that laws can not be changed, but theories can be changed. Same idea was seen at the seven 10th grade respondents. Participants did not use "absolute" and "change" in the same meaning. On the other hand, only one participant from 11th grade and 2 participants from 10th grade expressed that 'there is no difference between the LT, both of them are absolute'.

Three interviewees believed that there is a hierarchy between the LT. Two of them stated that 'laws represent absolute knowledge' during interview.

3.5. Theory-laden NOS (TLN)

Students who had informed view in this aspect were 3 (11th grade) and 1 (10th grade). Therefore, these students thought that some properties of scientists such as prior knowledge and beliefs affect their research. However, 46 of 11th grade and 21 of 10th grade participants stated that properties of scientists do not affect their research. For the question seven, 9 of 11th grade and 3 of 10th grade students answered that scientists made different comments on their research. However, they did not emphasize why scientists have different comments on their answers. Furthermore, one student from 11th grade emphasized the background of scientists and he stated that 'Einstein has effectively learned the studies of previous scientists'.

One student stated that 'scientists' background has an important effect to develop science because if they had sufficient knowledge in the past, they would suggest the modern atomic theory in the past'.

3.6. Creativity and imagination (CI)

There was no participant at the informed view on the 10^{th} grade level for this aspect. 4 of 11^{th} grade students had informed view. In other words, these students gave correct answers for question 6, 7, and 8. At the question 8, 11 of 11^{th} grade and 4 of 10^{th} grade students thought that scientists use their CI for all phases (planning and design, data collection, and after data collection). Also, 12 of 11^{th} and six of 10^{th} grade students thought that scientists use their CI for the phase of planning and design. 28 student from 11^{th} grade and 11 students from 10^{th} grade gave correct answer for question 8 and they expressed that scientists use their CI for the stage of planning and design and after data collection. On the other hand, students who stated CI cannot be used in the science were 13 (11^{th} grade) and 2 (10^{th} grade). Two interviewees stated that scientists use their CI for the stage of planning and design and after data collection.

3.7. Socio-cultural embeddedness

The number of informed students was 5 (11^{th} grade) and 1 (10^{th} grade) for this aspect. 63 of 11^{th} grade and 15 of 10^{th} grade respondents thought that science is universal. In contrast, 8 students from 11^{th} grade and 9 students from 10^{th} grade stated that science is infused with social and cultural values. Also, 10 students (grade 11) and 2 students (grade 10) thought that science reflects both universality and social and cultural values. At the interview, five students thought that science reflects both universality and social and cultural values. Only one student stated that science is universal. Three students expressed that religion is effective factor in the development of science.

4. Conclusion and Implications

Results showed that 10^{th} and 11^{th} grade high school students had some misconceptions or difficulties about NOS. They also had naïve understanding of NOS. These findings corroborate previous studies (Abd-El Khalick 2005; Akerson, & Donnelly, 2009; Khishfe & Lederman, 2007). Therefore, teachers should give adequately importance to the teaching of NOS. Teachers also need training in order to efficiently teach NOS.

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