Turkish Version of Students' Ideas about Nature of Science Questionnaire: A Validation Study

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Abstract

Mass assessment of large samples' nature of science views has been one of the core concerns in science education research. Due to impracticality of using open-ended questionnaires or conducting interviews with large groups, another line of research has been required for mass assessment of pupils' nature of science conception meaningfully. Considering these issues, Chen et al. (2013) developed the questionnaire titled Students' Ideas about Nature of Science (SINOS) to evaluate young students' NoS views. This study targeted to translate and adapt SINOS into Turkish with the aim of measuring Turkish middle-school students' nature of science (NoS) views. Analysis results presented confirmation for the reliability and validity of Turkish version of the questionnaire with seven-factor structure as similar to the original questionnaire. The study concluded with recommendations for use of SINOS in Turkish context in order to improve NoS perspectives in national science curriculum.

Keywords: Nature of science, nature of science scale, attitudes toward science, value given to science, validation study

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Introduction

Nature of science (NoS) has been a central topic in many international curriculum movements (e.g. American Association for the Advancement of Science [AAAS], 1990, 1993; Bell, Matkins & Gansneder, 2011; National Research Council [NRC], 1996; Koertge, 1998; Olson, 2008). More recently, NRC (2012) released Next Generation Science Standards in which learning about NoS still has been emphasized. As a result of these reform efforts, NoS has been established as permanent science education objective by many countries including Canada, United Kingdom, and United States and received an increasing emphasis among researchers (Lederman, 2007). Turkey also accepted NoS among the vision of science education in national science curricula since 2004 (MoNE, 2005).

With a well-known definition, nature is described as the epistemology of science or the values and beliefs inherent in the development of scientific knowledge (Lederman, 1992). According to Walls (2012), NoS includes "an individual’s beliefs about how scientific knowledge is constructed; where scientific knowledge originates; who uses science (including scientists); who produces scientific knowledge; and most importantly, where the individuals places themselves within the community of producers and users of science" (p. 1). NoS could also be conceptualized as an answer to the question of "what science is, how it works, how scientists operate as a social group, and how society itself both influences and reacts to scientific endeavors as well as the epistemological and ontological foundations of science" (Clough, 2006, p. 463).

Why it is important to help students have improved NoS comprehension is one of the central issues that need consideration. Abovementioned science education reform movements and many science education researchers proposed NoS as a critical component of scientific literacy (e.g., Abd-El-Khalich, Bell & Lederman, 1998; Bell & Lederman, 2003; Bybee, 1997; NRC, 1996). When describing the characteristics of a person who is scientifically literate, Abd-El-Khalick and BouJaoude (1997) underlined science content knowledge proficiency, science processes ability, science-technology-society relationship awareness as well as an improved NoS understanding. After gaining much importance, science education researchers conducted many studies about students’ and teachers’ understanding of NoS (Kang, Scharmann, & Noh, 2005) as well as ways for improving their understanding of NoS (Matkins & Bell, 2007; Rudge & Howe, 2009). In those and many other studies, NoS was generally considered as having several aspects. Abd-El-Khalick and Lederman (2000) provided seven aspects of NoS which refer to the characteristics of scientific knowledge as tentative, empirically-based, subjective or theory–laden, partially based on human inference imagination and creativity, and socially and culturally embedded. The distinction between observation and inference, and the relationship between scientific theories and laws were also considered as additional aspects for NoS. Lederman (2007) argued that those aspects are not the only NoS aspects and underlined that there may be aspects that can be added or deleted. Not markedly different from this list, Chen, Chang, Lieu, Kao, Huang, and Lin (2013) suggested two additional aspects for NoS; durability and science for girls and boys. Chen et al. (2013) added durability due to the fact that although scientific knowledge is tentative it is yet durable. They also stated that women and men both have a role in development of scientific knowledge, thus they included science for girls and boys as an aspect of NoS in their studies.

A Questionnaire from Learners’ Perspectives: Students’ Ideas about Nature of Science (SINOS)

Individuals’ understanding of NoS is generally measured by open-ended questionnaires. Views of Nature of Science (VNOS) versions (i.e., VNOS-A, Lederman & O’Malley, 1990; VNOS-B, Abd-El-Khalick, Bell, & Lederman, 1998; VNOS-C, Abd-El-Khalick & Lederman, 2000; VNOS-D, Lederman & Khishfe, 2002; and VNOS-E, Lederman & Ko, 2004) are the most used instruments to assess individuals’ NoS understandings for almost two decades. Individuals either write their answers to the questions or are interviewed using VNOS versions. Many researchers used these instruments in their studies and provided valuable information to science education research. Chen et al. (2013) discussed that such open-ended questionnaires and interviews help to learn about individuals’ NoS views and reveal how students’ NoS views change due to interventions. However, this type of instruments may be impractical under several conditions which led to the development of SINOS. Firstly, it is not convenient to use open-ended questionnaires and interviews with large samples. However, SINOS is a Likert-type scale which makes it easy to administer to larger samples (Chen et al., 2013). Second, although there exist other NoS questionnaires to be used with large samples, they have several drawbacks. For example, some multiple-choice questionnaires do not produce scores for running inferential statistics (e.g., Aikenhead, Flemming, & Ryan, 1992; Kang, Scharmann, & Noh, 2005). However, since SINOS is a Likert type questionnaire, it produces scores which allows performing parametric tests (e.g., t-test and ANOVA) as well as non-parametric tests (e.g., Mann-Whitney U Test). In addition, some other questionnaires are limited in terms of assessing diverse NoS aspects. For instance, Pupils’ Nature of Science Scale (Huang, Tsai, & Chang, 2005) assesses only three NoS aspects. In this respect, SINOS assesses seven NoS aspects. A great deal of prior instrument measuring learners' NoS conceptions has been developed based on the assumption that students and experts use the same lens to interpret the phenomena. However, some researchers criticized that students and experts' interpretations and viewpoints could be quite different from each other (Alters, 1997; Jungwirth, 1974; Lederman & O'Malley, 1990). Another gain in development of SINOS is that it was developed based on students’ own perspectives and expressions rather than experts’ speculations of possible views (Chen et al., 2013). Therefore, it is possible to assert that SINOS represents the perspectives of young students more adequately than existing instruments.

Method

The purpose of this study was to translate and adapt SINOS into Turkish with the purpose of measuring middle school students' conception of NoS. Following research questions guided this study:

1. To what extent is SINOS a valid and reliable instrument to measure Turkish middle school students’ NOS views?
2. After controlling for the possible effects of previous achievement and gender, to what extent do the aspects of SINOS predict middle school students’ attitudes towards science and value given to science?

Sample

Turkish version of SINOS was administered to 380 middle school students in 4 cities in northeastern region of Turkey. Sample includes 206 girls (54%) and 173 boys (45.5%) and 1 student did not report gender. 104 (27.4%) of these students were in the 5th grade, 158 (41.6%) were in the 6th grade, 46 (12.1%) were in the 7th grade, and 72 (18.9%) were in 8th grade. Students’ previous semester science achievement scores in ranged from 31 to 100 with a mean of 75.89 (SD = 15.91). Participants’ ages ranged from 11 to 16 with a mode of 12.

Instrument

Original version of SINOS instrument was developed by Chen et al. (2013) using Taiwanese students’ NoS views. As stated by Chen et al. (2013), they follow five main stages for ensuring its reliability and validity: (a) considering NOS issues that are closely related to students’ experiences of school science, (b) writing draft items based on written responses of students, structured interviews, and excerpts from books, (c) pilot testing the first version of SINOS, (d) conducting item analysis and rewriting problematic items, and (e) retesting the instrument for validation. SINOS consists of 47 Likert-type items in seven NOS aspects. These aspects are named as Theory-Ladenness (9 items), Coherence and Objectivity (11 items), Creativity and Imagination (6 items), Tentativeness (9 items), Durability (6 items), Science for Girls (3 items), and Science for Boys (3 items). Table 1 illustrates descriptions and sample items for each of the aspects of SINOS.

Table 1. *Descriptions and sample items for each aspects of SINOS*

Aspect: Description	Sample item
Theory-ladenness: Scientists' theoretical dispositions, knowledge, practice and mindset, may manipulate their science practice (Akerson, Cullen, & Hanson, 2009; Lederman, 2007; Rudge & Howe, 2009). Therefore, every scientific study includes subjective components (Bauer, 1992).	"When scientists from different research areas observe 'the same' experiment, they are interested in different things and so they make different observations and come to different conclusions."
Coherence and Objectivity: "Scientists do not pay much attention to claims about how something they know about works unless the claims are backed up with evidence that can be confirmed with logical arguments" (AAAS, 1993, p. 11). In other words, evidence-based explanations should be dominant in science.	"As long as we use the same experiment method, no matter where the experiment is done, the results will be the same."
Creativity and Imagination: "Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity" (NRC, 1996, p. 170).	"I believe that scientists work like artists. They both need creativity and imagination."
Tentativeness: The knowledge in science is always open to change (Lederman, Abd-El-Khalick, Bell, & Schwatrz, 2002) which means it is revolutionary in nature (Khishfe & Abd-El-Khalick, 2002).	"Better theories will be found and will replace some old theories because scientists will invent high technology machines to discover new findings in the future."
Durability: Even though knowledge in science is open to change, it is also durable (Lederman, 2007). Most of the time, the change in scientific knowledge is partial and limited to the modification of the peripheral concepts of science (Chen et al., 2003).	"Scientific knowledge will not be replaced because it has been proven by experiments and explanations".
Science for Girls: It is a well-known fact that science does not make gender discrimination. Therefore, it is evident that girls' contribution and participation to science cannot be underrated (Chen et al., 2003).	"Girls have talent for scientific research."
Science for Boys: Similar to the girls, boys take part in science, and contribute to the development of science (Chen et al., 2003).	"Boys have the capabilities for doing scientific research."

Chen and colleagues validated the final version of the instrument with 1029 students who did not receive NoS instruction before. The reliability coefficients of subscales using Cronbach's alphas ranged from 0.70 to 0.87. The Cronbach's alpha coefficient was reported as .85 for the whole instrument (Chen et al., 2013). According to Gronlund and Linn (1990) and DeVellis (2012) this is a good reliability for an instrument. Additionally, Confirmatory Factor Analysis (CFA) indices indicated a good model fit which provided evidence for construct validity (RMSEA= .46, NNFI = .99, CFI = .94, S-RMR = .059). Chi-square to degrees of freedom (df) ratio was 2.14 which was lower than 5. Taken all these together, fit indices indicated good model fit to the data.

Procedures

Firstly, SINOS items were translated into Turkish by two of the authors of the study. Then, Turkish version was back translated into English by other two researchers, separately. English versions and original items were compared. It was seen that most of the items have close meaning. The four researchers discussed on the items which did not have exactly the same meaning with the original items to make a consensus. For the items on which the researchers cannot reach a consensus, they communicated with developers of the original scale in order to be sure about items' meanings. Then, this Turkish version of the scale was also examined by a Turkish language expert and found appropriate to administer the scale to middle school students.

After these translation processes, this study was conducted in 2 steps. In the first step, in order to investigate 7-factor structure of SINOS in Turkish context, confirmatory factor analysis was conducted. In the second step, in order to investigate whether SINOS factors were related to attitudes towards science and value given to science, two hierarchical regression analyses were performed. Details of these steps are presented below.

Results

Step 1: Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) was run to investigate proposed 7 latent factors. According to analysis results, four items (item 3.1, 3.2, 4.1 and 5.2) were problematic. R2 values were at 0.1 and lower for these items. Furthermore, item loadings were lower than 0.40 and corrected item to total correlation values were lower for these items in comparison to other items (around 0.30). Field (2009) recommend dropping items if corrected item to total correlation values are lower than .30. When these items were deleted, chi square difference test was found to be significant [$\chi 2$ (174) = 309.79, $p < .05$] indicating improvement in model fit.

After dropping these four items, CFA were re-run. Chi-square to df ratio was 1.60 which was lower than 5. Fit indices indicated good model fit to the data (RMSEA= .40, NNFI = .96, CFI = .96, S-RMR = .056). Factor loadings (completely standardized solutions to Lambda X) were presented in Table 2. Factor loadings ranged from .44 to .70 for theory-ladenness, .41 to .54 for coherence and objectivity, .51 to .68 for creativity and imagination, .41 to .68 for tentativeness, .46 to .73 for durability, .75 to .85 for science for girls, .80 to .84 for science for boys sub-scale.

Table 2. *Factor loadings (completely standardized solutions to Lambda X)*

Item	Theory-Ladenness	Coherence and Objectivity	Creativity and Imagination	Tentativeness	Durability	Science for Girls	Science for Boys
1.1	.52						
1.2	.44						
1.4	.60						
1.5	.64						
2.2	.60						
2.4	.55						
3.5	.62						
3.6	.70						
4.2	.49						
1.3		.45					
2.1		.49					
2.3		.48					
3.3		.44					
3.4		.41					
3.7		.54					
4.3		.51					
4.4		.50					
5.1			.68				
5.3			.58				
5.4			.51				
5.5			.66				
5.6			.62				
6.1				.59			
6.2				.57			
6.3				.56			
6.4				.68			
6.5				.67			
6.6				.58			

6.7				.49			
6.8				.47			
6.9				.41			
6.10					.73		
6.11					.62		
6.12					.56		
6.13					.51		
6.14					.55		
6.15					.46		
7.1						.85	
7.3						.83	
7.5						.75	
7.2							.80
7.4							.80
7.6							.84

Internal consistencies for each factor were calculated by using Cronbach Alpha (see Table 3). Reliabilities ranged from .70 to .86 and total reliability for the whole scale was .85, which indicated sufficiently high internal consistencies within each factor and whole scale.

Table 3. *Number of items and reliabilities*

	Number of items	Cronbach Alpha
Subjectivity		
Theory-ladenness	9	.81
Creativity and Imagination	5	.75
Tentativeness	9	.80
Objectivity		
Durability	6	.75
Coherence and objectivity	8	.70
Science for all		
Science for girls	3	.85
Science for boys	3	.86
Total	43	.85

Descriptive statistics for factors of SINOS and zero order correlations among factors were presented in Table 4. The highest correlation was between Creativity and Imagination and Tentativeness (r = .67) while the lowest correlation was between Coherence and Objectivity and Science for Boys (r = -.01).

Table 4. *Descriptive statistics and zero order correlations*

	Mean	SD	2	3	4	5	6	7
1.Theory-ladenness	4.01	.72	.65**	.57**	-.20**	.09	.36**	.36**
2. Creativity and Imagination	4.04	.79		.67**	-.24**	.10	.51**	.40**
3. Tentativeness	3.70	.71			-.19**	-.07	.39**	.41**
4. Durability	2.67	.84				.38**	-.12*	-.15**
5. Coherence and Objectivity	3.44	.78					.08	-.01
6. Science for Girls	4.08	1.08						.27**
7. Science for Boys	4.21	.1.00						

Step 2: Hierarchical Regression

In this step, two separate hierarchical regression analyses were performed in order to investigate to what extent demographic variables and students' nature of science views explain (1) attitudes towards science and (2) value given to science. Attitudes towards science represents students' liking science related works, liking learning science, finding science easy, and perceiving importance of science for the life. This construct was measured by using 4 items from TIMSS 1999 questionnaire. Moreover, value given to science variable represents the degree of the students' perception about being successful in science course for himself/herself and for others (i.e. mother and friends) and it was measured by using 3 items from TIMSS 1999 questionnaire. Both variables were based on 4-point Likert scale ranged between completely disagree (1) to completely agree (4). In the present study, Cronbach alpha coefficients for attitudes towards science and value given to science was found to be .71 and .64, respectively.

Demographic variables included gender and science achievement score of previous semester. Moreover, students' views about nature of science include the factors of SINOS (i.e., Tentativeness, Theory-ladenness, Creativity and Imagination, Durability, Coherence and Objectivity, Science for Girls, and Science for Boys).

Results for attitudes towards science

In the first step of hierarchical regression analysis, student gender and previous achievement were incorporated in the analysis. Previous achievement ($\beta = .19$, $p < .05$) positively and significantly predicted students' attitudes towards science while gender ($\beta = -.01$, $p > .05$) was not a significant predictor of the outcome variable. In the next step, SINOS factors (i.e., Tentativeness, Theory-ladenness, Creativity and Imagination, Durability, Coherence and Objectivity, Science for Girls, and Science for Boys) were also incorporated to the model. Among these variables, previous achievement ($\beta = .11$, $p < .05$), Theory-ladenness ($\beta = .30$, $p < .05$) and Science for Girls ($\beta = .42$, $p < .05$) significantly and positively predicted attitudes towards science, while Durability ($\beta = -.12$, $p < .05$) was negatively and significantly related to science attitude. On the other hand, Tentativeness ($\beta = .06$, $p > .05$), Coherence and Objectivity ($\beta = -.04$, $p > .05$), Creativity and Imagination ($\beta = .06$, $p > .05$), Science for Boys ($\beta = .08$, $p > .05$) were not found to be significant predictors of the outcome variable. They explained an additional 32% of the variance in attitudes towards science. The R2 change was statistically significant indicating improvement of the model. Regression coefficients obtained from this analysis are presented in Table 5.

Table 5. *Hierarchical multiple regression analysis predicting science attitude and science value*

	Predicting science attitude			Predicting science value		
	B	*SE* B	β	B	*SE* B	*β*
Step 1						
Constant	2.77	0.16		2.97	0.16	
Gender	-0.01	0.06	-0.01	0.03	0.07	0.03
GPA	0.01	0.00	0.19*	0.01	0.00	0.12*
R^2		0.04			0.02	
Step 2						
Constant	1.28	0.23		1.17	0.24	
Gender	-0.07	0.06	-0.06	-0.02	0.06	-0.01
GPA	0.00	0.00	0.11*	0.00	0.00	0.01
Theory-ladenness	0.26	0.05	0.30*	0.18	0.05	0.20*
Coherence and objectivity	-0.03	0.04	-0.04	-0.01	0.04	-0.02
Creativity and Imagination	0.05	0.06	0.06	0.10	0.06	0.12
Tentativeness	0.05	0.05	0.06	0.18	0.05	0.21*
Durability	-0.08	0.04	-0.12*	-0.06	0.04	-0.08
Science for girls	0.11	0.03	0.21*	0.10	0.03	0.17*
Science for boys	0.05	0.03	0.08	0.04	0.03	0.07
R^2		0.36			0.37	
ΔR^2 for step2		0.32*			0.36*	

*p < .05
Gender coded 0 = Boy, 1 = Girl.

Results for value given to science

In order to predict value given to science, student gender and previous achievement were incorporated in the analysis as the first step. While previous achievement (β = .12, $p < .05$) was found to be positively and significantly related to science value, gender (β = .03, $p > .05$) was not a significant predictor of the outcome variable. In the second step of hierarchical analysis, SINOS factors (i.e., Tentativeness, Theory-ladenness, Creativity and Imagination, Durability, Coherence and Objectivity, Science for Girls, and Science for Boys) were also entered. Results showed that, Theory-ladenness (β = .20, $p < .05$), Tentativeness (β = .21, $p < .05$), and Science for Girls (β = .17, $p < .05$) positively and significantly predicted science value. On the other hand, Creativity and Imagination (β = .12, $p > .05$) Coherence and Objectivity (β = -.02, $p > .05$), Durability (β = -.08, $p > .05$), Science for Boys (β = .07, $p > .05$) were not found to be significant predictors of science value. Additionally, after adding SINOS variables into the model, previous achievement (β = .01, $p > .05$) was not related to science value, any more. SINOS variables explained an additional 36% of the variance in the outcome variable. The R2 change was statistically significant, indicating improvement of the model. Regression coefficients obtained from this analysis are presented in Table 5.

Discussion

One of the purposes of this study was to validate SINOS into Turkish. The confirmatory factor analysis revealed seven-factor structure for Turkish version of SINOS as similar to the original questionnaire developed by Chen et al. (2013). This study is important in terms of providing adaptation and validation of SINOS with Turkish sample. Additionally, SINOS meets the need for a reliable and valid Likert-type NOS scale which can be administered large groups of young students in Turkey. Hereafter it can be used with different samples from Turkey for different research purposes. For example, how NoS views are related to other educational variables can be investigated in future studies.

Secondly, hierarchical regression analyses were conducted to examine predictive effect of SINOS aspects on attitudes toward science and value given to science. After controlling for the influence of previous achievement and gender, theory-ladenness and science for girls were positive predictors while durability was a negative predictor of attitudes towards science. Students who believe that science is influenced from scientists’ previous experiences, backgrounds, beliefs, and other personal values hold more favorable attitudes toward science. Similarly, students who believe that girls may also have a role in science displayed more favorable attitudes toward science. This means that to some extent NoS dimensions measured by SINOS are related to the attitudes toward science. Moreover, Theory-ladenness, Tentativeness, and Science for Girls positively and significantly predicted value given to science after controlling for the influence of previous achievement and gender. Students who think that scientific knowledge is subjective, is subject to change, and girls can contribute to science give more value to science. These findings provided evidence for predictive validity of SINOS.

As pointed out by Chen et al. (2013), the purpose of developing and/or validating SINOS does not undervalue other methods of evaluating students' NoS views such as interviewing or using open-ended instruments, but is an effort to fill the gap these techniques left in science education research. Meeting the requirement of a reliable and valid instrument with Turkish sample, SINOS has a potential for mass assessment of large groups' nature of science views in Turkey. The result of mass assessment of young students' NoS views are important for curriculum developers as well as boards of education executives in Turkey because NoS was set as a goal of science education in national science curricula since 2004. If curriculum developers are not aware of target groups' currents epistemological positions compared to earlier, then, their attempts will be hit-or-miss. Therefore, SINOS may have a particular contribution in terms of giving information about the current status of students regarding NoS. In other words, it may be helpful for stakeholders of science education in terms of reflecting on science curriculum.

To conclude, this study provided evidence for the validity and reliability of Turkish version of SINOS instrument to be used in Turkish context. Moreover, there is evidence that some factors of NoS assessed by SINOS are related to other measurable outcomes such as attitudes toward science and value given to science. As a last word, we need reliable and valid instruments such as SINOS. Because, misconceptions about NoS are unlikely to be replaced unless they are measured, and they are unlikely to be measured unless valid instruments are developed.

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