Advanced Science Students' Understandings on Nature of Science in Finland

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Majority of NOS studies comprise of determination or assessment studies conducted with ordinary students. In order to gain further understanding on variation in NOS understandings among the students, there should be different research attempts focusing on unconventional students such as academically advanced students. The purpose of this study is to determine epistemological understanding of Finnish academically advanced science students concerning aspects of NOS. The study was a case study (N=39) conducted with qualitative perspective. Questionnaires 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 diagnostic tools and data collection instruments. The study revealed that the majority of the students were found to be naïve in aspects such as "empirical basis of science", "observation and inference", "subjectivity of scientists", "social and cultural embeddedness", "creativity in science", "theories and laws" and "tentativeness".

Keywords: nature of science, scientific literacy, advanced students, epistemological thinking

Introduction

Scientific literacy is among the major purposes of science education researchers and science teachers to teach science to all citizens. This tendency on scientific literacy is also seen in current curriculum studies and international examination frameworks (Project 2061, 2007; OECD, 2003). Importance of scientific literacy is related to its role in decision making in daily life, making informed choices on socio-scientific issues, having advanced knowledge about science and its products (Damastes & Wandersee, 1992; Klymkowsky, Garwin-Doxas & Zeilik, 2003; Uno & Bybee, 1994). In the literature,one of the most studied aspects of scientific literacy is nature of science (NOS). NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992, p.331).

Knowing about NOS has importance in our lives for its close association with economical welfare, awareness of cultural productivity of human being, informed decision making in daily life and appreciating new jobs related to new scientific products (Lederman, 2007; Palmquist & Finley, 1997). The aspects of nature of science include a number of clearly described characteristics about definition of science, scientific knowledge, scientists, scientific methods and scientific processes. As two of the basic aspects of NOS, "science is a way of knowing" and "there is no universally accepted one way to

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do science" are accepted as fundamental to give meaning to other aspects of NOS. Another aspect is that scientific knowledge is not fixed, so it is tentative since it is based on evidence and observation which are driven by individuals' educational background and interests. At the same time, scientific knowledge is theory-laden which means theories are the most essential tools of science during production of scientific knowledge. And also theories are not lower-order knowledge than laws, there is no hierarchy among hypothesis, theory and law and, laws and theories are different knowledge types and have different roles in science (McComas, 1998, Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002).

In line with the theory-ladenness and personal differences, scientist is subjective when he or she begins to study; he or she has a background and focus. As another contributor to subjectivity aspect, development of scientific knowledge is embedded in social and cultural context. In addition, there is a certain difference between definitions of observation and inference. NOS studies point out that creativeness and imagination are important to produce scientific knowledge during all stages of scientific process (McComas, 1998, Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002).

Despite the fact that science textbooks, lessons and subjects begin with NOS topics and continue with science content, we see the existence of extensive misunderstandings about NOS aspects in textbooks and the minds of students (Blanco & Niaz, 1997; McComas, 2003). In addition, teachers, preservice teachers and teacher educators do not sufficiently understand and accept NOS as a school subject (Irez, 2006; Tsai, 2006; McComas, 2003; Blanco & Niaz, 1997). Majority of these studies have been conducted with ordinary pre-service teachers, teachers and students. Therefore problems about NOS understandings of different groups of students who are in current educational system are not clear.

While problems on understanding NOS aspects have been studied from different perspectives and new problems have been determined, curriculums and educational reforms have been strongly emphasizing the aspects of nature of science to increase quality of science education. In spite of these emphases, NOS studies have not been extended to different groups of students who are target of educational reforms and curriculums in science education. Nature of science studies generally comprise of determination or assessment studies conducted with ordinary students (Tsai, 2006; Khishfe & Lederman, 2007). In order to gain further understanding on NOS understandings of all groups of students who are enrolled in schools of current educational system, there should be different research attempts focusing on unconventional students such as academically advanced science students. As a special group for epistemological experiences and having higher level scientific knowledge, academically advanced science students have an important role in the study of NOS. Advanced science students are also included in an important group for curriculum implementation and educational reform in science education. Peterson and Mayes (1981) has stated that advanced science students are high achievers and they are significantly more interested in learning subject matter than ordinary science students. Research has also found that advanced science students have the most positive attitudes toward science (Cannon & Simpson, 1985). In addition, it has been shown that the relationship between advanced science students' high grades in science and rational logical thinking is strong (Goodroom, 1979). It is an evidence of advanced logical thinking ability of advanced science students.

Not only advanced science students represent difference in attitudes and cognitive outcomes, but they also behave differently in science classrooms from ordinary students. Park and Oliver (2009) have presented the advanced students' characteristics which are apparent in science classrooms; "asking challenging questions", "being impatient with the pace of other students", "having perfectionist traits", "disliking routine and busy work", "being critical of others" and "being aware of being different". At the same time, it has also been shown that advanced science students often contribute to a lecture by clarifying and emphasizing a basic concept presented by an instructor during a lecture (Near &Martin,2007).

There are studies providing evidence that many advanced science students have inconsistent epistemological understandings about similar situations, and also their statements on epistemological situations are naive (Leach,Millar, Ryder & Sere, 2000; Brickhouse, Dagher, Shipman & Letts,2000; Sandoval &Morrison, 2003). In addition, though Schommer and Dunnell (1994) indicated no difference in the comparison of advanced and non-advanced high school students in respect of epistemological beliefs, specific NOS aspects were not studied on this group of students. Determination and assessment studies with academically advanced science students might provide a new aspect for consideration in NOS studies and a way to determine variation in NOS understandings, and also it might contribute to educational reformers and curriculum designers. Therefore, the purpose of this study is to determine epistemological understanding of academically advanced science students concerning aspects of NOS.

Method

Fifteen years-old (9th grade) advanced science students were enrolled in five lower secondary schools in Joensuu, a town with 77 000 inhabitants in Eastern Finland. This study included 39 participants coming from these schools. A qualitative approach supported by a comprehensive selection process of advanced science students was adopted to get deeper understanding of NOS ideas. The study was carried out as a case study (N=39) conducted with qualitative perspective. Two scales on the students' attitude toward science and motivation toward science learning plus a form for the teacher's decisions and VNOS-C, were used as diagnostic tools and data collection instruments in this study. For selection of the advanced students, the way illustrated in figure 1 was used (Köksal & Sormunen, 2009).

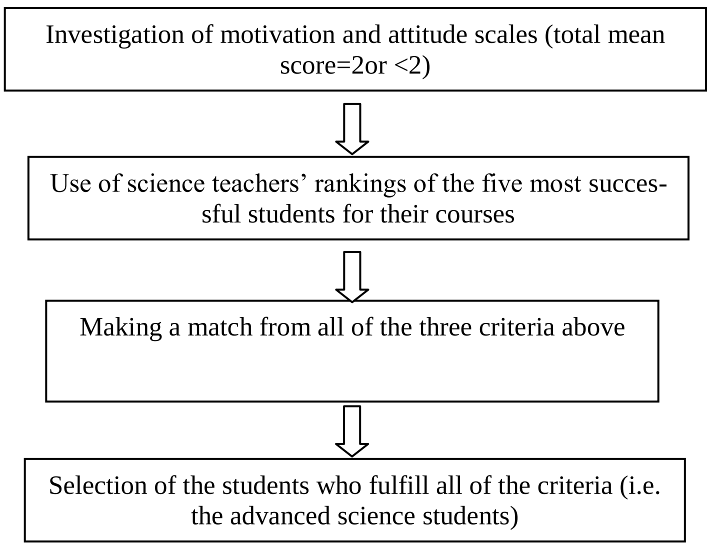

Figure 1. Selection process of the advanced science students

Firstly, student selection for this study was conducted through the use of the 'Motivation toward learning science' questionnaire (SLQ) developed by Tuan, Chin and Sheh (2005) and 'Attitude toward science' scale (ATSS) developed by Geban, Ertepınar, Yılmaz, Atlan and Şahpaz (1994).

Secondly, science teachers were asked to rank the five most successful students in their classrooms. After all the applications for selection, students who 2 or below on the 'Attitude towards science' scale (1 = I totally agree… 5 = I totally disagree), and 'Motivation toward science learning' questionnaire (1 = I totally agree… 5 = I totally disagree), and who were included in the science teachers' ratings, were being determined for further study.

Finally, 39 of the participants were selected for the VNOS-C questionnaire, developed by Lederman et al. (2002). The data was qualitatively analyzed and categorized according to the guidelines stipulated. The profiles of the participants on NOS aspects were tabulated and compared for analysis.

Instruments

The attitude scale (Attitude toward science' scale (ATSS)) and the motivation questionnaire (Motivation toward learning science' questionnaire (SLQ)) were responded by 414 lower secondary school students, in order to gather reliable and valid evidence on the 9th graders in Joensuu town. The results of this part of the study can be seen in the table 1.

Table 1. Cronbach Alpha values for the attitude scale and the motivation questionnaire

Instrument	Number of Items	Number of Factors	Cronbach Alpha	
ATSS	15	3	(6)+ .872* (3) .730 (6) .874	.928 (N = 414)
SLQ	35	5	(7) .402 (8) .847 (8) .858 (6) .751 (4) .731	.854 (n = 368)

+ Numbers in parenthesis shows item number of the factor
* Numbers show Cronbach alpha values of each factor

As the data collection tool on NOS understandings, VNOS-C Questionnaire has been used. The questionnaire has been developed by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) and it has 10 open ended questions about different aspects of NOS. One example of VNOS-C questions is presented below (Abd-El-Khalick, 1998; Lederman, Schwartz, Abd-El-Khalick & Bell, 2001).

> "Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?"

The explanation of this item is seen below (Abd-El-Khalick,1998; Lederman, Schwartz, Abd-El-Khalick & Bell, 2001).

> *[This question refers respondents to a concept from the biological sciences to assess their understanding of the role of human inference, creativity, and subjectivity in science. Desired responses describe the idea that "species" is defined by scientists to explain observed and inferred relationships, and that definitions as well as concepts in science are created by scientists to be useful for their endeavors. Additionally, this question elicits responses concerning the role of models in science and that scientific models are not copies of reality.]*

Analysis of the answers to VNOS-C has been done by using approach of Khishfe and Abd-El-Khalick (2002) for establishing profiles of the participants on the NOS aspects based on the statements provided by Lederman et al. (2002), Khishfe and Lederman (2006), Khishfe and Abd-El-Khalick (2002) and McComas (1998).

Results

The results of the study have shown that Finnish advanced science students who are included in the study group of this study is not as good as their science content success in the international examination programs and classroom assessment (TIMSS 2007 International Science Report, 2008). Table 2 presents the results of the study as NOS profiles.

Table 2. The results of content analysis of the students' answers (Note*: N: Naïve, M: Mixed, E: Expert)*

	NOS Aspects																				
Student	Empirical basis Q2&Q3			Observation and inference Q7			Subjectivity Q7&Q9			Tentativeness Q1&Q6			Social and cultural embeddedness Q10			Theories and laws Q5			Creativity Q4,Q7,Q8 &Q9		
	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E	N	M	E
1	**N**			**N**				**M**		**N**			**N**			**N**				**M**	
2		**M**		**N**				**M**		**N**				**M**		**N**			**N**		
3	**N**			**N**			**N**				**M**		**N**			**N**			**N**		
4			**E**			**E**		**M**			**M**		**N**			**N**					**E**
5		**M**		**N**				**M**		**N**			**N**			**N**			**N**		
6	**N**			**N**			**N**			**N**			**N**			**N**			**N**		
7	**N**			**N**			**N**			**N**			**N**			**-**	**-**	**-**	**N**		
8	**N**			**N**			**N**			**N**			**N**			**N**			**N**		
9		**M**		**N**			**N**			**N**			**N**				**-**	**-**	**N**		
10		**M**		**N**			**N**				**M**		**N**			**N**			**N**		
11	**N**			**N**			**N**			**N**			**N**			**N**			**N**		
12	**N**					**E**			**E**	**N**			**N**			**N**				**M**	
13		**M**		**N**			**N**				**M**				**E**	**N**				**M**	
14		**M**		**-**	**-**	**-**	**N**				**M**		**N**			**N**			**N**		
15	**N**				**M**			**M**			**M**			**M**		**N**				**M**	
16	**N**				**M**			**M**			**M**		**N**			**N**				**M**	
17		**M**		**N**			**N**			**N**			**N**			**N**			**N**		
18	**N**			**N**			**N**				**M**		**N**			**-**	**-**	**-**	**N**		

19	**N**	**N**	**N**	**N**	**N**	**N**	**N**
20	**N**	**N**	**M**	**N**	**N**	**M**	**N**
21	**N**	**N**	**N**	**N**	**N**	**N**	**N**
22	**N**	**N**	**M**	**N**	**N**	**N**	**M**
23	**M**	**N**	**N**	**M**	**N**	**N**	**N**
24	**N**	**N**	**N**	**N**	**N**	**N**	**N**
25	**M**	**N**	**N**	**M**	**N**	**E**	**N**
26	**N**	**N**	**N**	**M**	**N**	**M**	**N**
27	**M**	**N**	**M**	**M**	**N**	**M**	**M**
28	**N**	**N**	**N**	**N**	**N**	**N**	**N**
29	**N**	**N**	**N**	**N**	**N**	**N**	**N**
30	**N**	**N**	**N**	**N**	**N**	**N**	**N**
31	**N**	**N**	**N**	**M**	**N**	**N**	**N**
32	**N**	**N**	**M**	**N**	**N**	**N**	**M**
33	**N**	**N**	**M**	**M**	**N**	**N**	**M**
34	**N**	**N**	**N**	**N**	**N**	**N**	**N**
35	**M**	**M**	**M**	**M**	**N**	**N**	**M**
36	**N**	**N**	**N**	**N**	**N**	**N**	**N**
37	**N**	**N**	**N**	**M**	**N**	**N**	**N**
38	**N**	**N**	**N**	**N**	**N**	**N**	**N**
39	**N**	**N**	**N**	**N**	**N**	**N**	**N**

The study revealed that the majority of the students were found to be naïve in all aspects; “emprical basis of science”,“observation and inference”, “subjectivity of scientists”, “social and cultural embeddedness”, “creativity in science” “theories and laws” and “tentativeness”. Especially, misunderstandings of the participants on “social and cultural embeddedness” and “theories and laws” are the most serious.

Discussion and Implications

The results of this study have shown that NOS profiles of the Finnish advanced science students is not as good as their science content knowledge, science interest and attitudes toward science. In literature, there are some studies showing similar misconceptions of ordinary high school students in different countries. In USA, Khishfe and Lederman (2007) have studied with ordinary 89 ninth, 40 tenth and eleventh grade students by using Views on Nature of Science (VNOS) questionnaire and follow-up interviews to collect data. They have shown that some of the participants have presented naïve views on observation versus inference and creative/imaginative science aspects. And also some of them have believed scientific knowledge is not tentative and subjectivity would not be included in science. These results on this limited number of the aspects are consistent with the results of current study. But, the advanced science students have presented misunderstandings on the other NOS aspects in higher rates.

In another country, Meyling (1997) has studied with 737 German ordinary high school students at tenth, eleventh, twelfth and thirteenth grades. The author has pointed out that 99% of the participants have believed that "a verified theory becomes a law" . The author has also stated that majority of the German students in his sample ignored theory-laden nature of science and influence of contextual and social factors in their thinking. The results of present study are supported by Meyling study, for example, the students in Meyling (1997)'s study have similarly believed existence of a hierarchy between law and theory. This aspect is also among the most serious aspects on which advanced science students have misunderstandings.

Similar misunderstandings to study group of this study are shown in studies conducted in a country (Turkey) that has very different cultural and social environment from Finnish context. And also Turkey has lower success on science section in international examination studies than Finland. Kılıç, Sungur, Çakıroğlu and Tekkaya (2005) have studied with 575 Turkish ninth grade students by using Nature of Scientific Knowledge Scale (NSKS). The results of the study have shown that the participants are not certain whether the scientific knowledge is tentative or not. As another study showing existence of similar misunderstandings on NOS aspects in Turkish students, Dogan and Abd-El-Khalick (2008) have studied with 2087 Turkish tenth grade students using Views on Science-Technology-Society (VOSTS) instrument. The results have also shown that all of the participants have presented naïve understanding about lack of hierarchical relationship between hypotheses, theories and laws. Koksal, Cakıroglu and Geban (2013) also studied with advanced students and their findings were supported by the results of present study. The researchers found that advanced science students had misunderstandings about "laws and theories" and "observation and inference".

Although the results of the studies above have been showing similar understandings between advanced and ordinary science students, there are other understandings differing between advanced and ordinary science students. For example, the participants of the current study have presented serious misunderstandings on "social and cultural embeddedness" and "theories and laws" aspects which are not shown to be serious problem in the studies conducted with ordinary students. Reasons of higher rates in misunderstandings of advanced science students on NOS than ordinary students should be studied after an advanced selection process.

In addition to the studies conducted with ordinary students,there are also studies focusing directly on advanced science students and NOS aspects. Köksal and Sormunen (2009) have studied on 16 advanced science students' understandings of the NOS aspects by using case study approach as used in this research. The authors have revealed that majority of the partipants have been found to be naïve in the aspects such as "observation and inference", "social and cultural embeddedness" and "theories and laws". This results have shown that there is a clear consistency between the results of the current study and Köksal and Sormunen's research in spite of cultural differences and difference in the results of international exmination studies. As another study on advanced students, Liu and Lederman (2002) have studied on 29 Taiwanese advanced high school students by focusing directly on the NOS aspects. In opposite to the results of this study, the authors have revealed that majority of the students have presented basic understanding of tentative, subjective and empirical NOS while they have also had misunderstandings on some aspects. The results of this study is not consistent with the current results of this study, but as far as stated by the authors the study has had a problem regarding to a treat to internal validity.

The results of this study have importance due to the fact that ordinary science classrooms include advanced science students and they experience the same instruction about science and use the same sources in their studies in ordinary classrooms. But, Park and Oliver (2009), Near and Martin (2007) have revealed that these students with their higher achievement, more positive attitudes and interest toward science (Cannon & Simpson,1985; Goodroom,1979) have been carrying their different characteristics into science classrooms. So, their experiences in science classrooms differ from the experiences of ordinary students. This is also apparent in their difference in understandings on NOS aspects as stated in the current study. To show where is the difference and what are the most important problems regarding to NOS understandings of advanced science students, this study might provide an insight to make deeper research.

The misunderstandings found in the current study are crucial to overcome curricular problems and blocking effects of them on educational reform movements, therefore the misconceptions require making curricular arrangements which emphasize explicit-reflective way of teaching as en enrichment program (Khisfe &Lederman, 2007; Koksal, 2010). In ordinary classrooms they should be separately taken into consideration and different opportunities including learning NOS aspects with explicit-reflective applications should be provided. Park and Oliver (2009) have also stated a need of different teaching approach on science for advanced student due to their carrying the advanced characteristics into science classrooms.

In spite of valuable results of the study, the results should be examined with care due to low number of the participants and use of VNOS-C as the data collection tool on NOS understandings. By considering the limitations, there is a need to extend the results by applying the same approach on advanced science students in different countries who have higher successes in science examinations or science education. And also reasons of the serious NOS understandings among advanced science student should be studied by using multi-method approach.

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