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Eliciting the Views of Prospective Elementary and Preschool Teachers about the Nature of Science

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Abstract: Recent science education standards emphasize the importance of the instruction of nature of science (NOS) concepts at all levels of schooling from pre-K to K-12. Delivering a proper NOS education to students is excessively dependent on their teachers with an adequate understanding of NOS concepts. The present study investigated the science conceptions of preschool and elementary teacher candidates. The data collected from a total of 506 prospective teachers were analyzed with respect to the following demographic variables: majors, genders, grade levels, high schools and GPAs of teacher candidates. "Student Understanding of Science and Scientific Inquiry (SUSSI)" developed originally by Liang et al. (2008) was the instrument used to collect data in this study. The data analyses were conducted using MANOVA and Pearson Correlation Coefficient. The corresponding mean scores of the teacher candidates in specific aspects of NOS ranged from "poor" to "informed" conceptions of science. All but one of the demographic variables yielded statistically insignificant results on the NOS conceptions of teacher candidates. The majors of the teacher candidates were detected as a significant variable influencing the conceptions of the teacher candidates. The results of the study were discussed in reference with the relevant literature.

Keywords: *Exploratory and confirmatory factor analysis, MANOVA, nature of science conceptions, prospective elementary teachers, prospective preschool teachers.*

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Introduction

Research studies in neuroscience report that the rate of brain development is the highest in the very early years of the childhood (Marope & Kaga, 2015; Thompson & Nelson, 2001). The enormous rate of the brain growth especially from birth to age 5 is nowhere comparable with the later stages of life. Early years also include the critical periods for the physical, linguistic, cognitive, social and emotional growth of children (Karoly, Kilburn, & Cannon, 2005). As opposed to children deprived of adequate amount of sensory stimulus from their environment, children exposed to rich experiences in the early years make a higher number of neural connections in their brains (Shonkoff & Phillips, 2000). Considering the rapid pace of development in the early years of life, high quality experiences offered to young children serve as the building blocks for subsequent learning. There is already a growing consensus that investment made on the early education of children produces the highest return in terms of the economic and social well-beings of the countries (Heckman, 2000). Developed countries all over the world attempt to make the necessary regulations in order to maintain a quality education to the youngsters. In light of the preceding arguments, Turkish policy makers have recently declared their intentions to integrate preschool education as a part of mandatory education.

Recognizing the importance of the early education of children is definitely crucial, yet not sufficient for providing a quality education to youngsters. Recent studies consistently indicate that teacher quality is one of the most effective predictors of student success (Gerritsen, Plug & Webbink, 2016; Harris & Sass, 2011). Therefore, no incentives other than improving the qualifications of teachers in schools would produce the desired outcome in providing a quality education to children (Darling-Hammond, 2000; Huang & Moon, 2009). In enhancing the qualifications of practicing teachers, identifying the strengths and shortcomings of teacher candidates in specific areas would be a good starting point in structuring better strategies in teacher education programs. The present study is dedicated to do this specifically for science education in early childhood.

Young children start school with a great deal of knowledge about the natural world (Kloos et al., 2012). The desire to learn about the natural events is driven by the inherent curiosity in children. However, together with several

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misconceptions about scientific concepts, a variety of erroneous notions of science and scientists finds a fertile ground to grow in the minds of children. According to the results of several research studies conducted utilizing "Draw-a-Scientist Test", scientists are depicted by children stereotypically as an unattractive bold man wearing eyeglasses, using lab coats, and working at a laboratory environment (Losh, Wilke & Pop, 2008; Newton & Newton, 1992; Song & Kim, 1999). The numerous examples of children's immature perceptions of science and scientists in the literature signify that early intervention is necessary to correct the inadequate and inappropriate images of science and scientists held by young children (Akerson et al., 2011). Early education on nature of science (NOS) concepts is highly tenable when an appropriately designed instruction is delivered to children (Akerson & Donnelly, 2010; Bell & Clair, 2015; Quigley, Pongsanon & Akerson, 2010). Children deserve an accurate portrayal of science in order to gain a positive attitude toward science. Several elements of NOS concepts have already been integrated to science education curricula at all grade levels by developed countries. However, there are only a limited number of research studies uncovering NOS conceptions of younger children, especially at pre-K level and identifying the most suitable components of NOS for different grade levels (Bell & Clair, 2015; Leden & Hansson, 2017).

NOS as one of the most important constructs of science education is typically pertinent to "what science is, how it works, the epistemological and ontological foundations of science, how scientists operate as a social group and how society itself both influences and reacts to scientific endeavors" (Clough, 2006, p.463). In the education literature, there is a little disagreement, if any, about the importance of NOS concepts to be a part of science instruction given in the classrooms. On the other hand, no consensus about the genuine character of science exists among scholars from different disciplines in the academia (Lederman, Lederman & Antink, 2013; Wong & Hodson, 2010). The books written historically by the prominent philosophers of science (e.g. Feyerabend, 1975; Kuhn, 1962; Lakatos, 1976; Laudan, 1977; Popper, 1959) were not helpful to end the debates about offering a precise definition of science. No prescriptive framework is available to distinguish science from pseudoscience and non-science, known as the demarcation problem. Scholars' conceptions of science are possible to be classified either as closer to the conservative or the postmodern interpretations of science (Aflalo, 2014; Good & Shymansky, 2001). In spite of a lack of consensus in the academia about the precise definition of science and the demarcation criteria of science from other disciplines, the education community promotes the instruction of a list of NOS concepts thought to be suitable for the cognitive development of K-12 students (Bell & Clair, 2015; Lederman, Antink, & Bartos, 2014; Mesci & Schwartz, 2017). Although the list is by no means absolute, it is generally comprised of the following seven aspects of NOS: 1) Scientific knowledge is validated through empirical data. 2) Scientific knowledge is durable, yet always open to change. 3) Scientific knowledge is affected by the theoretical perspectives held by scientists. 4) Creativity and imagination play an important role in the production of scientific knowledge. 5) The social and cultural values of the society have an influence on scientific knowledge. 6) Scientific theories are not premature laws of nature. 7) A universal scientific method used by all scientific disciplines is nonexistent (Abd-El-Khalick, 2012; Lederman, 2006). The preceding aspects of NOS are called as "the consensus view" of NOS and adopted extensively by science educators in their instructions (Irzik & Nola, 2011).

The consensus list of NOS concepts has for some time been acknowledged as a norm in science education community. On the other hand, it seems that there has recently been an increasing tone of criticism directed towards the use of the consensus view as a pedagogical framework to design the instruction of NOS (e.g. Allchin, 2017; Eflin, Glennan & Reisch, 1999; Erduran & Dagher, 2014; Hodson & Wong, 2017; Irzik & Nola, 2011; Matthews, 2012; van Dijk, 2011). Despite the fact that a comprehensive discussion of the limitations of the consensus view is beyond the scope of this study, it is sufficient to mention here that the consensus view is criticized in terms of its failure to present a broader picture of science, to reflect the distinct characteristics of the various scientific disciplines, and to represent a systematic integrity among the items of the consensus list (Irzik & Nola, 2011). As an alternative to consensus view of science, another perspective named "Family Resemblance Approach (FRA)" is defended recently by some of the scholars as a "more comprehensive and systematic" (Irzik & Nola, 2011, p.593) account of NOS, which encompasses both domain-general and domain-specific characteristics of science, to be presented to students (e.g. Dagher & Erduran, 2016; Irzik & Nola, 2014). FRA was first introduced to the discipline of philosophy by Wittgenstein (1958) and popularized in science education by Irzik & Nola (2011). FRA conceptualizes science as a cognitive-epistemic and social-institutional system and offers a pedagogically more holistic and contextualized way of articulating NOS concepts (Irzik & Nola, 2014). Whereas cognitive-epistemic aspects of science cover "processes of inquiry, aims and values, methods and methodological rules, and scientific knowledge" (Erduran & Dagher, 2014, p.20), social-institutional aspects of science include "professional activities, scientific ethos, social certification and dissemination of scientific knowledge, and social values" (Erduran & Dagher, 2014, p.20). It is difficult today to predict the curricular effects of the new pedagogical approaches offered in the literature about NOS concepts as an alternative to the consensus view of NOS. The consensus view of NOS still maintains its dominant character in shaping the science education reform documents all over the world.

Without employing effective teaching strategies, helping students grasp a sound understanding of NOS concepts is nothing more than a futile effort. In science education literature, the instruction of the specific aspects of NOS is agreed to be delivered best by an explicit-reflective manner (Abd-El-Khalick & Akerson, 2009; Khishfe, 2013; McDonald, 2010; Quigley, Pongsanon & Akerson, 2010; Schwartz & Lederman, 2002). Instead of expecting students to gain a desired understanding of NOS concepts as a by-product of their engagement with scientific inquiry activities, explicit teaching approach involves designing instructional activities deliberately to make direct connections with the relevant aspects of NOS. It is imperative here to note that the phrase explicit in this context is free from any connotations of delivering NOS concepts through a direct or didactic instruction. Following the explicit instruction, reflections made by students through discussing the meaning of NOS concepts support them to internalize the specific experiences offered to them in the relevant activities.

In recent science education programs all over the world, teachers are expected to help their students learn not only the content knowledge of science but also NOS concepts (Irzik & Nola, 2011). The science education standards at all grade levels include several benchmarks about NOS for teachers to teach in their lessons. A successful instruction of NOS concepts is contingent upon the competency of teachers in helping their students engage with the appropriate activities targeting the specific aspects of NOS. However, having an inadequate education about NOS is a reality for a considerable number of teachers in schools (Karaman, 2017; Posnanski, 2010; Wong & Hodson, 2008). This situation constitutes a big hindrance for NOS concepts to be instructed to students as an important educational outcome in all levels of schooling from preK to K-12. Considering their relatively less exposure to science topics in their undergraduate education, preschool and elementary teachers are probably more vulnerable when it comes to introducing their students to a realistic image of science. It is not a secret that science is not regarded as their favorite subject by a considerable number of preschool and elementary teacher candidates (Abramzon, Saccoman & Hoeling, 2017; Akerson, 2004; Cobern & Loving, 2002; Luttrell & Crocker, 1990; Wilkins, 2010). There is no doubt that negative attitudes of teacher candidates towards science subjects are driven partly by their inaccurate images of science. How elementary and preschool teacher candidates view science is the major question investigated in this research study. This question is worth investigating because determining the conceptions of prospective teachers about science has the potential to shed light on our efforts to assist teachers to gain a better understanding of NOS concepts. Unlike an ample number of research studies investigated the NOS conceptions of pre-service and in-service middle and secondary school teachers, there are only a few number of studies conducted at the early childhood (from pre-K to K3) level (Akerson, Buzzelli & Donnelly, 2010). The present study promises to uncover the views of preschool and elementary teacher candidates about science in connection with the several demographic variables.

The main research question investigated in this study was as follows: How informed are teacher candidates about NOS concepts? The following sub-questions inquiring in the effect of several demographic variables on NOS conceptions of teacher candidates supported the main research question:

1. What are the views of prospective teachers in each specific aspect of NOS?
2. Is there any significant difference between NOS conceptions of prospective teachers with regard to their majors?
3. Is there any significant difference between NOS conceptions of prospective teachers with regard to their genders?
4. Are there any significant differences among NOS conceptions of prospective preschool teachers with regard to their grade levels?
5. Are there any significant differences among NOS conceptions of prospective elementary teachers with regard to their grade levels?
6. Are there any significant differences among NOS conceptions of prospective teachers with regard to the type of high school from which they graduated?
7. Is there any significant relationship between NOS conceptions and GPAs of prospective teachers?

Research Methodology

Survey research methodology was adopted in this study to investigate NOS conceptions of teacher candidates. Survey research is conducted widely in social science research studies in order to identify the certain characteristics of a population inferred from a representative sample (Fraenkel, Wallen & Hyun, 2011). Preschool and elementary teacher candidates studying in all of the Turkish universities were determined as the target population of the study. However, due to the convenience sampling technique used in the study, the accessible population of the study was restricted to teacher candidates enrolled in the preschool and elementary teacher education programs in a Turkish university. The sample used in the study included a total of 504 prospective teachers, 223 of whom were preschool teacher candidates and 281 of whom were elementary teacher candidates, attending a Turkish university located on the shores of Black Sea.

Data Collection

Data were collected from preschool and elementary teacher candidates using an instrument entitled "Student Understanding of Science and Scientific Inquiry (SUSSI)" developed originally by Liang et al. (2008). The instrument consisted of the following six aspects of NOS: 1) Observations and Inferences, 2) Change of Scientific Theories, 3) Scientific Laws vs. Theories, 4) Social and Cultural Influence on Science, 5) Imagination and Creativity in Scientific Investigations, and 6) Methodology of Scientific Investigation. Each aspect of the instrument included four Likert-type items and one open-ended item. The original instrument was, therefore, comprised of 24 Likert-type items and 6 open-ended items. SUSSI instrument was delivered to teacher candidates in a paper-and-pencil format. The participants were instructed properly that the author needed their most sincere responses without judging their answers as being right or wrong. The instructions given to the participant teacher candidates helped increase the likelihood of gaining their most accurate conceptions of science.

The items in the instrument were translated to Turkish language by the author. The corrections recommended by two bilingual scholars were handled properly in order to enhance the precision of the translated items in the instrument. Only Likert-type items were selected to be used in this research study. That was primarily because the main purpose of the study was determined to be making certain generalizations about NOS conceptions of prospective teachers and investigating the effects of some demographic variables on their conceptions rather than gaining an in-depth understanding of their NOS conceptions. Likert-type items were thought to be more appropriate to fulfill the aforementioned objectives.

Psychometric Properties of Data Collection Instrument

Psychometric properties (construct validity and internal consistency) of the instrument were examined in order to ensure the validity and reliability of the results. Construct validity of the results was tested via Principle Component Analysis (PCA) and Confirmatory Factor Analysis (CFA). Internal consistency of the results was investigated through Cronbach Alpha (α) Coefficient and McDonald's Omega (ω) Coefficient.

The value of Kaiser-Meyer-Olkin (KMO) as a measure of sampling adequacy in order to administer PCA was calculated as 0.687. The larger value of this figure than 0.5 indicated that the number of participants in the research study was adequate to conduct PCA. The statistically significant value of Barlett's Test of Sphericity [$\chi^2(136)=2147.667$, $p<0.001$] indicated that the correlations between the items were large enough to employ PCA. The results obtained from PCA were presented in Table 1.

Table 1. Principle Component Analysis of the SUSSI Instrument

Items	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Eigenvalues	% of Variance
Item 1A	0.650						2.234	13.140
Item 1B	0.799							
Item 1C	0.766							
Item 1D	0.568							
Item 2A		0.698					1.910	11.238
Item 2B		0.786						
Item 2C		0.748						
Item 3C			0.700				1.059	6.229
Item 3D			0.797					
Item 4B				0.886			1.489	8.759
Item 4C				0.876				
Item 5A					0.754		3.197	18.805
Item 5B					0.780			
Item 5C					0.830			
Item 5D					0.833			
Item 6A						0.749	1.165	6.854
Item 6B						0.830		
								Total Variance
								65.026

In reference to Kaiser's criterion of 1, six factors, each of which had eigenvalues greater than 1, were extracted to form the adapted instrument. Visual inspection via the scree plot revealed the six factorial structure of the instrument as well. A total of 17 items, each of which loaded only on a single factor and had factor loadings higher than 0.35, were retained in the adapted instrument. The six factors were accountable for 65.026 percent of the total variance in the adapted instrument. The corresponding percentages of variances explainable by each factor was as follows respectively: 13.140 %, 11.238 %, 6.229 %, 8.759 %, 18.805 %, and 6.854 %.

The next step in testing the construct validity of the instrument involved exposing the model constructed from PCA to CFA. In other words, the six factorial structure of the model devised from PCA was subjected to CFA in order to verify its goodness of fit to actual data collected from a sample of teacher candidates. In addition to the path coefficients (factor loadings) of the observed variables (items), Figure 1 illustrates the correlations between the latent variables (factors) in the instrument.

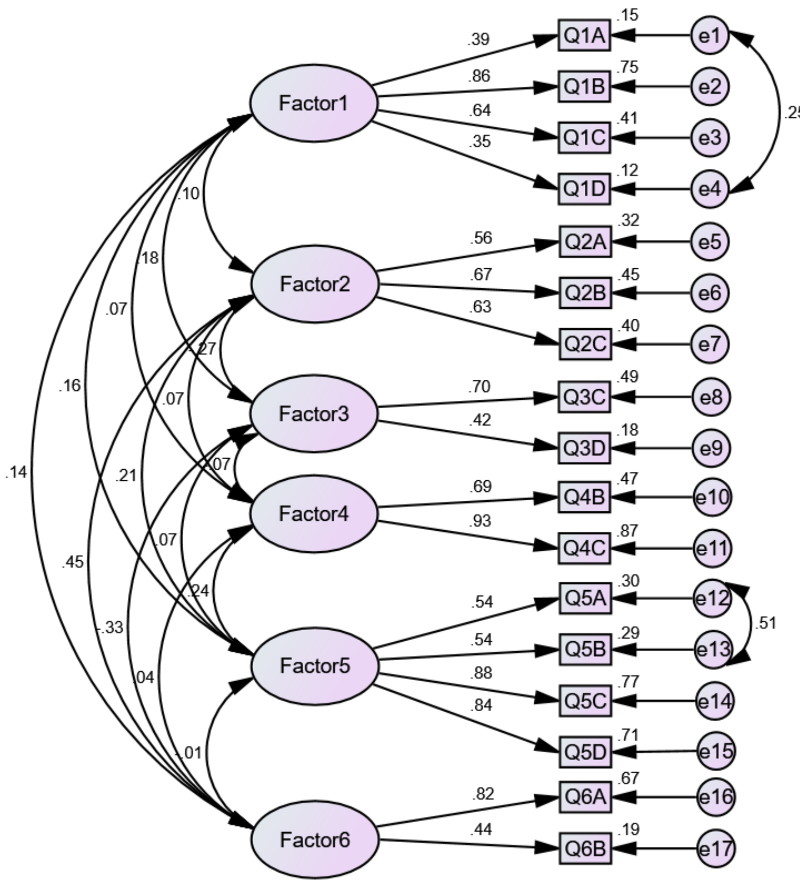

Figure 1. CFA Results: Path Diagram of the SUSSI Instrument

According to Figure 1, the correlations between the latent variables (factors) range from -0.33 to +0.45. Any values of correlation coefficients greater than 0.8 might be an alert of multicollinearity between the two factors, in that, both of the factors measure exactly the same construct. The relatively lower values of the correlations between the factors in this study signify that the factors are somewhat related, yet not measuring a completely identical construct. This is an expected result since the factors represent the distinct aspects of NOS concepts. Regression weights (factor loadings) range from 0.35 to 0.86 for the four observed variables (items) on factor 1, 0.56 to 0. 67 for the three observed variables (items) on factor 2, 0.54 to 0.88 for the four observed variables (items) on factor 5. Regression weights are 0.42 and 0.70 for the two observed variables on factor 3, 0.69 and 0.93 for the two observed variables on factor 4, and 0.44 and 0.82 for the two observed variables on factor 6. All of the regression weights (factor loadings) unconstrained to 1 in the study were found to be statistically significantly higher than zero ($p < 0.001$). The squared multiple correlation coefficients (R^2) attached to the upper right hand corner of the observed variables (items) in Figure 1 indicate the amount of variance in an observed variable (item) accountable for by its corresponding latent variable (factor). For instance, 75 % of the variance in item Q1B was explainable by Factor 1. The remaining 25 % of the variance in item Q1B was attributable to the error term e2 (unique aspects of the item) or measurement error.

Several goodness-of-fit indices were provided in order to examine the level of fit between the proposed model and the actual data. In order to improve the model fit, modification indices (MI) were checked and the error terms (e1-e4 and e12-e13) belonging to the items of the same factor were connected via covariance arrows. The obtained values of the fit indices and their corresponding threshold values supported with the references from the literature were presented in Table 2.

Table 2. CFA Results: Goodness-of-Fit Indices

GOODNESS-OF-FIT INDICES			
FIT INDEX CATEGORY Hooper, Coughlan & Mullen (2008)	MODEL FIT INDEX	OBTAINED VALUE	ACCEPTABLE THRESHOLD VALUE
Absolute Fit Indices	Chi-Square (χ^2)**	251.635 (df=102)	p < 0.05 Poor Model Fit Brown (2015); Kline (2011)
	Chi-Square / Degrees of Freedom (χ^2/df)	2.467	χ^2/df < 3 Good model fit Hoe (2008); Kline (2011); Schreiber et al. (2006)
	Root Mean Square Residual (RMR)	0.068	RMR < 0.08 Good model fit Hu & Bentler (1999); Tabachnick & Fidell (2013)
	Standardized Root Mean Square Residual (SRMR)	0.060	SRMR < 0.08 Good model fit Hu & Bentler (1999); Tabachnick & Fidell (2013)
	Root Mean Square Error of Approximation (RMSEA)	0.054	RMSEA < 0.06 Good model fit Brown (2015); Hu & Bentler (1999)
	RMSEA (90 % Confidence Interval)	0.046-0.062	RMSEA (90 %) < 0.06 to 0.08 Good model fit Schreiber et al. (2006)
	Goodness-of-Fit Index (GFI)	0.944	0.90 < GFI < 0.95 Acceptable model fit Hooper, Coughlan & Mullen (2008)
	Adjusted Goodness-of-Fit Index (AGFI)	0.916	0.90 < AGFI < 0.95 Acceptable model fit Hooper, Coughlan & Mullen (2008)
Incremental or Comparative Fit Indices	Comparative Fit Index (CFI)	0.927	0.90 < CFI < 0.95 Acceptable model fit Brown (2015); Hoe (2008)
	Normed Fit Index (NFI)	0.884	NFI < 0.90 Poor model fit Bentler & Bonnet (1980)
	Non-normed Fit Index (NNFI) or Tucker-Lewis Index (TLI)	0.902	0.90 < TLI < 0.95 Acceptable model fit Brown (2015); Hoe (2008)
Parsimony Correction Fit Indices	Parsimony Goodness-of-Fit Index (PGFI)	0.629	No threshold value specified but closer to 1 is better fit. If other fit indices > 0.90, PGFI closer to 0.5 is possible. Mulaik et al. (1989)
	Parsimonious Normed Fit Index (PNFI)	0.663	No threshold value specified but closer to 1 is better fit. If other fit indices > 0.90, PNFI closer to 0.5 is possible. Mulaik et al. (1989)

**significant at α=0.01

There is no consensus in the literature about which fit indices should be reported and what cutoff values should be obeyed in order to verify an acceptable or a good model fit (Brown, 2015; Kline, 2011). Researchers are, in general, recommended to report a couple of different goodness-of-fit indices, at least one from each fit class (absolute, comparative and parsimony), in their research studies because each one offers an additional information about the fit of the model (Brown, 2015; Harrington, 2009). However, none of the threshold values suggested for fit indices in the literature is supposed to be treated as a “golden rule” (Kline, 2011, 197). Good or acceptable values of the vast majority of the various fit indices reported in a specific study might be interpreted as an indication of good or acceptable model fit (Schreiber et al., 2006). As suggested in the literature, several different fit indices in this study were presented in Table 2. Acceptable or good threshold values of the fit indices in Table 2 were supported with the references retrieved from the relevant literature. The vast majority of the fit indices provided in Table 2 corresponded to either good or acceptable model fit. Only the values of the two fit indices (Chi-Square Test and Normed Fit Index) was found to be outside the acceptable limits of the model fit. Due to the fact that the chi-square test is very sensitive to the sample size, having a significant result, which is a sign of poor fit, is highly probable with large samples (Harrington, 2009). The significant result [$\chi^2(102)=251.635$, $p=0.001$] found in this study might be due to the considerably large sample size. Researchers devised another fit index (χ^2/df) to minimize the effect of the sample size. The value of (χ^2/df) in this study was calculated as 2.467, which corresponded to a good model fit due to its smaller value than 3 (Kline, 201; Schreiber et al., 2006). Another fit index found to be problematic in this study was Normed Fit Index (NFI). The greater values of Normed Fit Index (NFI) than 0.90 is usually considered as acceptable model fit in the literature (Bentler & Bonnet, 1980). Despite very closer to the acceptable range of NFI, its value (0.884) in this study represented a poor model fit. However, the higher number of the fit indices with acceptable or good levels of model fit in the study might be considered as the verification of the construct validity of the adapted instrument.

After verifying the construct validity of the instrument, internal consistency was tested via Cronbach Alpha and McDonald's Omega coefficients. Table 3 illustrates the reliability coefficients for both original and adapted instrument.

Table 3. Coefficients for Internal Consistency of the Instrument

ASPECTS OF NOS	ORIGINAL VALUE Cronbach Alpha (α)	ADAPTED VALUE Cronbach Alpha (α)	ADAPTED VALUE McDonald's Omega (ω)
Factor-1 (Observations and Inferences)	0.61	0.67	0.68
Factor-2 (Change of Scientific Theories)	0.56	0.65	0.65
Factor-3 (Scientific Laws vs. Theories)	0.48	0.46	0.46
Factor-4 (Social and Cultural Influence on Science)	0.64	0.78	0.78
Factor-5 (Imagination and Creativity in Scientific Investigations)	0.89	0.82	0.83
Factor-6 (Methodology of Scientific Investigation)	0.44	0.52	0.53
Overall Instrument	0.69	0.68	0.82

In Table 3, the following two reliability coefficients were used in examining the internal consistency of the adapted instrument: Cronbach Alpha (α) and McDonald's Omega (ω). Whereas Cronbach Alpha (α) is precise enough in reporting the internal consistency of the unidimensional scales, it usually underestimates the overall reliability value of the multidimensional scales. Cronbach Alpha assumes the identical factor loadings (Tau Equivalence) among the items in a specific factor. McDonald's Omega provides a more accurate value of the reliability coefficient for multidimensional instruments. While SPSS software was employed in calculating Cronbach Alpha (α) coefficients, R Statistics program was used in determining McDonald's Omega (ω) coefficients. The values of the reliability coefficients of the subscales are recommended to be more than 0.5 for an acceptable level of internal consistency. In Table 3, none of the figures except Factor 3 (Scientific Laws vs. Theories) are below 0.5, which signifies the reliability of these subscales of the instrument. Although the reliability coefficient of Factor 3 ($\alpha=0.46$) is a little less than 0.5, it is almost identical to this subscale's original value ($\alpha=0.48$) calculated by Liang et al. (2008). When it comes to the overall reliability of the adapted instrument, the figure ($\omega=0.82$) is pretty satisfactory for social science research purposes.

Data Analysis

The data analysis was conducted using Multivariate Analysis of Variance (MANOVA) statistical test and Pearson Correlation Coefficient. Teaching disciplines, genders, and university grade levels of the teacher candidates were defined as the independent variables of the MANOVA statistical test. Pearson Correlation Coefficient was calculated in order to investigate whether any statistically significant relationship exists between the teacher candidates' Grade Point Averages (GPAs) and NOS mean scores.

Study Results

Starting with Table 4, the specific findings of the research study will be presented in this section of the article. Table 4 displays the overall mean scores of the teacher candidates, which provides an insight about how knowledgeable prospective teachers are in specific aspects of NOS.

Table 4. Overall Mean Scores of the Teacher Candidates

ASPECTS OF NOS	N	MEAN	SD
Factor-1 (Observations and Inferences)	504	3.724	0.772
Factor-2 (Change of Scientific Theories)	504	4.267	0.690
Factor-3 (Scientific Laws vs. Theories)	504	2.078	0.772
Factor-4 (Social and Cultural Influence on Science)	504	3.235	1.051
Factor-5 (Imagination and Creativity in Scientific Investigations)	504	3.170	1.105
Factor-6 (Methodology of Scientific Investigation)	504	4.473	0.629

As presented in Table 4, the prospective teachers achieved the highest mean score (M=4.473) in "Factor-6 (Methodology of Scientific Investigation)". The lowest mean score (M=2.078) was obtained by the teacher candidates in "Factor-3 (Scientific Laws vs. Theories)". The figures in Table 4 indicate that the notions of the teacher candidates about NOS concepts exhibited a diversity ranging from poor to informed levels of comprehension. This suggests that teacher candidates demand more support in select aspects of NOS than some others.

Table 5 presents the multivariate analysis of the mean scores of the prospective teachers with respect to their specific majors.

Table 5. Multivariate Analysis with Respect to Majors of Teacher Candidates

F(6, 497)=6.004, p=0.001; Wilks' Lambda=0.932; Partial Eta Squared=0.068

ASPECTS OF NOS	MAJOR	N	MEAN	SD	UNIVARIATE F-STATISTICS	PARTIAL ETA SQUARED
Factor-1 (Observations and Inferences)	PT	223	3.789	0.845	F(1, 502)=2.798; p=0.095	0.006
	ET	281	3.673	0.707		
Factor-2 (Change of Scientific Theories)	PT	223	4.303	0.655	F(1, 502)=1.097; p=0.295	0.002
	ET	281	4.238	0.717		
Factor-3 (Scientific Laws vs. Theories)**	PT	223	2.251	0.718	F(1, 502)=21.006; p=0.001	0.04
	ET	281	1.940	0.787		
Factor-4 (Social and Cultural Influence on Science)*	PT	223	3.121	1.058	F(1, 502)=4.757; p=0.030	0.009
	ET	281	3.326	1.038		
Factor-5 (Imagination and Creativity in Scientific Investigations)*	PT	223	3.050	1.129	F(1, 502)=4.682; p=0.031	0.009
	ET	281	3.264	1.078		
Factor-6 (Methodology of Scientific Investigation)	PT	223	4.493	0.584	F(1, 502)=0.381; p=0.537	0.001
	ET	281	4.458	0.663		

*Significant at α=0.05, **Significant at α=0.01

PT=Preschool teacher candidates, ET=Elementary teacher candidates

Table 5 demonstrates that a multivariate analysis of the mean scores of the prospective teachers with respect to their majors yielded a statistically significant difference [F(6, 497)=6.004, p=0.001; Wilks' Lambda=0.932; Partial Eta Squared=0.068]. The preschool teacher candidates obtained significantly higher mean scores than the elementary teacher candidates in Factor-3 (Scientific Laws vs. Theories). In Factor-4 (Social and Cultural Influence on Science) and Factor-5 (Imagination and Creativity in Scientific Investigations), the elementary teacher candidates outperformed their preschool peers.

Table 6 illustrates the multivariate analysis of the mean scores of the prospective teachers with respect to their genders.

Table 6. Multivariate Analysis with Respect to Genders of Teacher Candidates

F(6, 497)=0.679, p=0.649; Wilks' Lambda=0.992; Partial Eta Squared=0.008

ASPECTS OF NOS	GENDER	N	MEAN	SD	UNIVARIATE F-STATISTICS
Factor-1 (Observations and Inferences)	F	398	3.729	0.784	F(1, 502)=0.058; p=0.810
	M	106	3.708	0.733	
Factor-2 (Change of Scientific Theories)	F	398	4.268	0.694	F(1, 502)=0.003; p=0.957
	M	106	4.263	0.682	
Factor-3 (Scientific Laws vs. Theories)	F	398	2.071	0.778	F(1, 502)=0.147; p=0.702
	M	106	2.103	0.756	
Factor-4 (Social and Cultural Influence on Science)	F	398	3.215	1.062	F(1, 502)=0.717; p=0.398
	M	106	3.312	1.009	
Factor-5 (Imagination and Creativity in Scientific Investigations)	F	398	3.126	1.133	F(1, 502)=3.016; p=0.083
	M	106	3.335	0.983	
Factor-6 (Methodology of Scientific Investigation)	F	398	4.484	0.621	F(1, 502)=0.532; p=0.466
	M	106	4.434	0.658	

F=Female, M=Male

According to the results in Table 6, gender made no statistically significant multivariate effect [F(6, 497)=0.679, p=0.649; Wilks' Lambda=0.992] on NOS conceptions of the teacher candidates. In other words, male and female teacher candidates appeared to have a similar pattern in their conceptualization of NOS concepts.

The analysis of the mean scores of the teacher candidates in regard to their grade levels was administered separately for preschool and elementary teacher candidates. Table 7 shows the multivariate analysis of the mean scores of the preschool teacher candidates with respect to their grade levels.

Table 7. Multivariate Analysis with Respect to Grade Levels of Preschool Teacher Candidates

F(18, 605.769)=1.499, p=0.084; Wilks' Lambda=0.884; Partial Eta Squared=0.040

ASPECTS OF NOS	GRADE	N	MEAN	SD	UNIVARIATE F-STATISTICS
Factor-1 (Observations and Inferences)	First	59	3.644	1.008	F(3, 219)=2.338; p=0.074
	Second	51	3.727	0.856	
	Third	62	3.763	0.768	
	Fourth	51	4.049	0.665	
Factor-2 (Change of Scientific Theories)	First	59	4.354	0.708	F(3, 219)=2.071; p=0.105
	Second	51	4.222	0.621	
	Third	62	4.188	0.663	
	Fourth	51	4.464	0.589	
Factor-3 (Scientific Laws vs. Theories)	First	59	2.186	0.754	F(3, 219)=1.116; p=0.343
	Second	51	2.265	0.751	
	Third	62	2.379	0.745	
	Fourth	51	2.157	0.596	
Factor-4 (Social and Cultural Influence on Science)	First	59	3.054	1.147	F(3, 219)=2.782; p=0.042
	Second	51	2.833	1.052	
	Third	62	3.177	1.044	
	Fourth	51	3.416	0.910	

Table 7. Continued

ASPECTS OF NOS	GRADE	N	MEAN	SD	UNIVARIATE F-STATISTICS
Factor-5 (Imagination and Creativity in Scientific Investigations)	First	59	2.844	1.122	F(3, 219)=2.120; p=0.099
	Second	51	2.992	1.218	
	Third	62	3.030	1.028	
	Fourth	51	3.372	1.126	
Factor-6 (Methodology of Scientific Investigation)	First	59	4.568	0.598	F(3, 219)=1.571; p=0.197
	Second	51	4.480	0.616	
	Third	62	4.368	0.620	
	Fourth	51	4.569	0.469	

According to Table 7, no statistically significant multivariate effect [F(18, 605.769)=1.499, p=0.084; Wilks' Lambda=0.884] was detected among the grade levels of preschool teacher candidates. This finding is a kind of sign that no significant changes occur in teacher candidates' notions of science as they go through their education in the preschool program.

Table 8 presents the multivariate analysis of the mean scores of the elementary teacher candidates with respect to their grade levels.

Table 8. Multivariate Analysis with Respect to Grade Levels of Elementary Teacher Candidates

F(18, 769.817)=1.264, p=0.204; Wilks' Lambda=0.921; Partial Eta Squared=0.027

ASPECTS OF NOS	GRADE	N	MEAN	SD	UNIVARIATE F-STATISTICS
Factor-1 (Observations and Inferences)	First	57	3.711	0.793	F(3, 277)=0.194; p=0.900
	Second	102	3.689	0.684	
	Third	75	3.623	0.681	
	Fourth	47	3.672	0.704	
Factor-2 (Change of Scientific Theories)	First	57	4.253	0.688	F(3, 277)=1.702; p=0.167
	Second	102	4.335	0.745	
	Third	75	4.090	0.751	
	Fourth	47	4.245	0.610	
Factor-3 (Scientific Laws vs. Theories)	First	57	1.818	0.749	F(3, 277)=1.803; p=0.147
	Second	102	1.882	0.830	
	Third	75	1.980	0.790	
	Fourth	47	2.148	0.708	
Factor-4 (Social and Cultural Influence on Science)	First	57	3.309	1.043	F(3, 277)=0.082; p=0.970
	Second	102	3.347	1.104	
	Third	75	3.284	1.049	
	Fourth	47	3.367	0.881	
Factor-5 (Imagination and Creativity in Scientific Investigations)	First	57	3.021	1.174	F(3, 277)=2.804; p=0.040
	Second	102	3.364	1.114	
	Third	75	3.133	1.068	
	Fourth	47	3.553	0.796	
Factor-6 (Methodology of Scientific Investigation)	First	57	4.474	0.741	F(3, 277)=1.970; p=0.119
	Second	102	4.555	0.543	
	Third	75	4.424	0.743	
	Fourth	47	4.279	0.643	

According to Table 8, there is no statistically significant multivariate difference [F(18, 769.817)=1.264, p=0.204; Wilks' Lambda=0.921] among the mean values of elementary teacher candidates' NOS scores. Similar to preschool teacher candidates, elementary teacher candidates exhibited an insignificant progress from one grade level to another in their teacher education programs.

The results of a multivariate analysis of the mean scores of the teacher candidates are displayed in Table 9.

Table 9. Multivariate Analysis with Respect to High Schools of Teacher Candidates

F(18, 1375.101)=1.521, p=0.074; Wilks' Lambda=0.946; Partial Eta Squared=0.018

ASPECTS OF NOS	HIGH SCHOOL	N	MEAN	SD	UNIVARIATE F-STATISTICS
Factor-1 (Observations and Inferences)	NHS	113	3.621	0.755	F(3, 491)=1.680; p=0.170
	AHS	214	3.707	0.761	
	VHS	111	3.784	0.810	
	ATHS	57	3.877	0.781	
Factor-2 (Change of Scientific Theories)	NHS	113	4.193	0.706	F(3, 491)=1.034; p=0.377
	AHS	214	4.259	0.709	
	VHS	111	4.292	0.669	
	ATHS	57	4.384	0.636	
Factor-3 (Scientific Laws vs. Theories)	NHS	113	2.061	0.757	F(3, 491)=4.357; p=0.005
	AHS	214	1.970	0.751	
	VHS	111	2.293	0.773	
	ATHS	57	2.114	0.840	
Factor-4 (Social and Cultural Influence on Science)	NHS	113	3.294	0.977	F(3, 491)=2.199; p=0.087
	AHS	214	3.274	1.045	
	VHS	111	3.035	1.131	
	ATHS	57	3.426	1.002	
Factor-5 (Imagination and Creativity in Scientific Investigations)	NHS	113	3.206	1.041	F(3, 491)=0.292; p=0.831
	AHS	214	3.151	1.088	
	VHS	111	3.096	1.188	
	ATHS	57	3.240	1.122	
Factor-6 (Methodology of Scientific Investigation)	NHS	113	4.463	0.593	F(3, 491)=0.038; p=0.990
	AHS	214	4.485	0.626	
	VHS	111	4.467	0.604	
	ATHS	57	4.474	0.776	

NHS=Normal High School, AHS=Anadolu High School, VHS=Vocational High School, ATHS=Anadolu Teacher High School

The multivariate analysis with respect to the high schools of teacher candidates in Table 9 produced no statistically significant difference [F(18, 1375.101)=1.521, p=0.074; Wilks' Lambda=0.946], which indicates that the specific high schools of the teacher candidates were ineffective in their conceptions of NOS.

Pearson correlation coefficients in each specific aspects of NOS were calculated to investigate the correlational relationship between GPAs and NOS scores of the teacher candidates. The results were presented in Table 10.

Table 10. Correlational Analysis between GPAs and NOS Scores of Teacher Candidates

ASPECTS OF NOS	N	CORRELATION	SIGNIFICANCE
Factor-1 (Observations and Inferences)	293	r=0.024	p=0.688
Factor-2 (Change of Scientific Theories)	293	r=0.038	p=0.516
Factor-3 (Scientific Laws vs. Theories)	293	r=0.065	p=0.267
Factor-4 (Social and Cultural Influence on Science)	293	r=0.038	p=0.516
Factor-5 (Imagination and Creativity in Scientific Investigations)	293	r=0.044	p=0.455
Factor-6 (Methodology of Scientific Investigation)	293	r=-0.008	p=0.886
Overall Instrument	293	r=0.074	p=0.208

None of the correlation coefficients in Table 10 yielded a statistically significant result, which implied that school success had no direct relationship with prospective teachers' comprehension of NOS concepts.

Discussions, Conclusions and Implications

Helping students develop accurate conceptions of science from their younger ages is feasible only through supplying classrooms with competent teachers about NOS concepts (Akerson, Buzzelli, & Donnelly, 2010). How informed are preschool and elementary teacher candidates about NOS concepts, which is compatible with the contemporary interpretations of science? The overall mean scores of the teacher candidates in this study indicated that their grasp of NOS concepts exhibited variations from one aspect of NOS to another. They achieved relatively high scores in the following aspects of NOS: Factor-1 (Observations and inferences), Factor-2 (Change of scientific theories), and Factor-6 (Methodology of scientific investigation). Their scores corresponded to a mediocre result in the following aspects of NOS: Factor-4 (Social and cultural influence on science) and Factor-5 (Imagination and creativity in scientific investigations). They scored poorly in Factor-3 (Scientific laws vs. theories). These results imply that the teacher candidates were not necessarily in need of support in all but only select aspects of NOS. It seems that the participant teacher candidates had a lack of prior reflections on these select aspects of NOS (Factor-3, Factor-4 and Factor-5). A closer look into these specific aspects of NOS reveals that the participant teacher candidates failed to recognize the distinctions between scientific laws and theories, the influence of social and cultural factors on scientific research, and the significance of imagination and creativity in scientific investigations. The naïve conceptions of the participant teacher candidates in these aspects of NOS are not at odd with the several number of research studies reporting inadequate NOS conceptions of pre-service and in-service teachers (e.g. Abd-El-Khalick & Akerson, 2009; Herman, Clough, & Olson, 2015). Statistically insignificant differences among NOS scores of the teacher candidates from first to fourth grade in this study indicate that the situation gets no better as they progress through higher grades in teacher education programs. In other words, teacher education programs fall short of giving an adequate education to preschool and elementary teacher candidates about NOS concepts. Other than science teacher education programs, no course completely devoted to NOS is offered to student teachers in preschool and elementary teacher education programs. Preschool and elementary prospective teachers are usually engaged with limited experiences, if any, about NOS concepts in science method courses. Indeed, this is not exclusive to the Turkish teacher education programs. The vast majority of teachers in developed countries graduate from teacher education programs without enrolling even a single course dedicated completely to NOS concepts (Aflalo, 2014; Backhus & Thompson, 2006; Herman & Clough, 2014). Although the benchmarks related to NOS concepts are becoming an essential part of science education standards at all grade levels all over the world, method courses seem to be far from helping teacher candidates develop a comprehensive understanding of the specific aspects of NOS and gain the necessary pedagogical skills to engage their students with NOS concepts (Akerson, Morrison, & McDuffie, 2006).

Is teaching discipline a significant variable affecting science conceptions of teacher candidates? According to the results of this study, the answer is affirmative only when we focus on the certain aspects of NOS. In that, a statistically significant difference was detected between the conceptions of the preschool and elementary teacher candidates in the following three aspects of NOS: Factor-3 (Scientific Laws vs. Theories), Factor-4 (Social and Cultural Influence on Science) and Factor-5 (Imagination and Creativity in Scientific Investigations). While the preschool teacher candidates scored statistically higher than the elementary teacher candidates in Factor-3, the case was completely reverse in Factor-4 and Factor-5. In fact, neither the preschool nor the elementary teacher candidates obtained the satisfactory mean scores in the preceding aspects of NOS. With regard to the distinction between the scientific laws and theories, the preschool teacher candidates seem to be relatively more knowledgeable than the elementary teacher candidates. The elementary teacher candidates had a higher recognition than their preschool peers to the involvement of social and cultural factors in science and the role of imagination and creativity in scientific knowledge. Although providing a readily available answer to the reasons of the observed difference between the conceptions of the preschool and the elementary teacher candidates is an uneasy task, one possible explanation might have something to do with their educational backgrounds shaped primarily by their respective teacher preparation programs. One might intuitively assume that having a stronger background in science leads to developing informed views of science, which are compatible with the contemporary interpretations of science. However, this is not necessarily the case at all according to the results of several research studies (Karaman & Apaydin, 2014). For instance, in comparing the conceptions of scientists, secondary science teachers and elementary teachers about NOS, Pomeroy (1993) concluded that the scientists adopted significantly more traditional views of science than both the secondary and elementary teachers. In addition, the elementary teachers held significantly more nontraditional views of science than the secondary science teachers. Liu and Tsai (2008) investigated the scientific epistemological views of freshmen college students and reported that non-science majors developed more sophisticated conceptions than science majors in theory-laden and cultural-embeddedness aspects of NOS. Longer exposure of science majors to an educational environment in which science is conceptualized as an objective and universal source of knowledge was offered by the authors as one of the plausible explanations for the difference between the conceptions of science and non-science majors. Likewise, in a research study conducted by Miller et al. (2010), it was found that non-science majors in undergraduate education scored significantly higher than science majors in the following two aspects of NOS: the scientific theories vs. laws and the methodology of science. The results of the aforementioned studies imply that individuals enrolling more science courses are inclined to develop more traditional views of science. Considering the limited engagement of both preschool and elementary teacher candidates with science content in their university education, the observed difference between their conceptions in the specific aspects of NOS might be attributed, to certain extent, to the method courses in which they enroll in their respective teacher education programs.

Other than the majors of teacher candidates, the effect of their genders on their conceptions of NOS were investigated in this study. The number of students in preschool teacher education programs is usually dominated by female students. Gender is definitely one of the influential variables in shaping the attitudes of people towards science. There is a myriad of research studies reporting the more positive attitudes of males towards science than females (e.g. Dare & Roehrig, 2016; Jones, Howe, & Rua, 2000; Osborne, Simon, & Collins, 2003). One's personal conception of science is an important factor in determining his/her attitudes towards science (Christidou, 2011; Hsiao-Ching, 1998). If males, in general, develop higher positive attitudes towards science than females, could the same hold true when it comes to their conceptions of NOS? The answer is apparently no, at least according to the results of this study. No statistically significant difference was existent between the NOS conceptions of the teacher candidates with respect to their genders. This result suggests that gender of the teacher candidates does not make a difference in their conceptions of science.

The analysis of available data in this study yielded no statistically significant difference among the NOS conceptions of the teacher candidates graduated from different types of high schools. It seems that attending a specific type of high school does not make a difference on how teacher candidates perceive science. Within the borders of the unitary structure of the Turkish education system, specific education programs followed in different types of high schools are indifferent to equip students with diverse viewpoints about science. Neither grade levels nor GPAs of the teacher candidates made a statistically significant impact on their conceptions of NOS. The NOS conceptions of the teacher candidates from first to fourth grade exhibited no significant difference. No changes in the NOS conceptions of the teacher candidates arise as they progress through the higher grades in their respective teacher education programs. Statistical analysis of GPAs and NOS scores of the teacher candidates produced a statistically insignificant correlation. In other words, high achievers in the teacher education programs were not necessarily tended to obtain the higher scores from the SUSSI instrument. This result signifies that the courses offered in preschool and elementary teacher education programs appear to be irrelevant in terms of supporting teacher candidates to develop informed conceptions of science. In order to supply the schools with competent teachers holding sophisticated conceptions of science, teacher education programs should include a course completely dedicated to NOS concepts. Future research studies conducted with more representative samples of prospective teachers would be affirmative in terms of the generalizability of the results reached in this study. Furthermore, research studies with different target populations would be informative to grasp an understanding of how science is conceptualized by prospective teachers in various disciplines.

References

Abd-El-Khalick, F. (2012). Examining the sources for our understandings about science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education, 34*(3), 353-374.

Abd-El-Khalick, F., & Akerson, V. (2009). The influence of metacognitive training on preservice elementary teachers' conceptions of nature of science. *International Journal of Science Education, 31*(16), 2161-2184.

Abramzon, N., Saccoman, S., & Hoeling, B. (2017). Improving the attitude of pre-service elementary school teachers towards teaching physics. *International Journal of Elementary Education, 6*(3), 16-23.

Aflalo, E. (2014). Advancing the perceptions of the nature of science (NOS): Integrating teaching the NOS in a science content course. *Research in Science & Technological Education, 32*(3), 298-317.

Akerson, V.L. (2004). Designing a science methods course for early childhood preservice teachers. *Journal of Elementary Science Education, 16*(2), 19-32.

Akerson, V.L., Buck, G.A., Donnelly, L.A., Nargund-Joshi, V., & Weiland, I.S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology, 20*, 537-549.

Akerson, V.L., Buzzelli, C.A., & Donnelly, L.A. (2010). On the nature of teaching nature of science: Preservice early childhood teachers' instruction in preschool and elementary settings. *Journal of Research in Science Teaching, 47*(2), 213-233.

Akerson, V.L., & Donnelly, L.A. (2010). Teaching nature of science to K-2 students: What understandings can they attain? International Journal of Science Education, 32(1), 97-124.

Akerson, V.L., Morrison, J.A., & McDuffie, A.R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching, 43*(2), 194-213.

Allchin, D. (2017). Beyond the consensus view: Whole science. *Canadian Journal of Science, Mathematics and Technology Education, 17*(1), 18-26.

Backhus, D.A., & Thompson, K.W. (2006). Addressing the nature of science in preservice science teacher preparation programs: Science educator perceptions. *Journal of Science Teacher Education, 17*, 65-81.

Bell, R.L., & Clair, T.L.S. (2015). Too little, too late: Addressing nature of science in early childhood education. In K.C. Trundle, & M. Sackes (Eds.), Research in early childhood science education (pp.125-141). New York, NY: Springer.

Bentler, P.M., & Bonett, D.G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88*(3), 588-606.

Brown, T.A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.). New York, NY: The Guilford Press.

Clough, M.P. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science Education, 15*, 463-494.

Cobern, W.W., & Loving, C.C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching, 39*(10), 1016-1031.

Dagher, Z.R., & Erduran, S. (2016). Reconceptualizing the nature of science for science education: Why does it matter? *Science & Education, 25*, 147-164.

Dare, E.A., & Roehrig, G.H. (2016). If I had to do it, then I would: Understanding early middle school students' perceptions of physics and physics-related careers by gender. *Physical Review Physics Education Research, 12*, 1-11.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives, 8*(1), 1-42.

Eflin, J.T., Glennan, S., & Reisch, G. (1999). The nature of science: A perspective from the philosophy of science. *Journal of Research in Science Teaching, 36*(1), 107-116.

Erduran, S., & Dagher, Z.R. (2014). *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories*. New York, NY: Springer.

Feyerabend, P. (1975). Against method. New York, NY: Verso.

Fraenkel, J.R., Wallen, N.E., & Hyun, H.H. (2012*). How to design and evaluate research in education* (8th ed.). New York, NY: McGraw-Hill.

Gerritsen, S., Plug, E., & Webbink, D. (2016). Teacher quality and student achievement: Evidence from a sample of Dutch twins. *Journal of Applied Econometrics, 32*, 643-660.

Good, R., & Shymansky, J. (2001). Nature-of-science literacy in benchmarks and standards: Post-modern/relativist or modern/realist? *Science & Education, 10*, 173-185.

Harrington, D. (2009). *Confirmatory factor analysis*. New York, NY: Oxford University Press.

Harris, D.N., & Sass, T.R. (2011). Teacher training, teacher quality and student achievement. *Journal of Public Economics, 95*, 798-812.

Heckman, J. J. (2000). Policies to foster human capital. *Research in Economics, 54*(1), 3-56.

Herman, B.C., & Clough, M.P. (2014). Teachers' longitudinal NOS understanding after having completed a science teacher education program. *International Journal of Science and Mathematics Education, 14*, 207-227.

Herman, B.C., Clough, M.P., & Olson, J.K. (2015). Pedagogical reflections by secondary science teachers at different NOS implementation levels. *Research in Science Education, 45*(4), 1-24.

Hodson, D., & Wong, S.L. (2017). Going beyond the consensus view: Broadening and enriching the scope of NOS-oriented curricula. Canadian Journal of Science, *Mathematics and Technology Education, 17*(1), 3-17.

Hoe, S.L. (2008). Issues and procedures in adopting structural equation modeling technique. *Journal of Applied Quantitative Methods, 3*(1), 76-83.

Hooper, D., Coughlan, J., & Mullen, M. (2008). Structural equation modeling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods, 6*(1), 53-60.

Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1-55.

Huang, F.L., & Moon, T.R. (2009). Is experience the best teacher? A multilevel analysis of teacher characteristics and student achievement in low performing schools. *Educational Assessment, Evaluation and Accountability, 21*, 209-234.

Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science for science education. *Science & Education, 20*(7), 591-607.

Irzik, G., & Nola, R. (2014). *New directions for nature of science research*. In M. R. Matthews (Ed.), International Handbook of Research in History, Philosophy and Science Teaching (pp.999-1021). New York, NY: Springer.

Jones, M.G., Howe, A., & Rua, M.J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*(2), 180-192.

Karaman, A. (2017). Identifying demographic variables influencing the nature of science (NOS) conceptions of teachers. *Universal Journal of Educational Research, 5*(5), 824-837.

Karaman, A., & Apaydin, S. (2014). Improvement of physics, science and elementary teachers' conceptions about the nature of science: The case of a science summer camp. *Elementary Education Online, 13*(2), 377-393.

Karoly, L.A., Kilburn, M.R., & Cannon, J.S. (2005). *Early childhood interventions: Proven results, future promise*. Santa Monica, CA: RAND Corporation.

Khishfe, R. (2013). Transfer of nature of science understandings into similar contexts: Promises and possibilities of an explicit reflective approach. *International Journal of Science Education, 35*(17), 2928-2953.

Kline, R.B. (2011). *Principles and practice of structural equation modeling* (3rd ed.). New York, NY: The Guilford Press.

Kloos, H., Baker, H., Luken, E., Brown, R., Pfeiffer, D., & Carr, V. (2012). *Preschoolers learning science: Myth or reality?* In H. Kloos, B.J. Morris, & J.L. Amaral (Eds.), Current topics in children's learning and cognition (pp.45-60). Rijeka, Croatia: InTech Open Access Publisher.

Kuhn, T.S. (1962). *The structure of scientific revolutions.* Chicago, IL: The University of Chicago Press.

Lakatos, I. (1976*). Proofs and refutations: The logic of mathematical discovery*. Cambridge, UK: Cambridge University Press.

Laudan, L. (1977). *Progress and its problems: Towards a theory of scientific growth*. Los Angeles, CA: University of California Press.

Leden, L., & Hansson, L. (2017). Nature of science progression in school year 1-9: A case study of teachers' suggestions and rationales. *Research in Science Education*, NA, 1-21.

Lederman, N.G. (2006). *Syntax of nature of science within inquiry and science instruction*. In L.B. Flick & N.G. Lederman (Eds.), Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education (pp.301-317). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Lederman, N.G., Antink, A., & Bartos, S. (2014). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science & Education, 23*, 285-302.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 138-147.

Liang, L.L., Chen, S., Chen, X., Kaya, O.N., Adams, A.D., Macklin, M., & Ebenezer, J. (2008). Assessing preservice elementary teachers' views on the nature of scientific knowledge: A dual-response instrument. *Asia-Pacific Forum on Science Learning and Teaching, 9*(1), 1-20.

Liu, S., & Tsai, C. (2008). Differences in the scientific epistemological views of undergraduate students. *International Journal of Science Education, 30*(8), 1055-1073.

Losh, S.C., Wilke, R., & Pop, M. (2008). Some methodological issues with "Draw a Scientist Tests" among young children. *International Journal of Science Education, 30*(6), 773-792.

Luttrell, H.D., & Crocker, B.C. (1990). Science as a favorite or least favorite subject. *Journal of Elementary Science Education, 2*(1), 3-9.

Marope, M., & Kaga, Y. (2015). *Repositioning ECCE in the post-2015 agenda*. In M. Marope & Y. Kaga (Eds.), Investing against evidence: The global state of early childhood care and education (pp.9-33). Paris, France: UNESCO Publishing.

Matthews, M.R. (2012). *Changing the focus: From nature of science (NOS) to features of science (FOS).* In M.S. Khine (Ed.), Advances in nature of science research: Concepts and methodologies (pp.3-26). New York, NY: Springer Publishing.

McDonald, C.V. (2010). The influence of explicit nature of science and argumentation instruction on preservice primary teachers' views of nature of science. *Journal of Research in Science Teaching, 47*(9), 1137-1164.

Mesci, G., & Schwartz, R.S. (2017). Changing preservice science teachers' views of nature of science: Why some conceptions may be more easily altered than others. *Research in Science Education, 47*(2), 329-351.

Miller, M.C., Montplaisir, L.M., Offerdahl, E.G., Cheng, F., & Ketterling, G.L. (2010). Comparison of views of the nature of science between natural science and nonscience majors. *CBE-Life Sciences Education, 9*, 45-54.

Mulaik, S.A., James, L.R., Van Alstine, J., Bennett, N., Lind, S., & Stilwell, C.D. (1989). Evaluation of goodness-of-fit indices for structural equation models. *Psychological Bulletin, 105*(3), 430-445.

Newton, D.P., & Newton, L.D. (1992). Young children's perceptions of science and the scientists. *International Journal of Science Education, 14*(3), 331-348.

Osborne, J., Simon, S., & Collins, S. (2003). *Attitudes toward science: A review of the literature and its implications. International Journal of Science Education, 25*(9), 1049-1079.

Pomeroy, D. (1993). Implications of teachers' beliefs about the Nature of Science: Comparison of the beliefs of scientists, secondary science teachers, and elementary teacher. *Science Teacher Education, 77*(3), 261-278.

Popper, K. (1959). *The logic of scientific discovery*. Vienna, Austria: Hutchinson & Co.

Posnanski, T.J. (2010). Developing understanding of the nature of science within a professional development program for inservice elementary teachers: Project nature of elementary science teaching. *Journal of Science Teacher Education, 21*, 589-621.

Quigley, C., Pongsanon, K., & Akerson, V.L. (2010). If we teach them, they can learn: Young students views of nature of science aspects to early elementary students during an informal science education program. *Journal of Science Teacher Education, 21*, 887-907.

Schreiber, J.B., Stage, F.K., King, J., Nora, A., & Barlow, E.A. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of Educational Research, 99*(6), 323-337.

Schwartz, R.S., & Lederman, N.G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching, 39*(3), 205-236.

Shonkoff, J.P., & Phillips, D.A. (2000). *From neurons to neighborhoods: The science of early childhood development*. Washington, DC: National Academy Press.

Song, J., & Kim, K. (1999). How Korean students see scientists: the images of the scientist. *International Journal of Science Education, 21*(9), 957-977.

Tabachnick, B.G., & Fidell, L.S. (2013). *Using multivariate statistics* (6th ed.). Boston, MA: Pearson.

Thompson, R.A., & Nelson, C.A. (2001). Developmental science and the media: Early brain development. *American Psychologist, 56(*1), 5-15.

Van Dijk, E.M. (2011). Portraying real science in science communication. *Science Education, 95*(6), 1086-1100.

Wilkins, J.L.M. (2010). Elementary school teachers' attitudes toward different subjects. *Teacher Educator, 45*(1), 23-36.

Wittgenstein, L. (1958). *Philosophical investigations*. Oxford, UK: Basil Blackwell Ltd.

Wong, S.L., & Hodson, D. (2008). From the horse's mouth: What scientists say about scientific investigation and scientific knowledge. *Science Education, 93*, 1-22.

Wong, S.L., & Hodson, D. (2010). More from the horse's mouth: What scientists say about science as a social practice. *International Journal of Science Education, 32*(11), 1431-1463.