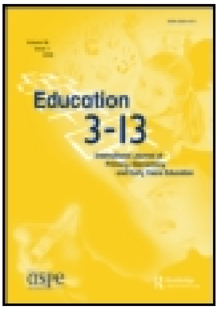

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Development and validation of nature of science instrument for elementary school students

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Development and validation of nature of science instrument for elementary school students

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The purposes of this study were to develop and validate an instrument for assessing elementary students' nature of science (NOS) views and to explain the elementary school students' NOS views, in terms of varying grade levels and gender. The sample included 782 students enrolled in sixth, seventh, and eighth grades. Exploratory factor analysis factor structures and confirmatory factor analysis fit indices confirmed the existence of the hypothesised four dimensions in the structure of the nature of science instrument (NOSI). These dimensions and associated Cronbach α reliabilities of scores were observation and inferences (0.74), tentative NOS (0.76), imagination and creativity (0.80), and empirical NOS (0.63). Descriptive analyses revealed that the most favourable NOS views were obtained for the empirical nature of scientific knowledge. The students were uncertain about NOS views related to tentative NOS and imagination and creativity. The least favourable NOS views were obtained for observation and inferences.

Keywords: nature of science; elementary student; instrument development; grade level; gender

1. Introduction

The student's understanding of the nature of science (NOS) has become a key issue in recent discussions concerning science education (Abd-El-Khalick, Bell, and Lederman 1998; Dush 1990; Griffiths and Barry 1993; Huang, Tsai, and Chang 2005; Kang, Scharmann, and Noh 2005; Khishfe and Abd-El-Khalick 2002; Khishfe and Lederman 2006). Teaching and learning science is an important point for being responsible members of society and having the skills required to be effective citizens of the twenty-first century in Turkey as supported by Ergul (2009). Researchers have thought that science and technology education will play an important role for societies' future over the last century (Ministry of National Education of Turkey (MoNE) 2008). Therefore, after World War II, scientists and educators started to develop education systems in their countries. In many countries, science curriculums began to be reconstructed. Foreign educators were invited to investigate and make suggestions about our education system. It was suggested that necessities should be determined for each grade level and curriculums should be structured by Turk

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educators instead of adapting the other countries' curriculum (Sozbilir and Canpolat 2006). Curriculum/reform studies are addressing this issue worldwide, in countries as disparate as Canada, Venezuela, Taiwan, Lebanon and Turkey (Dogan and Abd-El-Khalick 2008). In Turkey, the vision of a new curriculum for science and technology course includes educating students to become scientifically literate, regardless of their individual differences (MoNE 2008). Major components of scientific literacy can be summarised as the ability to understand not only basic scientific concepts, but also the nature and development of science and scientific knowledge; this skill is critical because it allows individuals to make personal decisions in a society that is becoming highly dependent on science and technology (Dogan and Abd-El-Khalick 2008; Lawson 1995). It is evident that understanding the NOS is a key component of developing scientific literacy. The NOS has been described as 'the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge' (Abd-El-Khalick and Lederman 2000, 666). Although no definition for the NOS is agreed on by all philosophers and sociologists of science, they do agree on several aspects of scientific knowledge: scientific knowledge is tentative, empirically based, subjective, partly the product of the human imagination and creativity, and socially and culturally embedded. In addition, during the scientific process one must make distinctions between observations and inferences, and also understand the relationships between scientific theories and laws (Abd-El-Khalick, Bell, and Lederman 1998; Khishfe and Lederman 2006; Schwartz and Lederman 2007).

Researchers have explored students' views about the NOS through qualitative methods (e.g. Griffiths and Barman 1995; Griffiths and Barry 1993; Sadler, Chambers, and Zeidler 2004). In one of these studies conducted by Griffiths and Barry (1993), the results indicated that the students had many misconceptions. For example, the students believed that scientific theories are tentative, but that laws and facts are certain. Moreover, according to these students, theories become laws and laws represent a higher level of knowledge. The result of Griffiths and Barman's (1995) cross cultural study revealed that while all Canadian students and most of the Australian students supported that science is tentative, of the participants 60% of American students believed that scientific knowledge does not change. Moreover, 60% of Australian students, 45% of Canadians and 25% of the Americans believed that observations come before theories. Most of the American students could not differentiate between observations and theories. Most participants, across all countries, did not fully appreciate the changing nature of scientific laws. In another study, Shiang-Yao and Lederman (2002) examined 29 seventh-grade gifted Taiwanese students' conception of the NOS. During a summer course, these students were exposed to an explicit inquiry-oriented NOS instruction in which they carried out several activities emphasising scientific inquiry and the NOS. Before and after the instruction, an open-ended questionnaire (given in the form of tests) assessed the students' views about several aspects of the NOS. Pre-test results revealed that half of the participants held informed views on at least four dimensions of the NOS. The finding was striking: the students' views of the NOS remained unchanged. Indeed only nine participants showed changes in how they view the NOS and these changes were only modest.

In addition to qualitative research focusing on how students at different ages view the NOS, researchers have investigated student views by using a variety of instruments. One of the most widely used 'paper and pencil' instruments is the Test on Understanding Science (TOUS), which was developed by Cooley and Klopfer (1961). This instrument included 60 items, in a multiple choice format, to evaluate junior high school students' understanding of science. This instrument includes three dimensions, namely: (1) understanding the scientific enterprise, (2) the scientist, and (3) the methods and aims of science. Welch (1969) criticised this instrument in terms of validity and suggested reorganising all items under two different subscales: the social aspects of science and the nature of scientific inquiry. Mackay (1971) assessed Australian secondary students' views of NOS aspects by using this instrument. The test was given to 1556 students at the beginning of a semester and to 1203 students at the end of a semester. Findings indicated that the students had insufficient perceptions about the function of scientific models, the role of creativity in science, and the differences among hypotheses, laws, and theories.

Another instrument is the Nature of Scientific Knowledge Scale (NSKS), developed by Rubba and Anderson (1978) for high school and college students. This 5-point Likert-scale includes 48 items with 6 subscales regarding scientific knowledge; namely being amoral, creative, developmental, parsimonious, testable and unified. Another instrument is the Views on Science–Technology–Society (VOSTS), which was developed and designed for high school students by Aikenhead, Fleming, and Ryan (1987). Over a six-year period, Aikenhead, Fleming, and Ryan (1987) revised this instrument to enhance validity and reliability; the new test was administered to various samples throughout Canada by Aikenhead and Ryan (1992). The revised VOSTS concentrated on a wide range of issues related to science, technology, and society; the number of items increased from 46 to 114 over the course of validation.

Similar to those in western cultures, non-western researchers have recently shown interest in using instrumentation to measure NOS views. The Pupils' Nature of Science Scale (PNSS) was developed by Huang, Tsai, and Chang (2005) to assess how Taiwanese fifth and sixth graders understand the NOS. The instrument was based on changing NOS views, the role of social negotiation in science, and the cultural context of science. In another study, Kang, Scharmann, and Noh (2005) developed another instrument, by modifying the VOSTS questionnaires originally developed by Aikenhead, Fleming, and Ryan (1987). These were used to investigate Korean elementary students' views on the NOS. Kang, Scharmann, and Noh (2005) investigated 6th, 8th and 10th grade Korean students' NOS views and compared their findings with those of studies conducted in western countries. In that study, questionnaires were used to assess students' NOS views in terms of five aspects: the purpose of science, the definition of scientific theory, the nature of models, the tentativeness of scientific theory and the origin of scientific theory. Like in western countries, this study reveals that in a non-western country students also hold naïve understandings about scientific work and scientific theory, and yet hold an informed view about the tentative nature of scientific theories.

The newest Likert-type instruments are the Student Understanding of Science and Scientific Inquiry (SUSSI), developed by Liang et al. (2008) and the Views on Science and Education Questionnaire (VOSE), developed by Chen (2006); both were designed for college students. SUSSI included both 24 Likert-type items and 6 open-ended questions, in an effort to assess pre-service teachers' NOS views in terms of six aspects: observations and inferences, tentativeness, scientific theories and laws, social and cultural embeddedness, creativity and imagination, and scientific methods.

VOSE was developed by selecting some items from VOSTS and modifying them according to the results of interviews carried out for American and Taiwanese pre-service secondary science teachers (Chen 2006). This instrument included 15 questions and each question had a different number of related items. A total of 85 follow-up items includes 7 dimensions: tentativeness, nature of observations, scientific methods, theories and laws, use of imagination, validation of scientific knowledge, and subjectivity and objectivity. Another Likert-type instrument was developed by Tsai and Liu (2005) – the Students' Epistemological Views of Science (SEVs) Test. This instrument was constructed to assess high-school students' NOS views and included 19 items in 5 dimensions: the role of social negotiation in science, the invented and creative reality of science, the theory-laden exploration of science, the cultural impact on science, and the changing and tentative features of scientific knowledge.

Similar research lines have also been observed in Turkey. Some studies have used existing instruments to assess secondary school students' and pre-service and in-service teachers' views of the NOS (e.g. Aslan 2010; Dogan 2011; Dogan and Abd-El Khalick 2008; Sahin, Deniz, and Gorgen 2006; Yaman and Nuhoglu 2010). In one of these studies, researchers (Dogan and Abd-El Khalick 2008) used a pre-existing instrument to assess a large sample which included 2020 10th grade students and 362 teachers from 7 geographical regions of Turkey. To assess the NOS views held by students, a 25-item questionnaire adapted from VOSTS was administered and student interviews were conducted. Results of this study showed that while participants had naive views of the nature of scientific models, target NOS, and the relationship among hypotheses, theories and laws, they had informed views concerning the tentative nature of scientific knowledge. All participants believed that hypotheses, theories, and laws are hierarchically related, assuming that when scientists find new scientific evidence, hypotheses become theories and then laws. Most students did not appreciate the role creativity plays in generating scientific knowledge. Moreover, the findings indicate that while most of the student views regarding the NOS are the same as their teachers', their views about how theory drives the NOS, the relationships among classification schemes and reality, the nature of scientific theories, myths regarding 'the scientific method' and the epistemological status of scientific theories are significantly different. In another study, Kılıç et al. (2005) explored ninth grade students' understanding of the NOS and the effects of gender and school types on their understanding. An adapted version of the NSKS developed by Rubba and Anderson (1978) was administered to the students. The results of the study revealed that Turkish high school students possessed understandings of the NOS that were inadequate. Also, results revealed that students in vocational high schools have more traditional views about the nature of scientific ideas than those students in general high, Anatolian high, and super lycee. Also, a significant gender difference was found regarding unified and amoral dimensions of NSKS, showing that, at this age, girls held a deeper appreciation of these complicating factors.

1.1. Rationale for the development of the nature of science instrument (NOSI) for elementary students

In this study, the nature of science instrument (NOSI) was developed to measure elementary students' NOS views. NOSI was intended to explore several areas of investigation.

First, although many studies have investigated the NOS views of high school students (e.g. Chen 2006; Griffiths and Barman 1995; Griffiths and Barry 1993; Liang et al. 2008; Lederman and O'Malley 1990; Ryan and Aikenhead 1992) and college students (e.g. Abd-El-Khalick, Bell, and Lederman 1998; Bell, Lederman, and Abd-El-Khalick 2000; Eichinger, Abell, and Dagher 1997; Lederman et al. 2001; Pomeroy 1993; Tsai and Liu 2005), and in both western and non-western countries, only a limited number of studies have examined the views of students in elementary school settings (Akerson and Volrich 2006; Huang, Tsai, and Chang 2005; Kang, Scharmann, and Noh 2005; Khishfe 2008; Khishfe and Abd-El-Khalick 2002; Khishfe and Lederman 2006, 2007; Shiang-Yao and Lederman 2002). Most studies conducted at the elementary level were qualitative in nature; and in them, researchers tried to provide in more detail information and explanations about participants' NOS views. However, in parallel with the globalisation efforts in education (e.g. Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS)), researchers need some general information about students' NOS views to better help these students develop sound NOS views.

Second, most of the qualitative studies revealed similar results regarding students' views about the characteristics of the NOS; for example, high school and college students had a naive understanding about the social embeddedness of scientific knowledge and the relationships between scientific theories. Few studies have been conducted at the elementary level and these were mainly qualitative. Moreover, these studies revealed that students had a naive understanding about the tentative, empirical, inferential and creative aspects of the NOS. The results of these studies clearly indicate the findings were consistent across different age groups and countries. Thus, by considering these consistent themes, it is important and interesting to investigate patterns across a large sample. To serve this purpose, this study using NOSI aimed to develop on these themes.

Third, researchers have suggested that it is crucial to determine and improve students' understanding of the multi-dimensional characteristics of the NOS (Cotham and Smith 1981; Huang, Tsai, and Chang 2005; Tsai 2002) and have used different Likert-type instruments to assess different sub-dimensions and characteristics of the NOS. Table 1 provides a summary of instruments and some others which have been developed for measuring student NOS views.

Table 1. The instruments developed for measuring multi-dimensional characteristics of NOS.

Instrument	Researchers	Target	Dimensions
FAS	Stice (1958)	HSS	Science as an institution in society Knowledge of scientist as an occupational group
TOUS	Cooley and Klopher (1961)	HSS	Scientific enterprise The scientist Methods and aims of science
SPI and WISP	Welch and Pella (1967) Scientific Literacy Center (1967)	HSS	Scientific activities Scientific assumptions Products and ethics of science

(*continued*)

Table 1. (*Continued*).

Instrument	Researchers	Target	Dimensions
SSS	Schwirian (1968)	HSS and CS	Rationality Utilitarianism Universalism Individualism Progress Meliorism
NOSS	Kimball (1968)	CS	Curiosity in physical universe Curiosity in dynamic on-going activity Ever-increasing comprehensiveness and simplifications Scientific method Characteristics of the scientific method A faith in the susceptibility of the physical universe Openness in science Tentativeness and uncertainty
TSAS	Korth (1969)	HSS	Science and technology Science and society Nature of science Characteristics of science Scientists' role in society
NSKS	Rubba and Andersen (1978)	HSS and CS	Science is amoral Science is creative Science is developmental Science is parsimonious Science is testable Science is unified
COST	Cotham and Smith (1981)	CS	Ontological implications of theories Testing of theories Generation of theories Choice among competing theories
VOSTS	Aikenhead, Fleming, and Ryan (1987)	HSS	Science and technology Influence of society on science/technology Influence of science/technology on society Influence of school science on society Characteristics of scientist Social construction of scientific knowledge Social construction of technology Nature of scientific knowledge
PNSS	Huang et al. (2005)	ES	Changing NOS Role of social negotiation Cultural context
Revised VOSTS	Kang et al. (2005)	ES	Purpose of science Definition of scientific theory Nature of the model Tentativeness of scientific theory Origin of scientific theories

(*continued*)

Table 1. (*Continued*).

Instrument	Researchers	Target	Dimensions
SEVs	Tsai and Liu (2005)	HSS	The changing and tentative feature of science knowledge The invented and creative nature of science The cultural impacts The theory-laden exploration The role of social negotiations
VOSE	Chen (2006)	CS	Nature of observations Tentativeness Use of imagination Validation of scientific knowledge Theories and laws Scientific methods Subjectivity and objectivity
SUSSI	Liang et al. (2008)	CS	Observations and inferences Tentativeness Creativity and imagination Scientific theories and laws Social and cultural embeddedness of scientific methods

Notes: *Target:* CS: College Students, HSS: High School Students, ES: Elementary Students. *Instruments:* FAS: facts about science test, TOUS: test on understanding science, SPI: science process inventory, WISP: The Wisconsin inventory of science processes, SSS: science support scale, NOSS: nature of science scale, TSAS: test on social aspects of science, NSKS: nature of scientific knowledge survey, VOSTS: views on science–technology–society, VNOS: views of nature of science, PNSS: pupils' nature of science scale, SEVs: scientific epistemological views, VOSE: views on science and education questionnaire, SUSSI: student understanding of science and scientific inquiry.

According to Aikenhead (1973), TOUS, SPI, TSAS, WISP, NOSS and FAS have only limited utility. For example, these instruments always measure the degree to which learning about science and scientists has been made explicit in science courses. In other words, the instruments measure student knowledge about science and scientists. Aikenhead (1973) also argued that these instruments were better suited for experimental research designs that stressed the typical *content* of science lessons. These instruments all failed to address student NOS views in a particular science classroom – each teacher had his own favoured characteristics and teaching strategies. Therefore, these instruments were not in parallel with the currently accepted characteristics of the NOS, as suggested by Abd-El-Khalick, Bell, and Lederman (1998) and Lederman, Wade, and Bell (1998). However, even though SUSSI, VOSE, and SEVs included recently accepted characteristics of the NOS (as suggested by Abd-El-Khalick, Bell, and Lederman 1998), they were developed for pre-service teachers or high school students. Of these instruments, only PNSS (Huang, Tsai, and Chang 2005) and revised VOSTS (Kang, Scharmann, and Noh 2005) were developed to assess elementary students' NOS views. Therefore, NOSI was considered to be a valuable instrument for researchers interested in measuring elementary students' NOS views according to the currently accepted characteristics of the NOS.

Finally, most studies have focused on how to change students' NOS views, through interventions. The majority of these studies emphasised that students at different grade levels hold inadequate views regarding the characteristics of the NOS. More important is that these studies also have revealed that students develop understanding of the NOS at early grade levels. This is crucial since studies have also shown that it is very difficult to change a student's pre-existing conception of the NOS with a scientifically accepted one. Thus, it is critical that the view of an elementary school student concerning the NOS should be determined as early as possible (Kang, Scharmann, and Noh 2005; Meichtry 1992). Therefore, a new instrument should be valuable for researchers interested in measuring elementary student NOS views according to currently accepted multi-dimensional characteristics of the NOS. In this study, a new instrument, NOSI, has been developed for use in elementary school settings. It is proposed that valid and reliable instruments like NOSI would be helpful for researchers in testing the theoretical issues raised in currently accepted characteristics of the NOS. Thus, NOSI is meant to serve as a tool for researchers to attain this goal.

1.2. The effects of gender and grade level on students' NOS views

There are many studies which investigate gender and grade-level differences with respect to science learning and achievement. Specifically, few studies have explored gender and grade-level differences regarding student NOS views (e.g. Dogan and Abd-El-Khalick 2008; Huang, Tsai, and Chang 2005; Kang, Scharmann, and Noh 2005). Huang, Tsai, and Chang (2005) have investigated fifth and sixth graders' understanding of the NOS and the effects of grade level and gender on these views. A questionnaire (PNSS) was applied to 6167 students in Taiwan. Findings showed that there were significant mean differences in student NOS understandings, with respect to both gender and grade level. Males better understood the NOS regarding its tentative nature and the importance of social negotiation in scientific studies. When grade level was considered, it was found that fifth grade students held more accurate NOS views than did sixth grade students, concerning the changing nature of scientific knowledge.

Kang, Scharmann, and Noh (2005) found a statistically significant mean difference between the 6th, 8th and 10th graders, in terms of the nature of models and the tentativeness of scientific theories. Further, students showed no clear differences in their understanding of other NOS dimensions (the purpose of science and the definition and origin of scientific theory). Authors have argued that because of the differences in cultural characteristics and curricular materials, there are some differences between western countries' students' NOS views and for example, Korean students' NOS views with respect to a definition of scientific theory. In addition to these studies, Yenice and Saydam (2010) conducted a study to determine Turkish eighth grade elementary students' NOS views with respect to gender and student residence. The sample consisted of 189 students from randomly selected schools in different districts such as central city school, district school, and village schools. Data were collected by administering the NSKS developed by Rubba and Anderson (1978). The results revealed that students generally had unsatisfactory views of the nature of scientific knowledge with respect to closed knowledge tenets of NSKS. Students scored highest on changeable tenets of NSKS but they were confused about the statement of 'scientific knowledge being changeable'. While gender has significant effect on students' NOS regarding closed tenets of NSKS in favour of girls, type of students had no significant effect on students' NOS views.

1.3. The purpose of the study

More specifically, the purposes of this study were: (1) to validate a newly developed NOSI instrument for assessing elementary students' views of the NOS; and (2) to explain the elementary school students' NOS views, in terms of varying grade levels and gender.

2. Method

2.1. Study approach

In this study, a NOSI scale as well as analysis procedures were developed. More specifically, in this study both exploratory and confirmatory factor analyses were used during the scale development process. Exploratory factor analysis is required to collect information about features and interrelationships among variables in early stages of the development process. On the other hand, confirmatory factor analysis is used in following stages of this process to build a model in order to describe and confirm specific hypotheses of theories included in the scale (Jöreskog and Sörbom 1993; Pallant 2002). These two methods helped find the relationships among the items that were developed during exploratory factor analysis and then to test the hypothetical dimensions by means of confirmatory factor analysis. Thus, both analyses provided better grounds to use our findings about the NOSI instrument.

In this study, some information about our current science teaching practices in Turkey was needed. Because of this reason, while taking into consideration grade level and gender, our instrument was aimed at elementary school students. This survey, which was part of the study, provided a general picture of the population using the NOSI instrument with respect to gender and grade level.

2.2. Sample

The sample included 782 students enrolled in sixth, seventh and eighth grade in second stage of elementary schools (13–17 year olds) located in the Çankaya district of Ankara, the capital of Turkey. The Çankaya district is one of the largest districts in Ankara. This large district was selected for two reasons. One was the convenience of the district to the researchers. Second, it was also a very large district. Large districts generally include more schools and the high number of schools in the district was helpful in reaching the student number needed. Since the district was convenient in terms of transportation, it was easy to collect data from each school. The total number of elementary public schools in Çankaya was 103. Ideally, the researchers aimed to collect data from each school in the district. For this purpose, the researchers obtained an alphabetical list of schools in Çankaya and each school principal was asked whether he/she would like to be involved in the study or not. Of the 103 schools, 23 elementary schools responded positively. They involved 22% of the schools in the Çankaya district included in this study. This was a good representation of population characteristics for the sample in terms of grade level and gender. In accordance with the research design, data were gathered from sixth, seventh and eighth grade elementary students from each of these 23 schools located in different parts of Çankaya. The distribution of the students, according to demographic variables, is indicated in Table 2.

Table 2. Demographic characteristics of participants.

Demographic characteristics		Number	%
Gender	Female	391	50
	Male	391	50
Grade level	Sixth grade	329	42.1
	Seventh grade	320	40.9
	Eighth grade	133	17.0

The results of this study are from the grade levels included in elementary schools in Turkey. Grade levels from 1 to 8 are considered as elementary school grade levels. This study aimed to include only grades six to eight.

2.3. *Data collection*

Data were collected during the spring of 2008. After gaining approval from both the Ministry of National Education's ethics committee and the University's ethics committee, the researchers obtained an alphabetical list of schools in Çankaya. Each school principal from this list was contacted by telephone. Once the principal's permission was obtained, the instrument was administered at their school. The school principal specified the days for administering the test. The first author of this study and one or two teachers in each school who were appointed by the school's principal administered the instrument to the students. At each data collection site, the same administrative procedure was followed to avoid any potential variables that location might have on the results of the instrument. During administration, the researchers explained the purpose of the study to the students, in their classroom, and invited them to participate voluntarily. The students were given a class hour to provide their answers. Student anonymity was protected by assigning numbers to each form. Students were asked not to write their names on the forms and told that their responses would not affect their grades. Since the researchers collected the data in person, the return rate of the study was almost 90% at each data collection site.

2.4. *Instrument development*

The NOSI was developed for use in this study. In light of the available information about NOS in the literature, hypothetical NOSI dimensions and items were determined by a research team. The steps mentioned below were followed while determining the hypothetical dimensions and developing the items for each of these hypothetical dimensions of NOSI.

Initially, the research team thoroughly analysed articles published in refereed science-education journals (e.g. *Science Education, Journal of Research in Science Teaching* and *International Journal of Science Education*). The team then selected the studies carried out by Khishfe (2008), Khishfe and Lederman (2007), Akerson and Volrich (2006), Khishfe and Lederman (2006) and Khishfe and Abd-El-Khalick (2002) for use as a template for the instrument for this study. These studies were chosen for several reasons. Initially, the qualitative nature of these studies provided valuable information, allowing the research team to become familiar with elementary students' NOS views in their own words. For this purpose, quotes from students were examined before and after an interview. Based on these quotes, an item pool was formed. The items which we selected from quotes are the most repeated common quotes in our selected qualitative articles performed in elementary school settings. Additionally, these items were examined with respect to suitability of the content of the items according to the science and technology curriculum. For example, we deleted the items related to 'dinosaur' from the item pool. On the other hand, we kept the items regarding structure of the atom since in our science and technology curriculum elementary school students started to learn in sixth grade and continued through the other grades step by step. Therefore, the initial item pool did not include so many items because of the limited study carried out in the elementary school. Furthermore, a small number of items is more appropriate for elementary students. For instance, the junior meta-cognitive awareness inventory developed by Sperling, Howard, Miller, and Murphy (2002) consists of 12 items to measure elementary school students' metacognition. Schommer (1990) reduced the item numbers of the original questionnaire while developing an elementary school students' version of Schommer's epistemological questionnaire. Items originally written in English were translated into Turkish by the research team. The original items and their translated versions were also examined by three English-language experts. Revisions of the items were completed when all parties agreed on the translation for each item. Thus, with this procedure, students' thoughts and their expressions of scientific phenomena were better represented. This procedure was used to structure the NOSI items. Second, while determining the hypothetical dimensions of NOSI, the NOS characteristics most commonly investigated in other studies cited were considered as a basis for the hypothetical dimensions of the NOSI. In this study, the hypothetical dimensions were as follows: the tentative nature of scientific knowledge (tentative NOS), the distinction between observation and inferences (observation and inferences), the empirical nature of scientific knowledge (empirical NOS), and the role of imagination and creativity in generating scientific knowledge (imagination and creativity). Researchers have argued that these four aspects are understandable for elementary school students (e.g. Khishfe and Abd-El-Khalick 2002). These hypothetical dimensions and the sample for each are presented in Table 3.

Table 3. Nature of science instrument.

	Wrong	Do not know	Right
1. Scientific knowledge does not change, because if scientists are not sure about it they do not put it in the books for students.			
2. Everything scientists say in books does not change anytime.			
3. Scientific knowledge might change in the sense of adding new facts to extend knowledge.			
4. Scientists can only add knowledge but they cannot take anything of it because they are 100% sure of it.			
5. Scientists use their imaginations during their investigations.			
6. Scientists use their creativity during their investigations.			
7. Scientists are certain about the structure of atoms because they were able to see atoms using microscopes.			

(*continued*)

Table 3. (*Continued*).

	Wrong	Do not know	Right
8. Scientists cannot be certain about the structure of atoms because they did not observe atoms; they only inferred that it exists.			
9. Modern atomic theory accepted today might change in the future as scientists get new evidence.			
10. Science could never involve human aspects, such as imagination and creativity, because this would result in incorrect or wrong findings and new knowledge.			
11. Scientific knowledge can be influenced by scientists' imaginations and creativity.			
12. Scientific knowledge depends on evidence obtained from controlled experiments – not scientists' imagination and creativity.			
13. Scientists may reach different conclusions when looking at the same data.			

As a second step, the validity and reliability of the scores were assessed as the instrument was used in four pilot studies. Since the purpose was to capture student NOS views, the researchers assessed not only the student selection of the number (in Likert-scale) that best represents their preferences, but also their understanding about each. To do this, for each pilot study, students were given a chance to explain the reasons behind their opinions and their critiques for the items. The students provided this information in a space given after each item. Oral feedback, as informal conversations from students and their science teachers, was also recorded. Science teacher feedback was very helpful during the process. Since the age level of the students was young, sometimes students had difficulty in explaining their views and what they learned in their science lessons. Obtaining these from students as well as their ideas helped in clarifying misunderstood parts between researchers and students. Throughout this process, the teachers voluntarily participated in the study. The research team took all information into consideration when revising the items. During this process, it became clear that small changes in the item structure resulted in big differences in reliability as well as substantial differences in the nature of the factor structures obtained from factor analysis. Because of this, several pilot tests were performed, to better determine the students' real understanding of each item and to include this understanding in the item structure. After each pilot study, a revised item structure was judged by the research team; and reliability and validity were analysed. In the fourth pilot study, the scale was administered in schools from two different cities. First, second, third and fourth pilot studies were carried out with 75, 90, 86 and 131 sixth and seventh grade students, respectively.

The face validity of the NOSI was verified by seven science teachers. For construct-validity evidence, factor analyses were conducted. To determine which type of rotation to employ during factor analysis, bi-variate correlation coefficients were calculated among the dimensions of the NOSI (Table 4). According to results, we used an oblique rotation in our factor analyses because the four scales correlated with each other (Kim and Mueller 1978). For reliability analyses, the Cronbach alpha was calculated. To determine internal consistency of scores during the fourth pilot study, Cronbach's

Table 4. Bivariate correlations between NOSI dimensions.

	Observation and inferences	Tentative NOS	Empirical NOS	Imagination and creativity
Observation and inferences	1	0.244*	0.144*	0.138*
Tentative NOS		1	0.394*	0.127*
Empirical NOS			1	0.156*
Imagination and creativity				1

Notes: *Correlation is significant at the 0.01 level (2-tailed). *Tentative nature of scientific knowledge (tentative NOS), the distinction between observation and inference (observation and inferences), the empirical nature of scientific knowledge (empirical NOS), the role of imagination and creativity in generating scientific knowledge (imagination and creativity).

alpha was calculated and found to be 0.61, 0.45, 0.35 and 0.63 for each pilot study, respectively. For the first two pilot studies, the instrument contained 20 items; later, items were added including scientific theories, laws and facts. For the third pilot study, however, these items were removed because of low factor loading. The fourth pilot study also included 20 items. Factor analysis showed that, except for items 15 and 10, all items were successfully loaded into their expected dimensions. Since two items were not found vital, with respect to their loaded hypothetical dimensions, they were eliminated from the NOSI and further analyses. Moreover, items 5, 6, 7, 13 and 14 were removed from the analyses because of low factor loading. Therefore, the final version of NOSI included 13 items, 8 negatively-written and 5 positively-written, with a 3-point Likert-type scale that included ‘wrong’, ‘don’t know’, and ‘right’ options. This scaling type was chosen for two reasons. First, filtering the ‘don’t know’ choice is one of the important principles of questionnaire construction (Borgatti 1996). O’ Neil (2007) suggested that if people may not have an opinion regarding the items of the scale, the ‘don’t know’ option is necessary on these scales. Therefore, in order to determine whether students know the statement or not, scaling of NOSI included ‘don’t know’ options rather than an ‘undecided’ option. Second, when we considered the age of the students, the characteristics of the statements of the items of the NOSI, and other experiences with the 5-point Likert-scales for the pilot studies, it was decided to use a 3-point Likert-type scale. The first pilot study included 5-point Likert-type itself with the options ‘certainly disagree, disagree, undecided, agree, and certainly agree’. Since the students had difficulty in deciding their responses by using the scaling, they frequently asked, what would I say if I think the statement is right? Thus, from the feedback obtained from the students the researchers decided to use a 3-point Likert-scale to be clearer. Moreover, this type of scaling was also used for elementary school students to measure their ideas in different subject matter fields such as the junior meta-cognitive awareness inventory developed by Sperling, Howard, Miller, and Murphy (2002), the social skills rating system (SRS) developed by Gresham and Elliot (1990) and Questionnaire on Teacher Interaction (Elementary) (QTI) adapted by Goh and Fraser (2000). While Goh and Fraser (2000) adapted an elementary version of the QTI scale, they changed QTI’s original 5-point response scale to a 3-point scale to make it more suitable for elementary students. Moreover, researchers tried to use other 5-point types of scaling for NOSI; however, a 3-point Likert-type scale is more understandable because of the nature of the NOSI items for elementary students. Having high scores from NOSI resulted in having a good understanding about the NOS. These items were loaded in four factors. The distinctions between observation and inference (two items), the tentative nature of scientific knowledge (three items), the role of imagination and creativity in generating scientific knowledge (five items) and the empirical nature of scientific knowledge (three items) comprised the instrument. In the literature, elementary school students' version of Schommer's epistemological questionnaire (SEQ) (Schommer 1990) and the Turkish version of SEQ (Topcu and Yilmaz-Tuzun 2007) included factors with two items such as stability of knowledge and omniscient authority. According to Tabachnick and Fidell (2001), if two variables load on a factor, deciding whether this factor is reliable or not depends on the magnitude of correlation among these two items with each other and with other variables. If the two variables are highly correlated with each other and relatively small correlated or uncorrelated with other variables, this factor may be reliable. Cohen (1992) proposed the level of correlation for social science as follows: small, $r = 0.1$–0.23; medium, $r = 0.24$–0.36; large, $r = 0.37$ or larger. In the instrument used in this study, the distinction between the observation and inference factor has two items; these two items are highly correlated with each other ($r = 0.59$) and relatively small correlated with other items (with r values ranging from $r = 0.03$ to $r = 0.25$). Therefore, it was decided that this factor is reliable for NOSI and thereby it was kept as a factor for the rest of the analyses of this study.

After getting satisfactory factor-analysis results from the fourth pilot study, the researchers were ready to conduct the real study with this latest version of the NOSI.

2.5. *Data analyses*

To confirm the factor analysis obtained during the pilot studies, an exploratory factor analysis (EFA) was again conducted for the data of this study. Similarly, Cronbach's alpha reliabilities were calculated to determine the internal consistencies of the total NOSI and each dimension of the NOSI. For this study, the confirmatory factor analysis (CFA) was also conducted to identify the best-fit structure and verify the EFA factor solution. LISREL 8.30 was used to determine how well the 13 items fit the proposed four latent factors: observation and inferences, tentative NOS, imagination and creativity, empirical NOS.

Descriptive statistics were conducted to better represent students' understanding of each NOSI dimension, and two-way multivariate analysis of variance (MANOVA) was used to determine students' understanding of NOSI dimensions in terms of grade level and gender.

3. Results

3.1. *Exploratory factor analysis of the NOSI*

Factor analysis enabled us to determine the number and characteristics of factors that could account for students' responses on the NOSI. With oblique rotation and an Eigen value that is greater than one (as a cutoff point for factors), a 'maximum likelihood extraction' generated four factors that account for 64.34% of the variance. Factor analysis revealed four factor structures in the data; the factors 1, 2, 3 and 4 were named: (1) observation and inferences, (2) tentative NOS, (3) imagination and creativity and (4) empirical NOS, respectively (Table 5). For the total, NOSI Cronbach's alpha reliability was found to be 0.76. For each dimension, Cronbach alpha values ranged from 0.63 to 0.80. The smallest alpha value was obtained for the empirical NOS dimension of the NOSI.

Table 5. Factor loadings for final NOSI items.

NOSI dimensions	Items		Factor 1	Factor 2	Factor 3	Factor 4
Observation and inferences	7	Negative	0.990			
	8	Positive	0.595			
	Cronbach Alpha = 0.74					
Tentative NOS	2	Negative		0.975		
	1	Negative		0.846		
	4	Negative		0.353		
	Cronbach Alpha = 0.76					
Imagination and creativity	5	Negative			0.750	
	10	Negative			0.682	
	6	Negative			0.670	
	12	Negative			0.646	
	11	Positive			0.588	
	Cronbach Alpha = 0.80					
Empirical NOS	9	Positive				0.881
	3	Positive				0.756
	13	Positive				0.249
	Cronbach Alpha = 0.63					
Eigenvalues			3.40	2.36	1.45	1.14
Variance (%)			26.21	18.20	11.15	8.77
	Total Scale Alpha = 0.76					

3.2. *Confirmatory factor analysis of the NOSI*

To further validate the factor analysis results, a confirmatory factor analysis was performed, providing a model (Figure 1) with reasonable good-fit indices: a 'Goodness of Fit Index' (GFI) of 0.98; an adjusted Goodness of Fit Index (AGFI) of 0.97; a Root Mean Square Error of Approximation (RMSEA) of 0.068; and a χ^2/df of 3.81 ($\chi^2 = 225.19$; df = 59, $p = 0.000$).

In order to check whether this scale can be used for measuring total NOS views, a second order confirmatory factor analysis was conducted. The model represented in Figure 2 has also reasonably good-fit indices: a GFI of 0.98; an AGFI of 0.97; a RMSEA of 0.067; and a χ^2/df of 3.73 ($\chi^2 = 227.75$; df = 61, $p = 0.000$). Of these indices, χ^2/df (which is less than 5), GFI and AGFI, which have a range from 0 to 1 (with values exceeding 0.9), and RMSEA less than 0.08, indicated a good fit with the data (Kelloway 1998).

3.3. *Descriptive and inferential analyses*

Descriptive analyses revealed that, regarding the mean scores of each NOSI dimension, the most favourable NOS views were obtained for the empirical nature of scientific knowledge. The students were uncertain about NOS views related to tentative NOS and imagination and creativity. The least favourable NOS views were obtained for observation and inferences (Table 6).

Two-way MANOVA was conducted to investigate the effect of gender and grade level on students' NOS views. Preliminary analysis was conducted to check for univariate and multivariate normality, outliers, linearity, multicollinearity and homogeneity of variance–covariance matrices, the assumptions of MANOVA. In order to check the univariate normality of the distribution of scores, both reasonable skewness and kurtosis values between -2 and $+2$ and Normal Q–Q

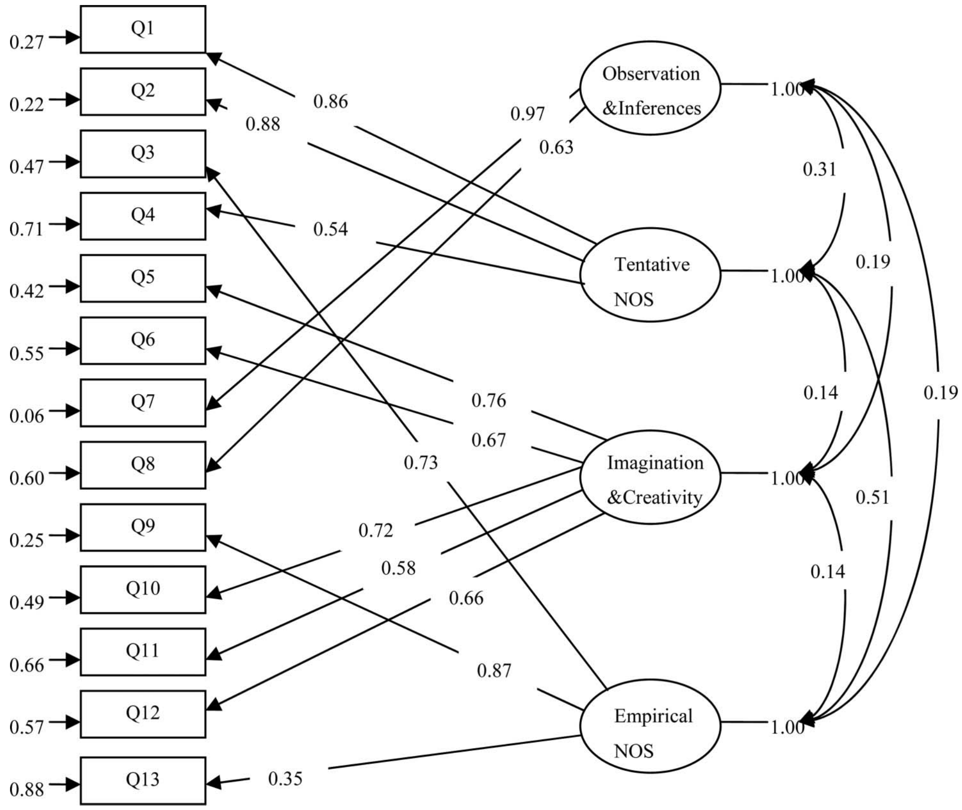

Figure 1. Model derived from confirmatory factor analysis. Chi-square = 225.19, df = 59, *p*-value = 0.00000, RMSEA = 0.068.

plots with reasonable straight line suggest the normality assumption was not violated. With respect to multivariate normality, Mahalanobis distance was calculated and values larger than the critical value for evaluating Mahalanobis distance for four dependent variables (16.27) (Pallant 2002) were deleted from the data, therefore there were no multivariate outliers in the data. Scatter plots generated for gender and grade level showed satisfactory evidence for assumption of linearity. Small and moderate levels of correlations among dependent variables (Table 4) indicated no violations about multicollinearity assumptions. Also, non-significant ($p > 0.001$) Box's Test of Equality of Covariance Matrices ($p = 0.006$) indicated that there was no violation in the homogeneity of covariance matrix assumption.

No significant differences were found between males' and females' views about the NOS.

Grade level significantly affected an elementary student's NOS views regarding observation and inferences, tentative NOS, imagination and creativity, and empirical NOS ($F(2, 782) = 17.93$, $p < 0.001$; $F(2, 782) = 18.83$, $p < 0.001$; $F(2, 782) = 12.39$, $p < 0.001$; $F(2, 782) = 9.68$, $p < 0.001$, respectively). Wilks' lambda revealed significant differences among grade levels (Table 7). Follow-up analyses were conducted to identify where the significant differences were. Cohen (1988) defined the effect sizes for MANOVA analysis as 0.01 small, 0.06 medium, and 0.14 for large (Pallant 2002). For this study, all of the effect sizes were found to be small.

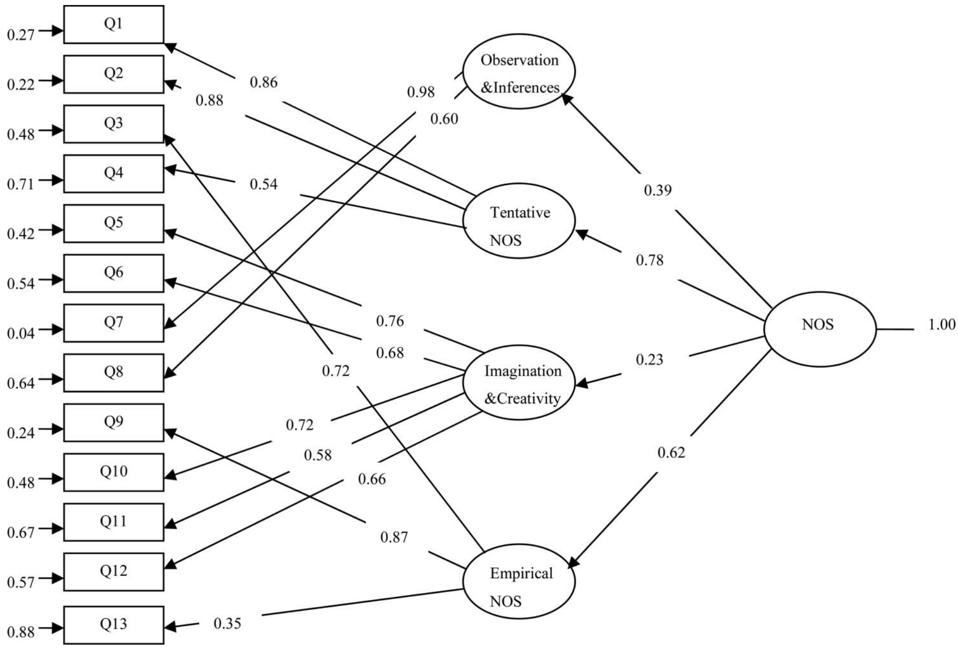

Figure 2. Model derived from second order confirmatory factor analysis. Chi-square = 225.19, df = 59, p-value = 0.00000, RMSEA = 0.068.

Table 6. Descriptive statistics of NOSI dimensions.

Sub-dimensions of NOS	M	SD
Observation and inferences	1.87	0.80
Tentative NOS	2.48	0.62
Imagination and creativity	2.29	0.62
Empirical NOS	2.77	0.37

In terms of observation and inferences, the mean scores of sixth, seventh and eighth grade students were significantly different from each other. Seventh grade students' views of the tentative nature of NOS and the empirical nature of NOS were significantly different from those of sixth and eighth grade students. Concerning imagination and creativity, eighth grade student responses had significantly lower mean scores than the sixth and seventh grade students. No significant difference was found between sixth and seventh grade student views in terms of imagination and creativity. Bonferroni test results, as a pairwise comparison, are presented in Table 8.

4. Discussion

4.1. Validity and reliability of NOSI

When constructing and developing a scale, it is most crucial to be certain that the scale measures what is intended. This issue also ensures that the instrument is valid. Thus, assessing what is intended to be measured regarding students' NOS views was the focus in developing the NOSI. Regarding ensuring the validity of NOSI, the most

Table 7. MANOVA results for effect of grade level and gender on student understanding of NOS.

	df	*F*	Partial Eta squared (η_p^2)	*p*
Gender				
Observation and inferences	1	0.010	0.000	0.919
Tentative NOS	1	0.565	0.001	0.453
Imagination and creativity	1	0.038	0.000	0.846
Empirical NOS	1	2.645	0.003	0.104
Grade level				
Observation and inferences	2	17.938	0.045	0.000*
Tentative NOS	2	18.839	0.048	0.000*
Imagination and creativity	2	12.397	0.032	0.000*
Empirical NOS	2	9.681	0.025	0.000*

Note: *$p < 0.05$.

Table 8. The Bonferroni test results for mean scores at different grade levels.

	Mean scores			
	Observation and inferences (OI)	Tentative NOS (TE)	Imagination and creativity (IC)	Empirical (EM)
Sixth graders	1.81^{a}*	2.38^{a}*	2.35^{a}*	2.74^{a}*
Seventh graders	2.06^{b}*	2.64^{b}*	2.34^{a}*	2.84^{b}*
Eighth graders	1.59^{c}*	2.32^{a}*	2.05^{b}*	2.69^{a}*

Notes: Means with similar letters (a, b) are not significantly different from each other; means with different letters (a, b) are significantly different from each other. *$p < 0.05$.

difficult issue was to ensure that we addressed an understanding of the NOS that was common to all participants. Therefore, it was crucial to conduct more than one pilot study. The previous results of the qualitative studies (Akerson and Volrich 2006; Khishfe 2008; Khishfe and Abd-El-Khalick 2002; Khishfe and Lederman 2006, 2007) provided valuable data about elementary student views about the NOS and a foundation for this study. During the pilot studies, it was observed that slight changes in the item structure produced big differences in the factor structure. These changes were based on responses from teachers and students, obtained during the pilot studies. To adapt into the Turkish language the quotes obtained from qualitative studies conducted in other languages, we needed to follow this procedure. For example, for this study some items were added to NOSI concerning scientific theories, laws and facts; however, in the pilot studies, when student responses to these items were considered, it was realised that the students did not know the differences among these concepts. Therefore, as these items were unreliable, they were eliminated from the final version of NOSI. Exploratory and confirmatory factor analyses showed that the final version of NOSI did measure the elementary students' NOS views.

Regarding score reliability of NOSI, the findings of this study reveal that scores have a significant level of reliability ($\alpha = 0.76$). According to Kline (1999) and DeVellis (1991), the alpha value for cognitive tests between 0.70 and 0.80 is in accordance with accepted standards. When dimensions' score reliability values were compared with score reliabilities of NOS scales that were developed previously, the score reliability values that were found for total NOSI and its dimensions were generally higher (Table 9).

The empirical dimension scores of NOSI have a moderate level of reliability ($\alpha = 0.63$), which is still a reasonable value for social studies, as supported by Hatcher and Stepanski (1994), Liang et al. (2008) and Tsai and Liu (2005), and a higher score reliability value compared with VOSE. These comparisons suggest that scores obtained with NOSI have good reliability indices and have the potential to determine the elementary students' NOS views.

4.2. Elementary students' general views about NOS

In terms of the tentative NOS and imagination and creativity dimensions of NOSI, elementary students had difficulty in sharing their views. They were hesitant regarding the tentative NOS. They did not accept the ideas that scientists are always correct, everything scientists say in books is correct, and scientists are 100% sure about the knowledge they generate. The students' views about tentative NOSI items revealed that they did not clearly understand the changing nature of both science and the knowledge scientists generate. These findings are in agreement with earlier studies in which researchers argued that students in elementary and high school had naïve understandings about the tentative natures of NOS (Ryan and Aikenhead 1992; Stein and McRobbie 1997).

Regarding imagination and creativity findings, the study revealed that students had mixed views about the ideas that scientists use their imagination and creativity during their investigations and that imagination and creativity do not result in flawed conclusions in scientific investigations. Not appreciating the place of imagination and creativity in the NOS has also been reported by earlier studies (e.g. Khishfe and Abd-El-Khalick 2002). In terms of a Turkish context, similar findings were presented by Celikdemir (2006) regarding the tentative NOS, and imagination and creativity.

Among all qualities tested, the student views regarding the 'empirical dimension of the NOS' were found to be the most developed. Generally, students accepted that scientists may interpret the same data differently and that, in light of new scientific knowledge, our scientific understandings can be enhanced. Similar to our findings, Sadler, Chambers, and Zeidler (2004) found that 80% of high school students in their sample could define data, but 17% of them had difficulty in understanding the empirical NOS. The majority of the students had a sound understanding regarding both the definition of data and the empirical views of the NOS.

The least developed views were found for the observation and inferences dimension of NOSI. The students generally believed that scientists could only be certain about their findings if they actually visualise the results. Moreover, they stated that if scientists must make inferences based on their data, then their findings could not be certain. Griffiths and Thompson (1993) conducted a study with students who were the same age as those in this study. They found that, related to observation, most students believed that observation is accomplished by visualisation. Like the students studied by Griffiths and Thompson (1993), the students in this study also gave credit to scientists' sense of sight, rather than their ability to make inferences.

Regarding the grade level of students, one might expect to see better NOS views in higher level grades. MANOVA results supported this expectation between sixth

Table 9. Reliability of the instruments and their dimensions.

NOSI (for elementary students)		SUSSI (for college students), (Liang et al. 2008)		VOSE (for college students), (Chen 2006)		SEVs (for high school students), (Tsai and Liu 2005)	
Dimensions	α	Dimensions	α	Dimensions	α	Dimensions	α
Observation and inference	0.74	Observation and inferences	0.61	Nature of observations	0.47		
Tentative NOS	0.76	Tentativeness	0.56	Tentativeness	0.34	The changing and tentative feature of science knowledge	0.60
Imagination and creativity	0.80	Creativity and imagination	0.89	Use of imagination	0.71	The invented and creative nature of science	0.60
Empirical NOS	0.63			Validation of scientific knowledge	0.44		
Total α	0.76	Total α	0.69	Test–retest correlation coefficient	0.82	Total α	0.67

and seventh grade students, and for all NOSI dimensions except the imagination and creativity dimension. It is interesting to note, however, that students at the eighth grade level had lower mean scores for all dimensions of NOSI. This may reflect the national exam system in Turkey where, generally, students take exams at the end of elementary school (i.e. the eighth grade) to enrol in one of the prestigious high schools and again at the end of high school, to enter a university. As recognised by Berberoglu and Hei (2003), rote learning may be reflected in both the format and content of these exams. Since students in eighth grade spend most of their time studying for this exam, they may have a tendency to memorise concepts. This study habit may be the reason behind the low mean scores as compared to other grade levels. To achieve concerning this problem, linking test questions to the course instruction and the science curriculum (Chapman and Snyder 2000) can be an effective way to improve student NOS views.

4.3. Contribution of this study to the Turkish context

In Turkey, the current science and technology curriculum has been implemented nationwide since 2008. The curriculum and most textbooks emphasise the importance of NOS. According to the new curriculum in Turkey, the scientific method includes observation, stating hypotheses, collecting data, testing hypotheses, rejecting or accepting hypotheses and interpreting data. It also states that imagination, creativity, objectivity, inquiry and being open to new ideas are all important in scientific processes. All these attempts aim to teach students the way to attain knowledge. More specifically, students are required to construct their knowledge through taking an active role in their own learning. To achieve this, students need to understand the basic aspects of NOS. Literature on NOS supports the idea that implementation of NOS aspects in classroom environments can be a challenging task to master for teachers as well as students. The data from this study support the notion that one- or two-year implementation of a new curriculum does not reach the stage of actually developing more accurate views of some NOS aspects in students. In this study, the least developed NOS views were found to be for observation and inferences and moderately developed NOS views for tentative NOS and imagination and creativity. Definition of data and the empirical views were found as the better developed aspects of NOS. The reasons for having better views of these aspects could be the reflection of the previous Turkish science curriculum. In the previous science curriculum, student-centred activities and the scientific method were emphasised. The students in this study were more familiar with investigation, collecting data, and providing evidence. Moreover, student-centred activities could further improve students' understanding of the empirical nature of scientific knowledge included in the new curriculum. This observation further supports the argument that in order to develop young students' NOS views, prolonged engagement of NOS aspects through science courses would be helpful.

As it was stated in the introduction section, a number of studies conducted at different age levels indicate that students at different grade levels hold inadequate views regarding the characteristics of the NOS. Moreover, it has been pointed out that students develop views of the NOS at early grade levels. If students had misconceptions concerning these views, it will be difficult for them to exchange these views with scientifically accepted ones. Researchers argue that elementary school students' views concerning the NOS should be determined as early as possible (e.g. Kang, Scharmann, and Noh 2005; Meichtry 1992). Therefore, with this study, by including grade level and gender, the aforementioned issues were explored in the Turkish context. The findings of this study support that the students developed NOS views at elementary level and also indicate that the views range from least developed to most developed for different NOS aspects. Regarding gender, no significant differences between female and male students at different grades were found. This finding is important because if we observed any difference, we could suggest possible ideas to policy makers, curriculum developers, researchers and teachers about eliminating such gender differences. As a matter of fact, researchers in some countries have reported gender differences in their studies (e.g. Huang, Tsai, and Chang 2005).

In Turkey, the Ministry of National Education has declared that one of the needs for the new curriculum must consider the results from international studies such as TIMSS and PISA (Ayral, Ozdemir, and Sadıc 2011). For assessing student science understanding, TIMSS and PISA emphasise the science process skills, real life experiences and some aspects of NOS in their questions. Since the students in this study were not familiar with these concepts, especially the NOS aspects, obtaining low scores can be explained as having no knowledge rather than failing to understand scientific knowledge. Thus, this study reveals that the students did not have necessary understanding about some aspects of NOS, but they could learn these concepts as a result of prolonged implementation of the new science and technology curriculum.

5. Conclusion and implications

In many countries, exploring student views about the NOS has been considered as an important focus for science educators and researchers. These studies help both to provide students with contemporary perspectives regarding the NOS while also developing their understanding about these perspectives (Abd-El-Khalick, Bell, and Lederman 1998; Lederman 1992). Moreover, researchers also argue that it is important to improve student views of the NOS at early grade levels. According to Bruer (1993), the elementary level is a pivotal time when students gain an understanding of the world around them. Moreover, Bruer (1993) contends that students use knowledge gained from formal science education to clarify the experiences gained outside and inside the school environment. It is now accepted that elementary school students may improve their own views about the NOS (Kang, Scharmann, and Noh 2005; Meichtry 1992); thus, determining and developing students' NOS views constitutes an important goal for elementary school science teachers and researchers.

This study provides an instrument for measuring elementary students' views of the NOS in four dimensions (the tentative NOS, the empirical NOS, observation and inferences, and imagination and creativity). Based on the reliability and validity evidence, it is concluded that this instrument can be used for elementary school students of different cultural backgrounds; however, researchers must be careful when adapting this instrument because students are influenced by the wording change that the items employ. It is proposed that valid and reliable instruments like NOSI can be helpful for researchers in testing the theoretical issues. For example, researchers argue that rather than implicit NOS teaching, the NOS should be taught explicitly because it would improve understanding of them. Making these instruments widely available may assist researchers who intend to test this assumption with experimental designs. This instrument could also provide a useful tool for researchers who wish to make cross-cultural comparisons and evaluate how well the NOS objectives are attained with a particular science curriculum. This information can be valuable for the administrators, curriculum developers and policy makers who decide how to teach about the NOS.

For future research, the number of items in each NOSI dimension can be increased, and the NOS dimensions not included in this study can also be considered. For example, new items related to scientific theories, laws and facts might be added, because these concepts play an important role in the growth of scientific knowledge (Abd-El-Khalick, Bell, and Lederman 1998; Bell, Lederman and Abd-El-Khalick 2000; Duschl 1990; Lederman 1992; Lederman et al. 2001). Tsai (2002) and Huang, Tsai, and Chang (2005) argue that students may have different views concerning different sub-dimensions of the NOS. Descriptive analyses support this argument. For some dimensions of the NOSI, the students had better views than for other dimensions. These findings enable us to conclude that views regarding different dimensions of the NOS develop 'more or less independently' from each other as also reported by Schommer (Schommer 1994, 300). In other words, developing better views in one dimension does not necessarily result in a better understanding of the other dimension(s). Thus, teacher awareness of student views regarding different dimensions of the NOS is crucial when improving the less sophisticated NOS views held by elementary students. NOSI can aid these teachers in determining their students' NOS views and organise their teaching plans accordingly.

This study has some limitations that researchers should consider while generalising and using the findings. The subjects of this study were limited to sixth, seventh, and eighth grade Turkish public school students who were selected in Çankaya district, one of the largest urban areas in Ankara. Therefore, results may not be reliable in different situations and cultural contexts. Researchers should be careful about the generalisation of the findings of this study. Research should be conducted again in different cities, regions and countries in both public and private schools to generalise results confidently.

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