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NINTH GRADE STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENTIFIC KNOWLEDGE

DOKUZUNCU SINIF ÖĞRENCİLERİNİN BİLİMSEL BİLGİNİN DOĞASINI ANLAMA DÜZEYLERİ

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ABSTRACT: The purpose of this study was to investigate the 9th-grade students' understandings of the nature of scientific knowledge. The study also aimed to investigate the differences in students' understanding of the nature of scientific knowledge by gender, and school types. A total of 575 ninth grade students from four different school types (General High, Anatolian High, Vocational High and Super Lycee) participated in the study. Data were collected utilizing an adapted version of the Nature of Scientific Knowledge (NSKS). Data were analyzed by using MANOVA. Results revealed statistically significant differences in the student's perceptions of nature of scientific knowledge by gender and school types. It was also found that many of the participants had inadequate understanding of nature of scientific knowledge.

Keywords: scientific knowledge, nature of science, school type, gender

ÖZET: Bu çalışmanın amacı lise 1 öğrencilerinin bilimsel bilginin doğasını nasıl algıladıklarını ve bu bilginin cinsiyete ve okul türüne bağlı olarak değişip değişmediğini saptamaktır. Araştırmaya dört farklı okul türünden (devlet lisesi, anadolu lisesi, meslek lisesi ve süper lise) 575 öğrenci katılmıştır. Veriler "Bilimsel Bilginin Doğası Ölçeği" kullanılarak toplanmış ve çoklu varyans analizi kullanılarak analiz edilmiştir. Sonuçlar lise 1 öğrencilerinin bilimsel bilginin doğasını algılamasının cinsiyete ve okul türüne bağlı olarak değiştiğini göstermiştir. Ayrıca katılımcıların büyük bir kısmının bilimsel bilginin doğası hakkında yeterli bilgiye sahip olmadığı saptanmıştır.

Anahtar Sözcükler: bilimsel bilgi, bilimin doğası, okul türleri, cinsiyet

1. INTRODUCTION

The Nature of Science (NOS) has been defined in numerous ways over the years, but there is a common theme within the varied definitions. In particular, the nature of science typically refers to "the values and assumptions inherent to science, scientific knowledge and/or the development of scientific knowledge" (Lederman, 1992). However, A.B.D.-El-Khalick and Lederman (2000) claimed the existence of the disagreement among philosophers, historians, science educators and sociologist concerning a universal definition of NOS. It is necessary to note that conceptions of NOS are tentative and dynamic and these conceptions have changed throughout development of science and systematic thinking about its nature working (Lederman, A.B.D.-El-Khalick, Bell, & Schwarts, 2002). Although disagreement exists regarding the specifics of NOS, there is an acceptable level of generality regarding NOS that is relevant and accessible to K-12 students (A.B.D.-El-Khalick & Lederman, 2000). Some aspects of NOS such as independence of thought, creativity, tentativeness, empirically based, subjectivity, testability, and cultural and social embeddedness might fall under this level of generality. Two additional important aspects are the distinction between observations and inferences and the functions of and relationships between scientific theories and laws (Lederman, 1992; A.B.D.-El-Khalick & Lederman, 2000).

The development of students and teachers' conceptions of the NOS has been a concern of science educators for several years (McComas, 1996; Clough, 1997; A.B.D.-El-Khalick Bell & Lederman, 1998; Akerson, A.B.D.-El-Khalick & Lederman, 2000; Morrison & Lederman, 2003; Tao, 2003; Schwartz, Lederman & Crawford, 2004; A.B.D.-El-Khalick & Akerson, 2004; Kang, Scharman, &

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Noh, 2005). However, these studies have consistently shown that kindergarten through Grade 12 (K-12) students, as well as teachers, have not acquired desired understanding of NOS. For example, Aikenhead and Ryan (1992) used the Views on Science-Technology-Society (VOSTS) instrument to assess high school students' viewpoints on the epistemology of science. They found that majority of the students were "apparently influenced by a classic but erroneous notion that many discoveries occur by accident, a notion heralded in the media and by popular writers of the history of science" (p.566). In another study, with a Likert-scale instrument Nature of Scientific Knowledge Scale (NSKS), Rubba, Horner and Smith (1981) indicated that even high ability secondary students tended to be neutral toward the statement of "scientific theories and laws are true beyond a doubt". Haidar and Balfakih (1999) reported that Emirate high school students held mixed understanding about the nature of science. Their study suggested that cultural background influence students views about the nature of science. In a separate study, Kang et al., (2005) reported that most Korean students had an absolutist/emprical perspective of the nature of science. In addition, they found no clear distiction in the distribution of 6the, 8th, and 10th graders' views on the NOS, indicating little influence of secondary school science on the development of students' views. Moss, Abrams & Robb (2002) demonstrated that students' conceptions of the NOS remained unchanged over the year despite their participation in the project-based, hand-on science course. However, Khishfe & A.B.D.-El-Khalick (2002) found that an explicit and reflective inquiry-oriented approach was more effective than an implicit inquiry-oriented approach in promoting 6th graders' NOS conceptions.

Studies on teachers' views on the NOS revealed that teachers also held many naive views (Lederman, 1992; A.B.D.-El-Khalick & Boujaoude, 1997) . For example, these studies reported that majority of teachers believed that scientists follow a receipt so called scientific method in their investigation and scientific models are copies of reality rather than human invention. In addition, they overlook the role of creativity and imagination in science. It is also indicated that teachers adopted a naive, simplistic, and hierarchical relationship between hypotheses, theories and laws.

Although a large research tradition has developed around the conceptions of nature of science in many countries, less has been done especially on students' understanding of the nature of science in Turkey. Therefore, this study aims at examining Turkish high schools students' understanding of the nature of scientific knowledge. The study was also interested in investigating the differences in students' understanding of the nature of scientific knowledge by gender and school types.

2. METHOD

2.1. Sample

To assess the nature of scientific knowledge, 575 ninth grade students were surveyed during the spring 2003 semester by means of identical written questionnaire. The sample consisted of 295 girls and 280 boys. Data were collected from four different school types namely General High Schools (GHS), Anatolian High Schools (AHS), Vocational High Schools (VHS) and Super Lycee (SL).

2.2. Instrument

Students' understanding of the nature of scientific knowledge was assessed by utilizing the Nature of Science Knowledge Scale (NSKS) developed by Rubba and Andersen in 1978. The NSKS is a 48 item Likert-type scale ranging from strongly agree to strongly disagree. It covered 6 tenets or postulates of nature of scientific knowledge. Scientific knowledge is characterized as: 1) amoral i.e., provides people with many capabilities, but does not provide instruction on how to use them; 2) creative i.e., is a product of human intellect; 3) developmental, i.e., is never proven in the absolute and final sense; 4) parsimonious, i.e., tends toward simplicity but not to the exclusion of complexity; 5) testable i.e., is capable of public empirical test; and 6) unified i.e., is born out of an effort to understand the unity of nature. Each of the six tenets includes 8 items. The NSKS was translated and adapted into Turkish by the researchers. The reliability of the Turkish version of the scale was found to be 0.74 by using Cronbach alpha. The validation of the scale was examined by a group of panel

judges. Responses to the NSKS questionnaire were scored according to the point-value system designed by Rubba and Anderson (1978). A maximum score of 40 was possible for each tenet and 240 points for the total NSKS score. In analyzing data we elected to collapse strongly agree and agree into one category and to do the same for disagree and strongly disagree.

3. RESULT

Descriptive analysis indicated that 9th grade students generally had a moderate (average) understanding of scientific knowledge (Total mean= 26.93). A testable tenet of the NSKS has the highest mean score (M=30.25), however parsimonious tenet has the lowest mean score (M=24.99) (Fig. 1). Generally, participants believed that scientific knowledge is capable of empirical test, but were hesitant about the tendency of scientific knowledge toward implicity.

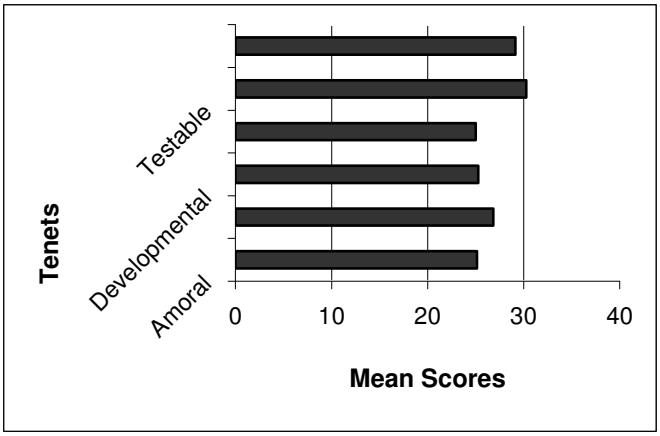

Figure 1. Distribution of mean scores with respect to six tenets of NSKS

Table 1 presents the students' understanding of nature of scientific knowledge with respect to 6 tenets of NSKS. For example, more than 40% of the students attending General High Schools, Anatolian High Schools, and SL thought that a piece of scientific knowledge should not be judged good or bad (amoral). On the other hand only 38% of students in Vocational High Schools agreed with this statement. More than half of the students (65%) in General High Schools, Anatolian High Schools, and Super Lycee agreed that scientific knowledge express the creativity of scientists (creativity). But this ratio decreased to 54% in Vocational High Schools. Majority of students in General High Schools, Anatolian High Schools, and Super Lycee agreed that today's scientific laws, theories and concepts may have to be changed in the face of new evidence (development). However only 38% of students in Vocational High Schools shared this idea.

Table 1. Responses to the NSKS with respect to gender and school type

Gender (%)				School Type (%)			
Male	Female	Tenets of NSKS	Item	GHS	AHS	VHS	SL
43.2	38.3	Amoral	Moral judgment can be passed on scientific knowledge.	47.6	37	33	38.9
46.8	43.4		A piece of scientific knowledge should not be judged good or bad.	43.2	49	38.3	48.6
61.8	69.8	Creative	Scientific knowledge expresses the creativity of scientist.	69.5	66.1	54.3	68.9
50.7	47.5		Scientific knowledge is a product of human imagination.	47.4	50.3	46.9	52.5
28.9	25.1	Developmental	The truth of scientific knowledge is beyond doubt.	47.8	40	50	44.6

(Table 1 cont.) Gender (%)				School Type (%)			
Male	Female	Tenets of NSKS	Item	GHS	AHS	VHS	SL
61.1	71.2		Today's scientific laws, theories and concepts may have to be changed in the face of new evidence.	62.9	82.5	38.3	72.8
31.4	21		Scientific knowledge is unchanging.	26.8	22.5	38.3	19.5
49.2	37.3	Parsimonious	Scientific knowledge is stated as simply as possible.	43.7	47.3	45.8	33
50	53.2		If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen.	58.2	47.3	42.6	53.4
69.6	82.2	Testable	The evidence for scientific knowledge must be repeatable.	76.6	88.4	54.3	75.7
58.2	69.5		Consistency among test results is a requirement for the acceptance of scientific knowledge.	59.7	76.4	36.2	78.6
66.4	84.1	Unified	The laws, theories and concepts of biology, chemistry and physics are related.	75.1	85.5	52.1	81.6
58.6	66.7		Biology, chemistry and physics are similar kinds of knowledge.	57.3	72.1	54.3	67

A two-way multivariate analysis of variance (MANOVA) was conducted to determine the effect of gender and school types on six tenets of nature of scientific knowledge: amoral, creative, developmental, parsimonious, testable, and unified at 0.05 significance level. Both gender and school types were found to have significant effect on the dependent measures, Wilks' Λ= 0.970, $F(6, 562)$= 2,919, p= 0.008 and Wilks' Λ= 0.856, $F(18,1590)$= 5.005, p= 0.000, respectively. No interaction were found between gender and school types Wilks' Λ= 0.951, $F(18, 1590)$= 1.574, p= 0.059.

Concerning gender difference, the univariate ANOVAs for amoral *(*$F(1, 567)$= 4.095, p=0.043) and unified tenets ($F(1, 567)$=7.640, p=0.006) of NSKS were significant in favors of girls while the univariate ANOVAs for creative, developmental, testable and parsimonious tenets were not significant ($p> 0.05$). The mean scores displayed in Table 2 indicated that girls had higher scores on amoral and unified tenets of the NSKS. These results indicated that there was significant mean difference between boys and girls with respect to amoral, and unified tenets of the NSKS.

Table 2. Descriptive Statistics on the six tenets of the NSKS by gender

Tenets	Girls (N= 295)		Boys (N= 280)	
	M	SD	M	SD
Amoral	25.83	4.17	24.42	4.09
Creative	27.37	4.52	26.25	4.07
Developmental	25.33	3.78	25.24	3.77
Parsimonious	25.08	3.35	24.91	3.25
Testable	31.43	5.02	29.02	5.23
Unified	30.56	4.83	27.60	5.12

Regarding school types, the univariate ANOVAs for amoral *(F*(3, 567)= 3.637, *p*=0.013), creative *(F*(3, 567)=3.097, *p*=0.026), developmental *(F*(3, 567)= 6.140, *p*=0.000), testable (*F*(3, 567)=20,156, *p*=0.000) and unified (*F*(3, 567)=12,490, *p*=0.000) tenets of the NSKS were significant. However, parsimonious tenet of NSKS scale was found to be nonsignificant. These results revealed that there was significant mean difference among school types on amoral, creative, developmental, testable and unified tenets of NSKS. However, there was no significant mean difference in parsimonious subscale of the NSKS with respect to school types. Post hoc analysis revealed that when the amoral tenet of the NSKS is considered there is a significant mean difference between students attending Super Lycee and Vocational High School. Moreover there is a significant mean difference between students attending Super Lycee and General High School. What is more, it was found that there were significant mean differences between Anatolian High Schools and Vocational High Schools, and Super Lycee. Regarding creative tenet, the results showed that mean score of the students in Vocational High Schools was significantly different from that of students in other school types. As it can be deduced from Table 3, students attending Vocational High Schools had the lowest score on this tenet. Concerning developmental tenet, there was significant mean difference between students in General High School and Anatolian High Schools, and Vocational High Schools. In addition, it was found that the mean scores of students in Anatolian High Schools and Vocational High Schools were significantly different in favor of Anatolian High Schools. When the testable and unified tenets were considered, there was significant mean difference between all school types except Anatolian High Schools and Super Lycee.

Table 3 Descriptive statistics on the six tenets of the NSKS for school types

	GHS		AHS		VHS		SL	
	M	SD	M	SD	M	SD	M	SD
Amoral	24.54	3.43	25.79	4.72	24.05	3.75	26.34	4.66
Creative	26.69	4.24	27.67	4.42	24.90	3.03	27.50	4.85
Developmental	25.26	3.30	26.66	3.79	23.82	3.58	25.20	4.36
Parsimonious	25.08	2.99	25.46	3.57	24.49	3.05	24.55	3.56
Testable	29.52	5.08	32.60	4.21	25.99	4.24	31.91	5.22
Unified	28.76	4.45	31.10	4.66	24.79	3.93	30.64	5.91

4. DISCUSSION

This study provides insight to 9th-grade students' understanding of nature of scientific knowledge. Generally speaking, students participated in this study have difficulty in understanding that there is a continous effort in science to develop a minimum number of concepts to explain the greatest possible number of observations. In other word, they failed to recognize that scientific knowledge tends toward simplicity, but not to do disdain of complexity. They also were not clear whether the scientific knowledge is absolute or not. Scientific claims, however, change as new evidence or as old evidence is reinterpreted in the light of the new theoretical advances or shifts in the directions of established research programs. On the other hand, participants appreciated that scientific knowledge involves human imagination and creativity. Lederman (1992) stresses that even though scientific knowledge is at least partially based on and/or derived from observations of natural world; it involves human imagination and creativity. He stated that science involves the invention of explanation, which requires a great deal of creativity. Many participants in this study agreed with the model on the testable and unified nature of scientific knowledge. They believe that scientific knowledge must be subject to testing and the interaction of the various disciplines of science contributes to the overall understanding of nature.

Results also revealed that student' ideas of nature of scientific knowledge is changing depending on their gender and school type they attend. It was found that students attending Vocational High School have more traditional views about the nature of scientific ideas than students attending other

school types. Concerning gender difference, the only significant difference was found in two tenets of NKSK-unified and amoral. These findings are worthy of further examination.

Helping students develop adequate conceptions of nature of science should be the main objective of science education. Therefore, students and teachers must be informed about the nature of scientific knowledge that scientific knowledge is partially a product of human creativity and imagination, scientific knowledge is tentative, scientific knowledge is partially a function of human subjectivity, and scientific knowledge necessarily involves a combination of observation and inference. Moreover, students held a hierarchical view of the relationship between theories and laws. They thought that theories become laws depending on the availability of supporting evidence. This notion leads to the ideas that laws have higher status than theories. Lederman (1992) claims that they (theories and laws) are different kinds of knowledge and one can not develop or be transformed into the other. In addition, contrary to popular belief, the sequence of processes and the specific processes used by scientist can vary from one investigation to another. Therefore, it must be emphasized that "there is no single set and sequence of steps known as the scientific methods". All these aspects of nature of science should be integrated into present science curricula and teacher education programs.

Although the generalizability of this study might be limited by the sample size and student background, we believe that findings of this study can help science educators in revising science programs and textbooks such a way that it enhances students' views on understanding of nature of science.

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