Advanced science students' understanding on nature of science in Turkey

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Abstract

Nature of science (NOS), as an aspect of informed decision making about science related issues in daily life, is frequently emphasised when reform and the curriculum are in question. When reflecting on studies done on the subject, it comes apparent that the majority of them comprise of determination or assessment studies conducted with traditional groups. In order to gain further understanding, there should be more comprehensive research approaches with non-traditional groups such as academically advanced students. The aim of this study is to determine epistemological understanding of academically advanced science students concerning aspects of the NOS. The study was a case study conducted with qualitative perspective. A questionnaire on the students' attitude toward science and motivation toward science learning plus a form for the teacher's ideas and VNOS-C, were used as instruments. The study revealed that the majority of the students were found to be naïve in aspects such as "observation and inference", "social and cultural embeddedness" and "theories and laws" whereas the majority of them were expert in aspects of "tentativeness" and "subjectivity".

Keywords: Nature of science, advanced science students, qualitative research

Introduction

The science and its aspects have importance for life in future society due to the new innovations of science and their integration into daily life. This significance is reflected under the title of "scientific literacy" in many attempts to education for life. Scientifically literate society of future requires decision making based on knowledge about science and its aspects. Nowadays, educational studies emphasise the importance of learning to use informed decision making ability in the problems of daily life (Damastes & Wandersee, 1992). Although literature covers many studies on the aspects of informed decision making in various areas of research, the Nature of Science (NOS) as an issue of informed decision making has become one of the most studied issues in science education research (Lederman, 2007; Palmquist & Finley, 1997).

Nature of science has many aspects for science education from scientific method to science in society. The results of epistemological and educational studies showed that there were common aspects to teach about nature of science in spite of some consensus problems (McComas, 1998). The aspects of nature of science which are commonly indicated are described with the following sentences. In its basic definition, science is a way of knowing and there is no universally accepted one way to do science. And also scientific knowledge is tentative since it is based on evidence and observation and it is also theory-laden. In addition, creativeness and imagination are important to produce scientific knowledge. In line with the theory-ladenness and personal differences, scientist is not objective when he or she begins to study; he or she has a background. As another aspect, there is a certain difference between observation and inference. There is no hierarchy among hypothesis, theory and law and laws and theories have different roles in science. As a different aspect, scientific knowledge is embedded in social and cultural context (McComas, 1998, Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002).

Although many science lessons, textbooks and subjects begin with NOS issues and continue with content knowledge, we can read of the existence of extensive misunderstanding about NOS aspects in textbooks and the minds of students (Blanco & Niaz, 1997; McComas, 2003). At the same time, teachers, prospective teachers and teacher educators do not sufficiently understand and accept NOS as a school subject (Irez, 2006; Tsai, 2006; McComas, 2003; Blanco & Niaz, 1997). The studies conducted in Turkey have also shown existence of many misunderstandings on different nature of science aspects. In the study conducted by Kılıç, Sungur, Çakıroğlu and Tekkaya (2005) with 575 ninth grade students by using survey approach with Nature of Scientific Knowledge Scale (NSKS), they found that the participants were not certain whether the scientific knowledge is absolute or not whereas they hold informed view about creative and imaginative science. As a large-scale survey study on Turkish high school students, Dogan and Abd-El-Khalick (2008) studied 2087 tenth grade students by using Views on Science-Technology-Society (VOSTS) instrument. They found that all of the participants presented naïve understanding about lack of hierarchical relationship between hypotheses, theories and laws whereas majority of them hold informed views about tentativeness aspect. One important point is that studies which focus on NOS aspects, are generally determination or assessment of the aspects, whereas few of them are intervention studies using implicit, explicit or embedding strategies (Tsai, 2006; Khishfe & Lederman, 2007).

The dominant approach of determination and assessment studies in NOS literature, are limited in their capacity to explain what the varying aspects in misunderstanding are. This is because they have been performed on common students, teachers or prospective teachers. But, the epistemologies of them can vary with their background experiences and this variation makes it harder to study their knowledge about nature of science. Studying more specific groups in terms of science content knowledge may provide more comprehensive information. As a special group for epistemological experiences, advanced science students might provide different picture of understandings on the nature of science. Because these students become successful in the standard subject tests or other standard measurements on science content are taking part in more science courses or advanced science courses. Advanced science student means the student with high level of achievement, motivation, and attitude toward science. Therefore; there is a gap in the literature and a need to study advanced science students in terms of epistemological understanding. Studying advanced science students might provide a different pattern to consider in-class activities and experimental studies. Taking these problems into consideration, the purpose of this study is to determine academically advanced science students' understanding of NOS in Turkey.

Advanced high school students and epistemology studies

Although many studies about understandings of high school students on epistemology of science exist, the studies examining specifically NOS aspects with advanced science students are lacking. In spite of lack of studies with advanced science studies, there are some studies on epistemology of science with gifted and talented high school students as similar groups to advanced science students. Since advanced science students have also higher IQ scores and are successful on any content of study (Özaslan, Yıldız & Çetin, 2009). The epistemological studies with gifted students as advanced students were conducted by using different approaches. As the first example, Thomas (2008) studied on Perry epistemological development model and he made his study by focusing on 485 gifted high school students. The author focused on nature of knowledge and learning, then selected the ethnicity difference for the study and used Learning Context Questionnaire as a measurement tool. The author used a course from dualism to relativism for classification of the students. They found that sophomore gifted students were in the position of multiplicity. As a comparison study, Shommer and Dunnell (1994) compared the gifted and non-gifted high school students in terms of beliefs in fixed ability to learn, simple knowledge, quick learning, and certain knowledge. They studied with 1165 high school students. They classified the students as gifted based on the criteria that students must score not less than at the 97th percentile on a standardized individual test of intelligence or rank no less than the 95th percentile on two or more academic areas of a standardized achievement test in order to be classified as gifted. They found that there were no significant differences in students' epistemological beliefs at the beginning of high school whereas gifted students were less likely to believe in simple knowledge and quick learning by the end of high school. Non-gifted students' beliefs in simple knowledge and quick learning remained stable across time. As similar to the results of Thomas (2008), there was not enough evidence to suggest differences between gifted and non-gifted students' beliefs in the early years of high school. The study's the most consistent result indicated that while gifted students changed their beliefs in simple knowledge and quick learning over time, the non-gifted students' beliefs remained stable for this time interval.

In the other study on epistemological beliefs with gifted students, epistemological intentions and epistemological beliefs were studied from self-regulation theory perspective by Neber and Schommer-Aikins (2002). The study included the total number of the participants of the study is 133, 69 of them are boys whereas 64 of them are girls. The participants had been determined by a screening procedure using the Stanford–Binet and they scored in the top 2–3% of this test. They were enrolled in the gifted schools in New York. Context of the study was science for the elementary level and physics for secondary level. The "epistemological intention" aspect was considered as intention to learn "facts" or "usable knowledge" while the "epistemological beliefs" aspect was considered beliefs on "innate ability", "no hard work", "quick learning", "single answers", "avoiding integration" and "certain knowledge" aspects of Schommer (1993). In general, there was no significant difference in epistemological beliefs between high school students and the elementary level students whereas there is a difference in epistemological intentions which showed that high school students aimed at acquiring more applicable knowledge than the elementary students. The significantly positive correlations between epistemological intentions focusing on the acquisition of facts and usable knowledge and strategy use were found in the study. For the deeper focusing the question for relationships among variables, a multivariate regression analysis was computed and the epistemological intention to acquire facts in science was found as one of strongest predictor of regulatory strategy use.

As seen in the studies mentioned above, high school gifted students epistemological beliefs were studied with different focus points than nature of science perspective and all of them were conducted from quantitative perspective.

By the proposed study, the field might gain new insights and different sources for the misunderstandings on the "aspects of nature of science".

Rationale

Studying more specific groups may provide more comprehensive information and a different pattern, since they share more common educational experiences and characteristics than other groups. As a special group for epistemological experiences, academically advanced science students have an important role in the study of NOS. Although Schommer and Dunnell (1994) found no difference in the comparison of gifted and non-gifted high school students in respect of epistemological beliefs, specific NOS aspects were not studied. Determination and assessment studies with academically advanced science students might provide a new aspect for consideration in NOS studies. A qualitative approach supported by a comprehensive selection process of advanced students might provide deeper understanding of the phenomenon which could give new insights into the matter.

Method

The proposed study was conducted with academically advanced 15-years-old students who were purposively selected. This age group has importance due to the appropriateness of it for international comparisons, it becomes clearer when taking into consideration the international examinations, e.g., of PISA. At the same time, it is the first time for students to see science branches as separate titles e.g. biology and chemistry. The students were enrolled in "Science high school" which selects students through a nation-wide examination. The school accepts about only 1 % of the students who participate in the examination. The participants included 16 advanced science students (10 male, 6 female). All of them were enrolled in ninth grade.

Instruments

Student selection for this study was conducted through the use of the 'Motivation toward learning science' questionnaire (MLSQ) developed by Tuan, Chin and Sheh (2005), the 'National science examination' results and 'Attitude toward science' scale (ATSS) developed by Geban, Ertepınar, Yılmaz, Atlan and Şahpaz (1994). The questionnaire and scale were applied to 98 Science high school students, to gather reliability and validity evidence on the 9th graders (n=98). The items translated into Turkish for elementary students by Yılmaz and Cavas (2007) were used in this study. Exploratory factor analysis was used with both instruments due to different group of study than original scale development process. The number of factors, items, Cronbach alpha values and explained variances for each instrument can be seen in table 1.

Table 1. Cronbach Alpha values for the scale and questionnaire (n=98)

<table>
<tr><th>Instrument</th><th>Number of Items</th><th>Number of Factors</th><th>Names of Factors</th><th colspan="2">Cronbach Alpha</th><th>Explained Variance</th></tr>
<tr><td>MLSQ</td><td>28</td><td>1</td><td>Science learning motivation</td><td colspan="2">.97</td><td>54.56%</td></tr>
<tr><td rowspan="2">ATSS</td><td rowspan="2">15</td><td rowspan="2">2</td><td>Positive attitudes toward science</td><td>.80</td><td rowspan="2">.83</td><td rowspan="2">65.40%</td></tr>
<tr><td>Negative attitudes toward science</td><td>.73</td></tr>
</table>

The example items can be seen in the following sentences. The sentence of "I am sure that I will be successful in exams related to science content" is one of the items in the MLSQ while "I want to learn more about science subjects" is an example for the ATSS.

Student selection and data collection process

For selection purpose, the instruments were applied to the participants and then science teachers were asked to rank the five most successful students in their classrooms. After all the applications for selection, matching among all data sources (teacher ranking, national examination scores, attitude scores and motivation scores) was provided. The students who had had 20 or more correct answer out of 25 science questions in the 'National science examination', 4 or more mean scores on total scores on the 'Attitude towards science' scale, and 'Motivation toward science learning' questionnaire, and who were included in the science teachers' ratings (Six science teacher; 2 biology, 2 physics and 2 chemistry), were being determined for further study. Finally, 16 of the participants were selected for the VNOS-C questionnaire, developed by Lederman et al. (2002). The data was qualitatively analysed and categorised according to the guidelines stipulated. The selection process can be seen in the following flow-chart.

Investigation of the national examination scores (20 or more correct answer)

↓

Investigation of motivation and attitude scales (4 or more total mean scores out of 5 in the scales)

↓

Use of six science teachers' rankings of the most successful five students for their courses

↓

Making matching among all of the four criteria above

↓

Selection of the students who provide all of the criteria (Advanced Science Students)

Figure 1. Selection process of the advanced science students

Description of study context

Turkey has an important geo-strategic locality for cultural diversity in the world as a transitional area between western and eastern culture. Again, income rates per individual, dense of population and expenditure for education are other important other factors to define Turkey. The population of Turkey was estimated as 70,586,256 in 2007 (TÜİK, 2008). For the income rates per individual, Turkey was reported to have 2.638 $ in 2003 (Celik, 2004). As the other parameter, expenditure percentage of Gross Product Domestic (GPD) for education is 3.5 for Turkey in 2001 (OECD, 2004). In addition to these general characteristics, Turkish students are one of the worst groups in international examinations such as TIMMS 1998 and PISA 2003 (Berberoğlu & Kalender, 2005; Özgün-Koca & Şen, 2002). Importance of these examinations for the study is that these examinations have been providing detailed findings about curricular effectiveness for scientific literacy as a higher order title for nature of science and clearer picture for international comparisons. So, 15-age group was selected for this study.

What is more, Turkish Educational System is based on centralized administration and has only one science curriculum for all schools at the same level. Among the high schools in Turkey, there are "Science High Schools". These schools have more time and dense content for science courses than traditional high schools (6 course-times per week for ninth grades, 12 course-times per week for tenth, eleventh and twelfth grades). The schools which are supported by state and located only at provinces of the country (The number of provinces is over 80) provide advanced science courses. Advanced science students in the country are selected here according to their results on a nation-wide examination. Teachers are also selected for the schools by a formal evaluation process and examination.

Results

The results of the study are presented by showing the categories of each participant for each aspect studied. For the categorization of the participants, three classes; naive, mixed and expert were utilized. If the participants provided accepted understanding to related aspect of NOS in their answers to all questions, they were classified as expert while they were classified as naive when they presented unaccepted positivistic understandings on the related NOS aspect in all answers. The participants who presented both accepted and unaccepted understandings in all their answers, they were classified as mixed. Table 2 shows statements of participants on seven aspects of NOS.

Table 2. The results of content analysis of the students' answers

Student	NOS Aspects																				
	Empirical basis			Observation and inference			Subjectivity			Tentativeness			Social and cultural embeddedness			Theories and laws			Creativity		
	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E
St1	•			•				•			•		•			•				•	
St2		•		•					•			•	•			•					•
St3	•			•					•			•	•			•					•
St4		•		•					•			•	•			•			•		
St5		•		•			•					•	•			•				•	
St6	•			•					•			•	•			•				•	
St7	•			•					•			•	•			•				•	
St8		•		•				•				•	•			•				•	
St9	•			•					•			•	•			•			•		
St10		•		•					•			•	•			•				•	
St11	•			•					•			•	•			•					•
St12		•		•				•				•	•			•			•		
St13	•			•					•			•	•			•				•	
St14	•			•					•			•	•			•					•
St15			•	•				•				•		•			•			•	
St16	•			•					•			•		•		•				•	

Note: *N: Naïve, M: Mixed, E: Expert*

As seen in table 2, the majority of the students were found to be naïve in terms of "observation and inference", "social and cultural embeddedness" and "theories and laws" aspects, whereas the majority of them were expert on the aspects of "tentativeness" and "subjectivity". The students had naïve or mixed understanding on the aspect of "empirical basis". In addition to these categories, quotations from students' writings might be more helpful to present understandings of them. Following sentences include the explanations of some participants.

Example excerpts for the aspects are provided in the following sentences in an order of the aspects presented in table 2. As the first aspect in table 2, majority of the participants are naive in terms of "empirical nature of science". This is clear in their statements for the related question, for instance, one of the participants (St1) claimed that "*science includes experiment and research and also uses evidence, but religion also includes use of evidence provided by the God*". Another participant (St12)' writings presented another naïve understanding about "observation and inference" aspect. The students stated that "*it is understood by the experiments conducted on structure of atom that electrons spin and are located at the outer part of an atom*". The participant's statement is an indication of the belief that experiment results are enough to construct atom model without any inference. In spite of these naïve understandings, there are expert understandings about "subjectivity" aspect. Writing of one participant (St4) can be shown as an example for this; the participant wrote that reaching different conclusions with the same data set is related to "*differences in interpretation of data, for example; if I loose my pencil, I might claim it is stolen whereas my mother might claim it is in your bag. Everything in this situation is related to human thinking*". As another aspect about which majority of the participants are expert, "tentativeness of scientific knowledge" is explained by the participant (St 5) stating that "*scientific theories are always in a change process, development in technology increases ways we use; therefore we can invent new things or improve existent things*". In addition, one of the participants (St14) believed that "*I think, science is universal and does not reflect social and cultural values*". These explanations are examples of misunderstandings about social and cultural embeddedness of science and scientific knowledge production process. Another participant (St5) answered the same question that "*scientific theories are accepted judgments that are not proved and they [scientific theories] always change. Scientific laws are proved judgments with experiments*". In this statement, the participant exhibited one common misunderstanding about existence of a hierarchy between theories and laws. Then, the same participant claimed that "*science should be universal and it [science] should not be affected by anything*". The aspect of creativity is another issue the participants provided pretty varied understandings. Majority of them were classified as mixed for this aspect. As an example, one participant (St 5) stated that "*science is made of creative thinking; creativity is seen in all of the phases of a scientific investigation such as* *planning, observing, analyzing and explanation producing*". In spite of the clear advocacy of creativity in science, the same participant made an inappropriate explanation as an example for use of creativity in science that "*Newton used creativity to find law of gravity when an apple fall on his head*". In this explanation, there is no clear cite to the scientific processes in which creativity is used and the basic idea behind this example is that science is related immediate observations and use of immediate creativity in that time.

Conclusions and implications

As expected, the results of the study showed a different pattern for the group of this study from regular high school students. Regular high school students are not informed about "tentativeness" and "subjectivity" whereas advanced science students are expert on these aspects. Khishfe and Lederman (2006), in their study, provided misunderstanding examples of common ninth grade students on the NOS aspects by using Views on Nature of Science (VNOS) questionnaire plus follow-up interview method. They studied 42 students and found that more than half of the participants presented naïve understandings on subjectivity and tentativeness by stating exchangeability and stability of scientific knowledge as opposed to the results of this study. Again, the authors showed existence of naïve beliefs about empirical science aspect among majority of the students. Similarly, distinction between observation and inference could not be made by small minority of the participants while both of the groups have certain naïve understandings about "observation and inference" aspect. In addition, majority of the participants also presented naïve understandings on creative and imaginative science aspect. The group of the present study has some differences that empirical basis aspect is partly understood despite existence of mixed understandings. Again, naïve understandings about creative and imaginative science are presented by only small minority of the group.

Similarly, Khishfe and Lederman (2007) studied 89 ninth, 40 tenth and eleventh grade students by using Views on Nature of Science (VNOS) questionnaire and follow-up interview method. In a differing way from the results of present study, many of the participants believed that scientific knowledge would not change and subjectivity would not be included in science. Similarly to the results on group of the present study, some of the participants hold naïve views on observation versus inference and creative/imaginative science aspects.

As another study with high school students, Meyling (1997), in his research, studied 737 German high school students at 10th, 11th, 12th and 13th grades. The author reported that 99% of the participants had the idea of "a verified theory becomes a law". In similar to the results of present study, the students in Meyling's (1997) study believe existence of a hierarchy between law and theory. What is more, the students drove a linear structure to represent pathway of scientific discovery. They ignored theory-laden science and influence of contextual and constitutive values in their thinking. This misunderstanding is also presented by the sample of present study.

In addition to the studies conducted in western culture, Kılıç, Sungur, Çakıroğlu and Tekkaya (2005) studied with 575 ninth grade students by using survey approach with Nature of Scientific Knowledge Scale (NSKS) in Turkey. They found that the participants were not certain whether the scientific knowledge is absolute or not whereas they hold informed view about creative and imaginative science. As another study conducted with Turkish high school students, Dogan and Abd-El-Khalick (2008) studied with 2087 tenth grade students using Views on Science-Technology-Society (VOSTS) instrument. They found that all of the participants presented naïve understanding about lack of hierarchical relationship between hypotheses, theories and laws whereas majority of them hold informed views about tentativeness aspect. The two studies presented above have an important place due to their sample size and culture in which the studies were conducted. These two survey studies in Turkish context showed that common high school students are different from advanced science students for the aspects of "creativity and imagination" and "tentativeness" whereas they are akin to the advanced science students for only "hierarchy between theory and law" aspect.

In conclusion, the differing factor concerning common high school students on "tentativeness" and "subjectivity" should be recognized in classroom activities. Ordinary classrooms also include advanced students, but they experience the same instruction about science and use the same sources in their studying. They clearly have potential use additional sources more efficiently, and to participate in additional programs. To provide alternatives with effective guidance might be enough to change their misunderstanding.

In experimental studies, these students should be studied with an explicit, reflective embedded strategy or in ordinary classrooms they should be separately taken into consideration in these applications. For the experimental explicit-reflective studies, advanced science students might change their misunderstandings on NOS aspects by using more effective ways than awareness-discussion-reflection way or they might change their misunderstandings by utilizing only limited components of the approach (only explicitness component might be enough for such a group). NOS teaching in ordinary classrooms might not be appropriate for advanced science students because of different understanding patterns from common students. Common misunderstandings in classrooms require differentiation in focusing on and giving importance to the certain aspects. More clearly, emphasized aspects in ordinary classrooms might not be appropriate for advanced science students.

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