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Examining science teacher's understandings of the NOS aspects through the use of knowledge test and open-ended questions

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Abstract
The nature of science aspects (NOS) are the most emphasized theme in many curriculum and reform attempts. Teachers as a curriculum implementer in the classroom play important role for policy, arrangements and classroom experiences on NOS understandings of students. Researchers generally assessed the teachers' NOS conceptions using open-ended questions plus interview in limited samples. However, in the literature, there have been some critics on this way of assessment. For that reason, this study aims to assess elementary science teachers' (N=47) NOS conceptions by using "Open-ended questions" and "Knowledge test". The results showed existence of some misunderstandings on NOS and the participants' responses to knowledge test and open-ended questions gave similar pattern in terms of ten aspects of NOS, except for three aspects.

Keywords: *Elementary Science Teachers, Nature of Science, Assessment of NOS*

Introduction
Scientifically literate society of future requires people to have informed decision making ability with the knowledge about science and its aspects. Today, informed decision making ability on daily life situations or problems has been emphasized to learn and use in many educational studies (Mbajıorgu & Ali, 2003; Damastes & Wandersee, 1992; Klymkowsky, Garvin-Doxas & Zeilik, 2003). Although there have been many studies in the literature focusing on the components of informed decision making process in different fields of study, "aspects of nature of science" as an issue of informed decision making emerged and took much interest as one of the most studied issue in science education research (Cooper, Cowie & Jones, 2010; Dekkars, 2005; Marra & Palmer, 2005; Lederman, 2007; Palmquist & Finley, 1997; McComas, 1998). Due to the importance of nature of science for scientifically literate society, the nature of science similar to scientific literacy has also been determined as an important aim of science education in many curriculums and international examination frameworks (Turkish Ministry of Education, 2007; AAAS, 1994; Kjærnsli & Lie, 2004; Olsen, Kjærnsli & Lie, 2005; OECD, 2003). Nature of science includes many aspects from scientific method to science in society for science education. The results of epistemological and educational studies indicated that there are commonly accepted aspects to teach about

nature of science in formal education (McComas, 1998; Khishfe & Lederman, 2006). These nature of science aspects are presented in the followings:

1. Scientific knowledge is theory-laden.
2. Scientific knowledge is tentative.
3. Observation is different from inference.
4. Scientific knowledge is based on evidence and observation.
5. There is no hierarchy among hypothesis, theory and law.
6. Laws and theories have different roles in science.
7. Scientific knowledge is embedded in social and cultural context.
8. Science is a way of knowing.
9. There is no universally accepted one way to do science.
10. Creativeness and imagination are also important to produce scientific knowledge.
11. Scientist is not objective when s/he begins to study; or when s/he has a background (McComas, 1998; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

For a long time, many of science lessons, textbooks and subjects have been beginning with nature of science issues and continued with content knowledge after nature of science part. In spite of these priority and consideration, research has consistently showed that there are inadequate explanations about nature of science aspects in textbooks and naïve understandings in the minds of students (Blanco & Niaz, 1997; Marra & Palmer, 2005; Tsai, 2006; Irez, 2006; Ryan & Aikenhead, 1992; McComas, 2003). In addition, nature of science as a school subject is not understood well enough by students, teachers and teacher educators (Irez, 2006; Thye & Kwen, 2003; Tsai, 2006; McComas, 2003; Sandoval & Morrison, 2003; Dagher & Boujaoude, 2005; Blanco & Niaz, 1997; Dogan & Abd-El- Khalick, 2008). Especially, teachers, among these groups, have an important role for organizing and conducting explicit-reflective instruction on and providing important experiences to help the students learn NOS aspects. Previous studies showed that there is no convincing evidence or tendency for transferring of teachers' understandings of NOS into their classroom practices and students' NOS understandings (Lederman & Zeidler, 1987; Akerson, Abd-El-Khalick, Lederman, 2000). In spite of lack of evidence, considering the fact that teachers are the key persons for implementing the science curriculum in classrooms and they are still thought to be important person in development of students' understandings of NOS aspects (as cited in Akerson et al., 2000). Practically determination of teachers' understandings on NOS aspects in large scale studies might provide data for teacher profiles. Then, these profiles can be used for decisions of authorities on the factors which are effective in integration of explicit-reflective teaching into classroom practices. When considered the current studies about nature of science with teacher or prospective teachers, it can be seen that many of the studies focused on determination or assessment of the NOS aspects by using open-ended questionnaire and interview. Some studies are also focused on examining the effects of interventions including implicit, explicit or embedding strategies on participants' NOS views with the help of an open-ended questionnaire and interviews (Akerson et al., 2000, Morrrison, Raab, & Ingram, 2009). The most widely used questionnaires in many studies are VNOS versions developed by Lederman et al. (2002), and Abd-El-Khalick (1998). The administration of the questionnaire was not seen enough to get comprehensive data, so the need for a follow-up interview became inevitable (Lederman et al., 2002; Lederman, Wade & Bell, 1998). When taken into consideration of questionnaire plus follow-up interviews, it is seen that they are time and effort consuming, require having ability and knowledge to use complex qualitative coding, analyzing and interpretation techniques. For instance; VNOS-C application takes 45-60 minutes and follow-up interview adds more time to the application (Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2008). In addition, working with more participants is a difficult task for any researcher if s/he uses both open-ended questionnaire and follow-up interview. What is more, the questions of VNOS versions include generally generic questions in spite of their comprehensive nature to obtain data. For that reason, researchers might obtain different data from the focus of the question. All of these limitations mentioned above were also stated by Wenning (2006) and Liang et al. (2008). In the literature, there are few examples using only standardized test to study relationship of NOS aspects with achievement, age, gender and academic background. For example, Wood (1972) studied relationship of NOS conceptions of 443 pre-service teachers with gender and academic background by using WISP (Wisconsin Inventory of Science Processes). The author found only little relationship between NOS conceptions and gender, number of university courses taken and year in high school science. Using same inventory Carey and Strauss (1969) explored the relationship between NOS conceptions of 17 pre-service teachers and academic variables including grades achieved in science and number of credits taken. The authors did not find any significant relationship. When they increased the sample of the study to 221 pre-service teachers, they found that WISP scores were related academic variables including college science grade mean, total college grade mean (Carey & Strauss, 1969). In another study, Billeh and Hassan (1975) developed a test including 60 multiple-choice items on four major NOS aspects. They found reliability of the test as .58 and used this test to examine the relationship of gain scores of teachers on NOS conceptions and other variables including subjects the participants taught, teaching experience and previous in-service teaching. The authors found no significant relationship between NOS gain scores and any investigated variables. The studies of Billeh and Hassan (1975), Wood (1972) and Carey and Strauss (1969) used only test to study NOS aspects and they presented conflicting results. So, limitations of using only the tests should be considered to get more complete picture of the situation. As seen, using only either test approach or open-ended questions plus interview even if open-ended questions were experimentally prepared has limitations for the inferential statistics and generalizability of the results. Similarly, using six, seven or eight open-ended questions with interview has problems about content validity and nature of data (categorical data). As the important point in the assessment of the NOS aspects, domain specificity should also be taken into consideration for determining naïve understandings on the NOS aspects. NOS aspects are emphasized as cognitive variables in the literature (Khisfe & Lederman, 2006; Khisfe & Abd-El-Khalick, 2002). To measure cognitive variables with specifications, multiple-choice format has many advantages (Haladayna, 1997). Multiple-choice tests have practical importance and can easily be constructed with specific objectives. The application and scoring procedure is easier than other types of assessment. If multiple choice tests are used with embedded open-ended questions by considering representative part of sample, it might decrease some problems such as use of generic items, problems for practical use. By this way, it is possible to provide more appropriate measure for cognitive variables. Using NOS knowledge test rather than interview and complementary open-ended questions with the test items on NOS might provide opportunities for practical purposes in assessment of teachers' understandings of the aspects of NOS. Therefore, this study was conducted to determine elementary science teachers' understandings of the NOS aspects by using NOS Knowledge Test and Open-ended Questions. So, the purpose of the present study was to investigate the following general research question: How are Turkish science teachers' understandings about NOS aspects when knowledge test and open-ended questions were used complementarily?

Method

Participants

The study was conducted with 47 elementary science teachers worked in schools in Bolu and Ankara cities of Turkey. The participants were selected by using convenience sampling since this way provide opportunities for cost, time and energy consumption. Turkey does not have states and is governed from the center of the one state. Therefore, decisions about sharing resources, money and assignment of administration are made from Ankara. Ankara as a large–scale middle-region city is the capital city of Turkey and the schools of Ankara have more resources and educational opportunity which cannot be found in the region of Turkey. For instance; science and technology centers, universities more than four and Teaching Material Development Center of the Turkish Ministry of Education exist in Ankara. Therefore, teachers have many opportunities to improve their abilities and knowledge by only visiting there. However, Bolu is a middle-scale north-western city of the Turkey and has less educational opportunities than Ankara. But, Bolu has one university and many places to visit for nature and environmental education. The participants' ages range from 25 to 56. Twenty of the participants were male and 27 were female. Thirteen of them graduated from elementary science education departments of education faculties while 11 science teachers were enrolled in secondary science education departments of education faculties. Apart from these, 13 participants graduated from biology, chemistry and physics departments of science and art faculties. The participants (N=5) who are older than others graduated from education institutes while one participant graduated from chemistry engineering. Over the half of the participants had experience over 10 years (N= 24), while 23 participants' experience were below the 10 years. The participants were asked if they join in any activities about history, philosophy, epistemology of science before. Twenty-eight participants stated no participation in these activities while the others joined at least one activity.

Instruments

In this study, quantitative research approach supported by qualitative data was used. To collect data from participants, NOS knowledge test, and open-ended questions were used. For the development of NOS knowledge test, firstly 60 items were constructed based on the related literature (McComas, 1998; Lederman et al., 2002; Kihsfe & Lederman, 2006; Khsife & Abd-El-Khalick, 2002). Table 1 displays each NOS aspect and corresponding item numbers in the NOS knowledge test.

Table 1. NOS aspect and corresponding item numbers in the NOS knowledge test

Aspects of Nature of Science	**Items**
Scientific knowledge is tentative	8, 9, 10, 11, 12, 13
Scientific knowledge is based on evidence and observation	14,15,16,17,18,19,20,21
Observation is different from interference	22, 23, 24, 25, 26
There is no hierarchy among hypothesis, theory and law	27, 28, 29, 30, 31
Scientific knowledge is theory-laden	32, 33, 34, 35,36,37
Scientific knowledge is embedded in social and cultural context.	38, 39, 40,41,42
There is no universally accepted one way to do science	1, 2, 3, 4, 5, 6, 7
Laws and theories have different roles in science	43, 44, 45, 46
Creativeness and imagination are also important to produce scientific knowledge	47, 48, 49

Scientist is not objective when he or she begins to study, he or she has a background	50, 51, 52, 53
Science is a way of knowing	54, 55, 56, 57, 58, 59, 60

The questions were structured as three-choice items with "*True*", "*False*" and "*There are both true and false parts*". In addition to the three-choice items, the participants were asked to explain their reasons about the answers given to the items numbered as 7, 13, 21, 26, 31, 37, 42, 46, 49, 53, and 60. Therefore, a total of 11 open-ended questions for reasons were also added in the test to obtain more focused data related to participants' understanding of the NOS aspects. Then, the open-ended answers were analyzed; representative number of the participants' writings were selected for practical purposes (N=22, 46%). The participants were asked to explain their reasons to the answer given for the following items:

a) Scientific knowledge is tentative.
b) Observation is different from inference.
c) Scientific knowledge is based on evidence and observation.
d) There is no hierarchy among hypothesis, theory and law.
e) Laws and theories have different roles in science.
f) Scientific knowledge is embedded in social and cultural context.
g) Science is a way of knowing.
h) There is no universally accepted one way to do science.
i) Creativeness and imagination are also important to produce scientific knowledge.
j) Scientist is not objective when he or she begins to study; he or she has a background.

For the content validity of the test, the opinion of one expert in the field of science education was considered. The three-choice part of the test was analyzed by using ITEMAN for the item and test characteristics. The items of 7, 13, 21, 26, 31, 37, 42, 46, 49, 53, and 60 were not considered for the analysis because they were focus questions for the NOS aspects related to them and covered all items of the NOS aspects within the same category. Some of the items were eliminated due to their discrimination index (Point-biserial correlation coefficients) values below .20 (Kehoe, 1995). Then, mean P value as an index for the test difficulty and alpha value were investigated. After the elimination of the items, the final version consisted of 29 items. The selected item numbers can be seen in table 2. The minimum score is 2 while maximum score is 56 in the scoring way of two-point for each correct answer. The mean P value as difficulty index was found to be .40 for the test while alpha value for whole test was .79. Mean biserial correlation value for whole test was .66. The item analysis showed that there is no item corresponding for the aspect of theory-laden science. Therefore, this aspect was also eliminated from the open-ended questions. Therefore, the final form of the instrument included 29 three-choice and 10 open-ended items. All of the items are at the level of knowledge category for taxonomy of cognitive abilities. Final version of the three-choice item examples and open-ended item example can be seen in the tables 3 and 4.

Table 2. Table of specifications for the nature of science knowledge test (Final Form)

Aspects of Nature of Science	Questions
Scientific knowledge is tentative	8,9,10,11,12, **13**
Scientific knowledge is based on evidence and observation	15,16,18,19, **21**
Observation is different from interference	24, **26**
There is no hierarchy among hypothesis, theory and law	27,28,29,30, **31**
Scientific knowledge is embedded in social and cultural context.	39, 40,41, **42**
There is no universally accepted one way to do science	1, 2,3,5,6, **7**
Laws and theories have different roles in science	43**, 46**
Creativeness and imagination are also important to produce scientific knowledge	47,48, **49**
Scientist is not objective when he or she begins to study, he or she has a background	50,51,52, **53**
Science is a way of knowing	54, **60**

**Bold items were used for open-ended questions, so they were not used in the item analysis process.*

Table 3. The three-choice item examples of the final version of the nature of science knowledge test

Items	*True*	*False*	*There are both true and false parts*
Observation and inference have the same meaning			
Theories might change over time			

Table 4. One open-ended item example of the final version of the nature of science knowledge test

Items	*True*	*False*	*There are both true and false parts*
Scientific knowledge is tentative			
Could you explain reason for your choice about the question above?			

Analysis of the data

To analyze data, total scores for each aspect in NOS knowledge test were used to categorize the participants by using the rule of original scale 0 for false answer, 2 for true one and 1 for the category of answer between them. After calculating the scores of the participants, means were used to categorize the participant group. The criteria for categorization by considering two decimals are established as 0-.44 for naïve category, .45-1.44 for transitional, 1.45-2 for the informed ones. Such a categorization was used to provide original scale intervals. Original limits in the test have whole numbers for each category as 0, 1, and 2, so, decimals which completed to whole numbers were used as cut-off points in categorization. The relationship between original scale and categorization scale is illustrated in Figure 1. Therefore, original categorization in the test was also represented in the means for the group of the participants. By providing larger interval for "transition" category, a strict rule for categorization on naïve and informed participants was also established to get a clear picture. Additionally, transitional category was re-categorized as approaching naïve or approaching informed to provide more detailed analysis and overcome vague results in this interval. To categorization of transitional understandings, the interval of .45-.94 for “approaching naïve” and the interval of .95-1.44 for “approaching informed” were used to show more detailed picture of the understandings. The figure 1 explains the categorization approach. To analyze the open-ended answers, categorization of the participants’ answers were conducted by using content analysis with the evaluation frame of Lederman et al. (2002). After the analysis of open-ended questions, categorization and mean score calculation by giving a score to each participant in line with their category and original scale and adding all scores, then, dividing the total score by 22 were conducted for each aspect. Comparison of mean scores on test items and open ended questions is the basis for this study (see table 5 and table 6).

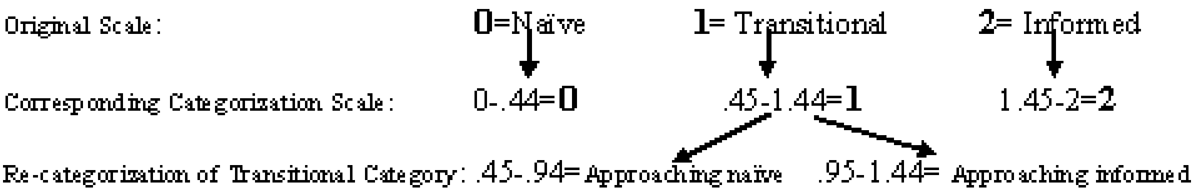

Figure 1. Relationship between original scale and corresponding categorization scale

Results

The results of the study will be presented in this section. The participants mean scores on each aspect can be seen in table 5.

Table 5. The mean scores of corresponding categories of the participants in the knowledge test

NOS Aspect	Mean Score	Category	Transitional Participants’ Categorization
Tentativeness	1.4	Transitional	Approaching informed
Evidence and Observation Based Science	.65	Transitional	Approaching naïve
Observation and Inference Difference	1.4	Transitional	Approaching informed
No hierarchy among hypothesis, theory and law	.1	Naive	-
Social and cultural embeddedness	1.14	Transitional	Approaching informed
No universally accepted one way to do science	.60	Transitional	Approaching naïve
Roles of Laws and Theories	.87	Transitional	Approaching naïve
Creativeness and imagination	1.5	Informed	-
Subjectivity	.77	Transitional	Approaching naïve
Definition of Science	1.2	Transitional	Approaching informed

Table 5 shows that Turkish elementary science teachers have naïve ideas about the aspect of “hierarchy among hypothesis, theory and law” whereas they have informed ideas about the aspect of “creativeness and imagination” in science. In general, majority of the participants are at the transitional category for the other aspects of NOS with changing degrees. Detailed examination of the transitional category showed that the participants approached to informed category for the aspects of “tentativeness”, “observation and inference”, “social and cultural embeddedness” and “definition of science” whereas they approached toward naïve category for the aspects of “ evidence and observation based science”, “no universally accepted one way to do science”, “roles of laws and theories” and “subjectivity”.

Table 6. The results of content analysis of the participants' answers to the open-ended questions

	NOS Aspects																													
	Tentativeness			Empirical basis			Observation & inference			No hierarchy between theory & law			Social & cultural embeddedness			No universal way to do science			Roles of theories & laws			Creativity & imagination			Subjectivity			Definition of Science		
P	N	T	I	N	T	I	N	T	I	N	T	I	N	T	I	N	T	I	N	T	I	N	T	I	N	T	I	N	T	I
P1	⊙					⊙			⊙	⊙				⊙		⊙				⊙			⊙		⊙				⊙	
P2	⊙					⊙		⊙		⊙			-	-	-	-	-	-	⊙					⊙			⊙		⊙	
P3	⊙			⊙			⊙			⊙			⊙				⊙		⊙			⊙			⊙				⊙	
P4	⊙			⊙			⊙			⊙			⊙			⊙			⊙					⊙	⊙				⊙	
P5	⊙				⊙			⊙		⊙			⊙			⊙			⊙					⊙	⊙				⊙	
P6	⊙					⊙			⊙	⊙			⊙			⊙			⊙					⊙	⊙				⊙	
P7		⊙		-	-	-		⊙		⊙				⊙			⊙		⊙				⊙		⊙				⊙	
P8	⊙					⊙		⊙		⊙				⊙		⊙				⊙				⊙			⊙			⊙
P9		⊙		⊙			⊙			⊙			⊙			⊙				⊙		⊙			⊙				⊙	
P10			⊙			⊙			⊙		⊙			⊙				⊙	⊙				⊙			⊙			⊙	
P11	⊙				⊙			⊙		⊙					⊙	⊙			⊙				⊙		⊙			⊙		
P12	⊙			-	-	-			⊙	⊙			-	-	-	⊙			-	-	-	-	-	-	-	-	-	-	-	-
P13	⊙					⊙			⊙	⊙				⊙		⊙			⊙				⊙		⊙			⊙		
P14	⊙				⊙			⊙		⊙				⊙		⊙			⊙				⊙		⊙				⊙	
P15			⊙		⊙			⊙		⊙				⊙		⊙				⊙			⊙		⊙			⊙		
P16		⊙			⊙		⊙			⊙				⊙			⊙		⊙			-	-	-	⊙			⊙		
P17			⊙			⊙			⊙			⊙			⊙			⊙	-	-	-			⊙			⊙		⊙	
P18		⊙		-	-	-	⊙			⊙			-	-	-	⊙			-	-	-			⊙	⊙			-	-	-
P19	⊙					⊙			⊙	⊙			⊙			⊙			⊙				⊙		⊙			⊙		
P20			⊙	-	-	-		⊙		⊙			⊙			⊙			⊙			⊙			⊙			⊙		
P21	⊙				⊙			⊙		⊙				⊙		⊙			⊙			⊙			⊙			⊙		
P22			⊙			⊙		⊙		⊙					⊙	⊙			⊙				⊙				⊙			⊙
Mean Score		**.63**			**1**			**1.09**			**.14**			**.68**			**.32**			**.18**			**1.05**			**.48**			**.68**	

Note:*P: Participants, N: Naïve, T:Transitional, I:Informed*

Table 6 presents categorization of the participants for the NOS aspects in terms of three categories as “Naïve”, “Transitional” and “Informed”. The example definitions and explanations for each NOS aspect from their writings include the following excerpts:

“Science is a study to reach correct knowledge”
“Observation is data gathered to see results of an experiment; inference is a result to be seen”
“Hypotheses and theories are established for explaining laws”
“To reach scientific knowledge, there is a need to present observations, experiments and scientific evidence”
“Law and theory have the same meaning, but law is the more proven type”
"Scientific knowledge do not develop in social and cultural structure, they are produced by using scientific method and techniques”
“Scientific method is only one way to reach correct knowledge”
“Scientists cannot find correct answer without being objective”
“Scientists and science use creativity and imagination at the beginning of any study”
“Laws cannot be changed due to the fact that they are absolute”
“If observations and data change, scientific knowledge also changes”

When table 5 and table 6 are taken into account together, it can be seen that “No hierarchy between theory and law” aspect is a problematic issue for the teachers as indicated in the results of both open-ended question analysis and knowledge test answers. In terms of “tentativeness”, “empirically based science”, “observation and inference”, “social and cultural embeddedness”, “subjectivity” and “definition of science” aspects, data from open-ended questions supported the knowledge test result showing the “transitional” category for the participants. However, different results were also obtained from the analysis of open-ended questions and knowledge test items. For example, analysis of participants’ answers to the open-ended questions showed that majority of the teachers hold naïve views regarding “no universally accepted one way to do science” (73%) and “roles of theories and laws” (68%) aspects whereas they were in transitional position regarding “creativeness and imagination”(41%) aspects of NOS. In spite of these differences on the transitional categories, re-examination of transitional categories in test score analysis provided more detailed picture by showing that the categories of the participants on the aspects of “no universally accepted one way to do science”, “roles of theories and laws” and “subjectivity” were determined as “approaching naïve”. Analysis of participants’ open-ended answers showed that the participants hold naïve views in terms of these NOS aspects. Categorizing the participants as “approaching naïve” and “naïve” on the aspects of NOS might be an evidence for complementary nature of the assessment including open-ended and multiple-choice knowledge test formats. Although they present some differences, two data sets give partially complementary results in terms of NOS aspects. Table 7 summarizes the scores on the each of the assessment ways to compare them easily.

Table 7. Mean scores on corresponding aspects for the "knowledge test" and "open-ended questions"

NOS Aspects	*Assessment Approach*		*Complementary Aspects*
	Knowledge Test	**Open-ended Questions**	
Tentativeness	1.4	.63	⊙
Evidence and observation based science	.65	1	⊙
Observation and inference difference	1.4	1.09	⊙
No hierarchy among hypothesis, theory and law	.1	.14	⊙
Social and cultural embeddedness	1.14	.68	⊙
No universally accepted one way to do science	.60	.32	-
Roles of laws and theories	.87	.18	-
Creativeness and imagination	1.5	1.05	-
Subjectivity	.77	.48	⊙
Definition of science	1.2	.68	⊙

Conclusion

The results of the study showed that science teachers had many naive understandings about the aspects of NOS. They had the most extreme naive understandings regarding relationship between theory and law. Most of the science teachers believed that there is hierarchy among hypothesis, theory and law. One of the possible reasons for this understanding might be explanations of theory, law and hypothesis as hierarchical and linear structures in the biology textbooks because NOS aspects are explained as a separate unit only in the biology textbooks (Irez, 2009). When the individual answers to open-ended questions were examined, it was seen that some of the teachers for each aspect presented at least more than one naive understanding. This result is consistent with previous studies (e.g. Akerson & Hanuscin, 2007; Akerson et al., 2000). For example, with a sample of three K-6 teachers Akerson and Hanuscin (2007) indicated that all teachers believed that theories become laws and laws are more certain than theories. In addition, teachers held the view that laws are proven whereas theories are unproven. Similar to present study, all participants claimed that science involves creativity and imagination. A similar result was reported in Morrison et al.'s (2009) study. They stated that most of the teachers had inadequate ideas regarding relationship between theories and laws while half of the teachers provided adequate ideas on the aspect of "creativity and imagination". In addition, the participants presented intermediary ideas on the majority of other aspects of NOS. In another study, Akerson et al. (2000) examined the elementary teachers' NOS views and found that majority of them had inadequate ideas on "theories and laws". For the other aspects, the elementary teachers showed various categories from naïve to transitional to informed without any certain tendency among the participants. The naïve understandings of science teachers might be eliminated by reflection based in-service programs on teaching practices about the NOS aspects. In the literature, explicit-reflective teaching was shown to be effective for elimination of naïve understandings (Khisfe & Lederman, 2006). In the science teacher education programs, more explicit activities with their rationales might also be effective to help science teachers question their naïve understandings about the NOS aspects.

Therefore, explicit attention to the NOS aspects might be strengthened in pre-service education level by this way.

As the important side of this study, the answers to knowledge test and open-ended questions gave partially complementary pattern in terms of ten aspects of NOS, except for the three aspects including "no universally accepted one way to do science", "roles of theories and laws" and "creative and imaginativeness" aspects. Lin and Chen (2002) also stated that multiple-choice format is more conservative and is not enough to use only one tool to study NOS. Limitations of only using tests for NOS studies also emerged in the literature by showing conflicting results related to relation of NOS conceptions with content knowledge and other academical variables (Billeh & Hassan, 1975; Carey & Strauss, 1969; Wood, 1972). Both practical purposes and conservative nature of multiple-choice format make it as a valuable complementary tool to use with open-ended question format which has been used more frequently in the NOS studies. In fact, large interval for transitional position in original scoring presents a problem for test use, but the use of open-ended questions presents additional evidence of the transitional position in the interval determined. Re-categorization of transitional category is useful to both compare the results of the test and open-ended questions in detail. In addition, the cut-off limits for the intervals included sensitive decisions about the scores, for example; one aspect might be in limits of the interval, in such situations, use of open-ended questions might provide complementary and supportive data to make decision. In general, two data sets are complementary to each other. This result might provide an evidence to use this way of assessing the NOS aspects for practical purposes with more participants in large scale studies. In the future studies, supported NOS aspects by both of the data types- quantitative and qualitative- can be used for generalizing the results for larger populations. The approach also provided to see tendencies of the group for each aspect and individual understandings of representative part of the group on each aspect.

Limitations of the study

This study was subject to some limitations. The results of this study should be examined with care due to limitations for sample of the present study and the instruments used. Further research on validation of the instrument needs to be continued. By using the same approach, knowledge test combined with open-ended questions on NOS should be applied to large sample size and the results should also be compared with the data collected by frequently used instruments such as VNOS-C and VOSTS to examine validity of the results. Usability of this way of assessment on NOS aspects by the teachers should also be investigated.

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