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Topological Analysis of Correlations (TACO) model for analyzing prospective preschool teachers' science teaching attitudes based on their epistemological beliefs and views on the nature of science

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ABSTRACT

This research aims to determine how prospective pre-school teachers' epistemological beliefs and nature of science (NoS) views predict their science teaching attitudes, and to interpret which sub-dimensions of NoS views and epistemological beliefs are more influence science teaching attitudes using the Topological Analysis of Correlations (TACO) model proposed in this study. The research was conducted with 388 (310 females, 78 males) prospective pre-school teachers in the 2018/2019 academic year. Analysis results revealed that preservice pre-school teachers' epistemological beliefs and NoS views predicted the variation in science teaching attitudes by 47% (F = 169.681, p = .000). It was determined that the "methodological approach" and "scientific attitude" sub-dimensions of epistemological beliefs and the "characteristics of science" sub-dimension of NoS have strong correlations with the science teaching attitudes. The TACO model showed that epistemological beliefs are a lowered altitude that begins from the nature of scientific knowledge and continues across all dimensions of NoS. Findings of this study could be significant to develop educational materials in prospective pre-school teacher education and we believe that TACO, with its holistic assessment structure that includes all the variables in the study, has the potential to be an alternative analysis method for further research on teacher views on the NOS and their epistemological beliefs that impact on their science teaching in pre-schools.

Keywords: epistemology; nature of science; prospective preschool teachers; science teaching attitudes; TACO

INTRODUCTION

Many researchers have emphasized the importance of science teaching at an early age in positively influencing the cognitive development of children in various ways. Some of the positive influences of science education in early childhood education include improving science process skills, supporting problem-solving and creative thinking skills, encouraging curiosity, and fulfilling their discovery needs (Saçkes, Trundle, Bell & O'Connell, 2011; Watters, Diezmann, Grieshaber & Davis, 2000). Woth (2010) stated that science education in the preschool period has the power to develop children's future understanding of science encompassing their learning abilities and attitudes toward science. Children taking pleasure in observing and thinking about nature (Eshach & Fried, 2005; Trundle, 2010) and their eagerness to explore the world in which they live (French, 2004; Gelman & Brenneman, 2004) are considered as opportunities offered by science teaching to satisfy their needs and interests (Bosse, Jacobs & Anderson, 2009; National Research Council, 2012).

Based on the importance of science teaching in pre-school education, Gutiérrez, Cruz-Guzmán, and Rodríguez-Marín (2019) argue that pre-school prospective teachers should improve their scientific knowledge to be able to carry out better quality learning and teaching in the future. To realize this and increase the quality of teacher education, they stated that giving more weight to science lessons in teacher education has a decisive effect. This situation shows the need to support prospective teachers' perceptions of scientific understanding and the nature of science.

More arguments are needed to discuss why prospective teachers' development of attitudes and beliefs about science education is important. This will help determine not only the quality of science teaching methods/techniques but also the different contributions they offer to science teaching (Luft & Roehrig, 2007). Together with the epistemological beliefs, the nature of science (NoS) views of teachers play an important role in teaching science (Abd-El-Khalick, 2013). It has been suggested that the epistemological beliefs of teachers are related to their views on the nature of scientific knowledge (Akerson, Abd-El Khalick & Lederman, 2000;

Cho, Lankford & Wescott, 2011), and a positive change in the latter leads to the sophistication of the former (Ab-El-Khalick, 2013; Loughran, 2007; Oliveira, Akerson, Colak, Pongsanon & Genel, 2012).
In this context, examining how the relationship between epistemology and NoS views shapes and predicts the science teaching attitudes of prospective preschool teachers (PPTs) is considered as a highly important problem. In this research, we aimed to examine how epistemological beliefs and NoS views predict science teaching attitudes with all sub-dimensions, using a statistical model developed for the study, namely the TACO (Topological Analyzes of Correlations).

Background of the Research
It is known that teachers' scientific thoughts and beliefs shape students' epistemological views and students' daily routines are affected by teachers' implicit or explicit beliefs (Tsai, 2007). At this point, there is clear evidence indicating that epistemological beliefs have a positive correlation with teachers' instruction and students' learning of science (Tsai, 2002). Tsai (2002) reported 21 of 37 teachers participating in his study had traditional epistemological views and their teaching strategies and applications were based on traditional methods. This problem can be solved if the prospective teachers' training process is supported by successfully integrating service learning in the classroom and improving their sophisticated epistemic cognition. Winterbottom and Munday (2017) emphasized that a dramatic change in early childhood education occurred with the use of different pedagogies in the classroom.
Current research shows that classroom practices shaped by teachers 'epistemological views play an important role in students' learning and epistemological views (Feucht, 2008; Feucht & Bendixen, 2010; Patrick & Pintrich, 2001; Schraw & Olafson, 2002; Tsai, 2002). Besides, Hofer (2001) stated that students' epistemic beliefs were affected by teachers' choices of instruction. It has also been established that the educational implication of developing children's epistemology is related to children's improved problem solving, argumentation skills, and academic achievement (Schommer-Aikins, Duell & Hutter, 2005; Walker, Wartenberg & Winner, 2013). Particularly, the results of some empirical studies show that there is a relationship between epistemological beliefs and science achievement (Bell & Linn, 2002; Elder, 2002); for instance, Wood and Kardash (2002) provided clear evidence that university students' epistemological beliefs (with the exception of the Attainability of Objective Truth in the ACT) had a strong correlation with academic aptitude on college readiness tests.

Purpose of the Study
From this point of view, investigating both the NoS and epistemological views of prospective preschool teachers toward science education is important concerning the achievement of early science education. It is emphasized that different points of view about the NoS and epistemology and their relationship between science education and culture have a direct influence on people's opinions of the content and pedagogy of science teaching in school (Ma, 2011; Wang, Lv, Jou & Zhang, 2016). Many science educators have emphasized that NoS is not only an important factor in science education (Bell, Lederman & Abd-El-Khalick, 2000; Lin, Chiu & Chou, 2004; Schwartz & Lederman, 2008) but also play a critical role in science teaching (Hanuscin, Lee & Akerson, 2011). Similarly, scientific epistemological beliefs are accepted as a powerful predictor of the achievement, structure, and effectiveness of science teaching (Chinn & Malhotra, 2002; Lederman, Lederman & Antink, 2013; Sandoval, 2005). Although the relationship between science teaching attitudes, NoS views, and epistemological beliefs have been demonstrated in the literature, more evidence is needed on how prospective pre-school teachers' epistemological beliefs and NoS views predict their science teaching attitudes. For this reason, this research aims to determine how prospective pre-school teachers' epistemological beliefs and NoS views predict their science teaching attitudes. Furthermore, this research endeavors to interpret which sub-dimensions of NoS views and epistemological beliefs have a greater influence on the science teaching attitudes of pre-service teachers via the Topological Analysis of Correlations (TACO) model proposed in this study. It is thought that providing concrete inferences about how the epistemological beliefs and NoS views support science teaching attitudes, may shed light on prospective pre-school teacher education policies.

Significance of the study
It is thought that prospective teachers' attitudes towards science teaching, epistemic approaches, and NoS views will be beneficial for the development of science education literature in early childhood (Oktay, 1999; Webster-Stratton, 1992). This research could be significant in that the proposed model measures pre-school pre-service teachers' epistemological beliefs and NoS views before their teacher training commence and could be used to design teacher training materials that develop teacher beliefs and views to enhance future pre-school teaching of science.

METHOD

Research Design

In this study, a correlational research design (Fraenkel & Wallen, 2006) was applied to examine how prospective pre-school teachers' epistemological beliefs and NoS views predicted their science teaching attitudes. According to Fraenkel and Wallen (2006) correlational research aims to develop our understandings about phenomena by revealing relationships between variables. In this context, the study first, determined the prospective preschool teachers' science teaching attitudes, epistemological beliefs, and NoS views. Second, the study determined if correlations existed between all variables (with sub-dimensions), and third, the study executed linear regression analysis to examine the contribution of PPTs' epistemological and NoS views to their attitudes toward science teaching. As specified above, NoS views and epistemological beliefs have predictive power on science teaching attitudes, however, a deeper examination was needed to determine which factors affected prospective teachers' attitudes towards science teaching the most and for this reason, the research applied TACO.

Participants

The convenience sampling method was used in the selection of the participants (Fraenkel & Wallen, 2006). The research was conducted in the academic year of 2018/2019 with 388 (310 females, 78 males) preservice teachers attending 2, 3, and 4 classes enrolled in the pre-school teaching program of two state universities in Turkey. Although science education has an important place in early childhood education and the preschool teacher program has science lessons, the school performance of preschool teachers in science is not a determinant for admission to early childhood education programmes in Turkey. In this context, it can be said that preschool teachers come to the pre-school teachers' programme with a limited science background.
The PPTs included in the study were volunteers and were informed that they could withdraw from the research at any time. No personal information of any participant was shared with third parties or recorded for a similar purpose. The response forms of all participants were coded and evaluated without any personal information (e.g., sample 1, sample 2, … sample 388).

Research Instruments

In order to determine the PPTs' attitudes toward science teaching (dependent variable), we used the Early Childhood Teachers' Attitudes toward Science Teaching Scale (ECTASTS), developed by Cho, Kim, and Choi (2003) and translated ~~to~~ Turkish by Adak (2006). This scale is a Likert-type scale with a total of 22 items under four subscales: "comfort-discomfort", "classroom preparation", "conducting applied science" and "developmental suitability". The epistemological beliefs and NoS views (comprising the interrelated and predictive independent variables on science teaching) of the participants were examined using the Scale on Scientific Epistemological Views (SSEV) (Authors, 2018) and the Nature of Science Scale (Özgelen, 2013), respectively. The Scale on Scientific Epistemological Views contains 23 items under three sub-scales: 'authority and accuracy in scientific knowledge', 'methodological approach and scientific attitude', and 'nature of scientific knowledge. The original version of the Nature of Science Scale developed by Özgelen (2013) consists of 11 sub-scales and 30 items. In the current research, a modified version reduced to four sub-scales ('characteristics of science', 'science, technology and scientific models, 'scientific method', and 'scientific creativity and socio-cultural effects') was used. Thus, in accordance with the purpose of the current research, preservice pre-school teachers' epistemological beliefs, NoS views, and science teaching attitudes were analyzed in a way to accommodate each other.

Internal - External Reliability and Validity

It was determined that all scales used in the study had high reliability and the data obtained from the scales were suitable for normal distribution. Table 1 presents the characteristics, reliability test results, and normality values of the measurement tools. The continuous structure of the collected data, the linear relationships obtained with the results of correlation analysis, and the fact that they were obtained as a result of independent observations show that linear regression can be applied.

Table 1:Description of the measurement tools, reliability test results, and normality values.

Instruments	Description	Cronbach α	Spearman- Brown (r)	McDonald's ω	Skewness Statistics	Kurtosis Statistics
Preschool Teachers' Attitudes Towards Science Teaching Scale	Contains 22 items under four sub-scales: 'comfort-discomfort', 'classroom preparation', 'managing hands-on science', and 'developmental appropriateness'.	.858	.882	.864	-.440	.134
Scale on Scientific Epistemological Views (SSEV)	Contains 23 items under three sub-scales: 'authority and accuracy in scientific knowledge', 'methodological approach and scientific attitude', and 'nature of scientific knowledge'.	.956	.952	.959	-.096	-1.049
Nature of Science Scale	The original version developed by Özgelen (2013) consists of 11 sub-scales and 30 items. In the current research, a modified version reduced to four sub-scales ('characteristics of science', 'science, technology and scientific models, 'scientific method', and 'scientific creativity and socio-cultural effects') was used.	.851	.767	.853	.158	-.651

Findings

Attitudes toward Science Teaching, Epistemological Beliefs, and NoS Views

Descriptive statistical values for all measurement tools and their sub-dimensions are presented in Table 2. In addition, the tendencies of the participants towards the relevant attitudes are shown as percentages.

Table 2:The results of descriptive statistics of the PPTs' science teaching attitudes, epistemological beliefs, and NoS views

Instruments	Sub-scales	Min.	Max.	Sd	$\bar{x}$	%
Early Childhood Teachers' Attitudes Towards Science Teaching Scale	Comfort-discomfort	7.00	30.00	4.49	19.24	53.22
	Classroom preparation	8.00	30.00	4.00	20.04	54.72
	Managing hands-on science	6.00	24.00	3.69	15.63	53.50
	Developmental appropriateness	10.00	24.00	2.81	16.52	46.57
	Total	37.00	103.00	12.81	71.44	52.18
Scale on Scientific Epistemological Views (SSEV)	Authority and accuracy in scientific knowledge	9.00	45.00	10.14	30.29	59.14
	Methodological approach and scientific attitude	10.00	50.00	12.77	31.64	54.10
	Nature of scientific knowledge	4.00	20.00	3.26	12.59	53.69
	Total	31.00	115.00	23.60	74.52	51.81
Nature of Science Scale	Characteristics of science	11.00	33.00	4.88	20.69	44.05
	Science, technology and scientific models	7.00	27.00	3.55	16.47	47.35
	Scientific method	10.00	32.00	4.43	21.43	51.95
	Scientific creativity and socio-cultural effects	6.00	19.00	2.76	11.88	45.23
	Total	43.00	101.00	12.98	70.47	47.36

The PPTs' scores in ECTATS were similar over the whole scale (52%) and the four sub-scales which are comfort-discomfort (53%), classroom preparation (54%), managing hands-on science (53%), and developmental appropriateness (46%). The PPTs' epistemological beliefs were parallel to their attitudes toward science teaching. The PPTs' epistemological views were at a level of 51% for the whole scale, 59% for the authority and accuracy in scientific knowledge sub-scale, 54% for the methodological approach and scientific attitude sub-scale, and 53% for the nature of scientific knowledge sub-scale.

The PPTs' NoS views were below the average level (47%); however, it is noteworthy that the participants' views on the scientific method were at a slightly higher level (52%) compared to other sub-scales.

Contribution of PPTs' Epistemological and NoS Views to their Attitudes toward Science Teaching

Table 3 shows the results of the t-test that aimed to examine the PPTs' attitudes toward science teaching in relation to their epistemological and NoS views.

Table 3:The t-test results of the PPTs' science teaching attitudes according to their epistemological beliefs and NoS views.

		N	Sd	$\bar{x}$	df	F	t	p
Epistemology	Naive	225	10.95	67.78	386	15.754	-7.010	.000
	Sophisticated	163	13.50	76.49				
NoS	Low-level	255	12.86	68.41	386	.553	-6.819	.000
	High-level	133	10.56	77.25				

The framework of SSEV was developed based on Schommer's (1990), Hofer & Pintrich's (1997), and Elder's (2002) studies. These resources emphasized that epistemological views improve from naïve to sophisticated and epistemological views are usually examined according to these (naïve / sophisticated) critical points.

The science teaching attitudes of PPTs with sophisticated advanced epistemological views were significantly higher than those with naive epistemological views, which was interpreted as those prospective teachers who understood the nature of knowledge and developed a scientific attitude felt more competent in teaching scientific subjects, and thus had a more positive attitude toward science teaching.

In order to reveal the joint contribution of the PPTs' epistemological and NoS views to their attitudes toward science teaching, it was first determined whether there was any correlation between these three variables using the Pearson correlation analysis.

Table 4:The results of the Pearson correlation analysis of the PPTs' science teaching attitudes, epistemological beliefs, and NoS views.

		Epistemological beliefs	NoS views
Science teaching attitudes	r	.614**	.501**
Epistemological views			.357**

Note. **p=.000.

Statistically significant (p=.000) and close-to-moderate and moderate correlations were determined. Science teaching attitudes were correlated with epistemological beliefs at a level of .61 and NoS views at a level of .50. The correlations between the three variables indicated that the PPTs' epistemological and NoS views had a joint contribution to their attitudes toward science teaching. To predict this contribution, the following multiple linear regression model was used:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(\text{epistemological beliefs}) + \beta_{2j}(\text{NOS views}) + r_{ij}, \text{Var}(r_{ij}) = \sigma^2$$

Table 5 presents the result of the multiple linear regression analysis.

Table 5: The results of the linear regression analysis concerning the prediction of the joint contribution of the PPTs' epistemological beliefs and NoS views to their science teaching attitudes

	Science teaching attitudes		
	B	SE B	β
Epistemological beliefs	.271	.022	.499
NoS views	.319	.039	.323
R^2		.47	
F		169.68**	

Note. **p=.000.

The PPTs' epistemological beliefs and NoS views were found to predict their science teaching attitudes at a rate of 47% (F=169.68, p=.000) from Table 5. Epistemological beliefs and NoS views contain sub-dimensions that cross each other, and these two variables together can explain 47% of the variance related to science teaching attitudes of preservice pre-school teachers. When the correlation values between science teaching attitudes, NoS, and epistemological views of preservice teachers were examined, a pattern was found among the sub-dimensions of variables. To reveal this pattern first, we applied the cluster analysis method (Edwards and Cavalli-Sforza, 1965; Jain & Dubes, 1988), and the correlation matrix approach (Dziuban & Shirkey, 1974) respectively. But these methods were not able to assist us in investigating the correlation values between sub-dimensions because of their two-dimensional structure. Therefore, we developed a new approach (TACO) to investigate the correlation pattern between sub-dimensions and to examine the relationships between sub-dimensions in a three-dimensional way.

TACO Modelling of PPTs' Science Teaching Attitudes

The PPTs' science teaching attitudes examined in relation to their epistemological and NoS views were modeled using a newly proposed method, TACO. The theoretical foundations and modeling steps of TACO are discussed in detail in the Algorithm of TACO section in the Appendix.

	e1	e2	e3	n1	n2	n3	n4
s1=0,53	0.42	0.43	0.31	0.40	0.45	0.29	0.30
s2=0,55	0.54	0.54	0.41	0.41	0.40	0.38	0.44
s3=0,54	0.42	0.41	0.34	0.36	0.30	0.32	0.29
s4=0,47	0.59	0.64	0.43	0.37	0.27	0.29	0.36

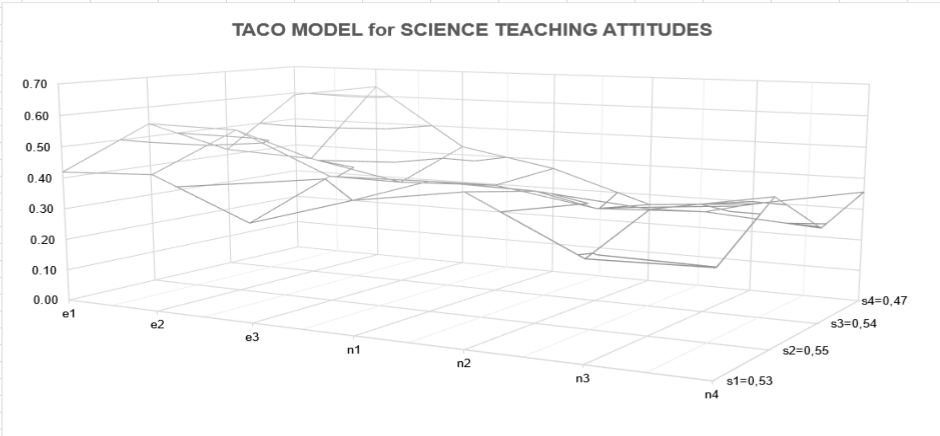

Figure 1: TACO Model for science teaching attitudes of PPT's

Figure 1 presents the topological map constructed using TACO. As revealed by the map, the PPTs' science teaching attitudes are highly correlated with epistemological belief sub-scales but have a low correlation with the NoS sub-scales. The most important finding is that the correlation with epistemological beliefs began to decrease after the "scientific method" dimension of NoS. We inferred from these findings that the PPTs' beliefs concerning the nature of scientific knowledge may change according to their science teaching attitudes. Another noteworthy finding based on the map is the decrease in the intercept between the fourth dimension of science teaching and the NoS sub-scales.

Although the "authority and accuracy in scientific knowledge" and "methodological approach and scientific attitude" sub-scales of epistemological beliefs overflow upwards on the map, there is a general decrease in altitude toward the fourth "Developmental appropriateness" sub-scale of attitudes of science teaching. We explain these surface fluctuations with the concept of topological agreement, which can be expressed as independent variables or their sub-scales consistently predicting the dependent variable in the linear regression analysis. The analysis results with topological agreement indicate that the independent variables have been effectively determined or the characteristics of one or more of the sub-scales of independent variables should be developed, as was the case in the current study. The results obtained from the topological graph in this study suggest that there are surface disagreements in the developmental appropriateness of science teaching. In order to determine whether the reduced altitude in this part of the topological map indicated a significant decrease; i.e., the topological disagreement was significant, we moved the topological map to the xy coordinate system and converted our 3D topological model to the coordinate system. The graph and the equation of the curve are presented in Figure 2 from the Appendix.

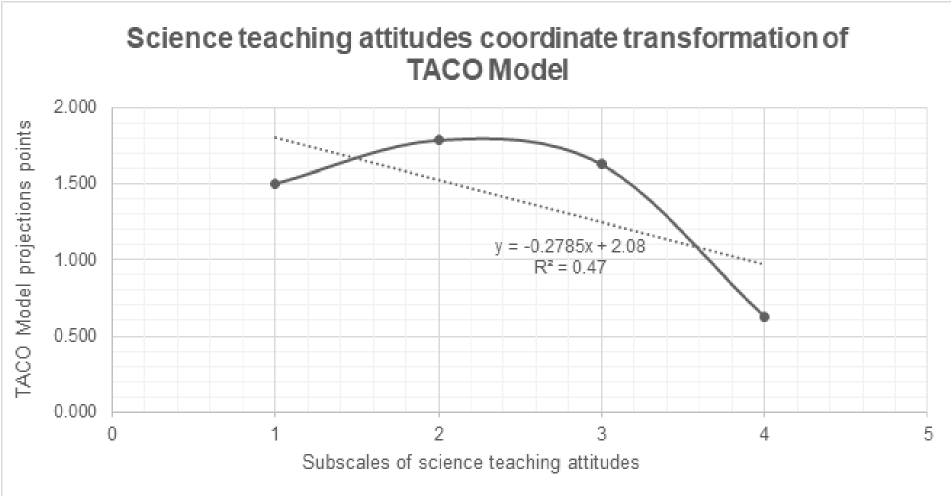

Figure 2: Science teaching attitudes coordinate transformation of TACO Model

An examination of the graph reveals that there is a large gap in the developmental appropriate dimension of science teaching, which was attributed to the PPTs' low average score in this sub-scale. This suggests that increasing the knowledge and skills of PPTs' in relation to this sub-scale is one of the most important steps in the development of their attitudes toward science teaching. Furthermore, the R^2 value between the science teaching sub-scale scores formed as a result of the joint relationships between the independent variables and the sub-scales of the dependent variable was calculated as .47, which corresponds to the R^2 value calculated in the regression analysis.

DISCUSSION

The similar Attitudes of the PPTs toward science teaching indicated a lack of a higher level of knowledge and skill levels, consistent with the literature (Gerde, Pierce, Lee & Van Egeren, 2018; Spektor-Levy, Baruch & Mevarech, 2013; Westman & Bergmark, 2014). The findings of PPTs' epistemological views found in this research were also in agreement with previous studies (Gerde et al., 2018; Tsai, 2002, Walker et al., 2012).

The findings that the epistemological and NoS views of the PPT predicted to science teaching were evaluated as a predictor of the results of previous researchers, indicating that NoS views have a positive effect on the development of epistemological views (Oliveira et al., 2012) and they advance epistemological approaches, thereby positively influencing science teaching. The strong relationship between the prospective teachers' attitudes towards science teaching and their nature of science and epistemological views, determined in this research, appears to be in parallel with the views of prospective teachers on the nature of science and the scientific method (Stott & Hattingh, 2020).

Developing prospective teachers' attitudes towards teaching (teaching science within the scope of this research) is one of the basic cornerstones of establishing a good teacher training policy. Schoeman and Mabunda (2012) revealed that teaching is not only a technical and cognitive practice, it is also emotional, and the inexperience of the trainees and/or not feeling competent enough is technically and emotionally challenge. Based on the findings of this research, it is predicted that a teacher education program that will support epistemological views and the nature of science in teacher education will positively affect the prospective teachers' attitudes towards science education and can support the quality of teacher education (Gutiérrez et al., 2019).

The prediction coefficient calculated in the regression analysis, without considering the sub-scales, demonstrated the changes in the predictive tendencies between TACO and sub-scales, and an equation of correlations curve was successfully obtained;

$y=-.28x+2.08$

These inferences show the strength of the functionality and practicality of the developed modeling and analysis method. In the equation of the curve obtained from the TACO analysis, the slope points to an acceleration that indicates a decrease in the epistemological and NoS views (two independent variables) beginning from developmental appropriateness, the fourth sub-scale of science teaching attitudes (dependent variable). The slope of the curve (m=-.28) was interpreted as the epistemological and NoS views being under the decreasing/regressive effect of this sub-scale (developmental appropriateness) at approximately 30%. In other words, the critical decreases in these two sub-scales are more clearly and effectively recognized in developmental appropriateness. In the current study, we found that the percentage of slopes that remained above 28% threatened topological agreement. However, to determine the critical value that would ensure topological agreement, comparative studies with different samples are required.

For the researcher and reader of this paper, the potential advantages of TACO are that it provides a three-dimensional examination of the correlations between the sub-dimensions of the variables and provides clues about the correlation between the sub-dimensions of the variables included in the analysis, as opposed to other correlation description methods such as cluster analysis and the correlation matrix. As exemplified in this study, although NoS and epistemological views have very similar sub-dimensions, TACO can show relationships between teacher candidates' attitudes towards science teaching. This differentiation between correlations is explained with the concept of topological agreement within the scope of this research. This concept, unlike the other correlation methods mentioned above, also provides clues concerning how meaningful the variables included in the analysis are in relational research. More specifically, TACO provides both the opportunity to examine the correlations of the sub-dimensions of the variables in greater detail and provides indications related to the significance of the variables included in the analysis.

CONCLUSION

It was found that the PPTs generally had moderately positive (52%) science teaching attitudes, and this was similar in the case of sub-scales: classroom preparation (55%), managing hands-on science activities (54%), and feeling comfortable when teaching science (53%). The lowest level of positive attitude was observed in the developmental appropriateness sub-scale (47%). According to these results, it was concluded that the PPTs in the current study did not have a high level of positive attitudes toward science teaching.

The PPTs' had sophisticated epistemological beliefs at a rate of 59% in authority and accuracy in scientific knowledge and 54% in methodological approaches and nature of scientific knowledge sub-scales. In general, it was concluded that the epistemic approaches of the PPTs showed a sophisticated structure at a rate of 52%. Considering the epistemic approaches, it can be stated that the participants had a more sophisticated structure in scientific knowledge being free from authority.

It was determined that the PPTs' NoS views were generally below the moderate level (47%). The PPTs showed a below-moderate level of development in NoS sub-scales of characteristics of science (44%), creativity in science and socio-cultural effects (45%), and science, technology, and scientific models (47%). Concerning the scientific method sub-scale of NoS, the PPTs had a similar developmental level (52%) to the methodological approaches sub-scale of epistemological beliefs (54%).

It was concluded that the PPTs with sophisticated epistemological beliefs and a high level of NoS views had significantly more favorable science teaching attitudes compared to those with naive epistemological beliefs and moderately or below-moderately positive NoS views. According to the findings obtained from this part of the research, it can be stated that individuals with high-level epistemic approaches and NoS views develop more positive attitudes toward science teaching.

The PPTs' science teaching attitudes were found to be statistically positively and moderately correlated with epistemic approaches ($p=.000$, $r=.614$) and NoS views ($p=.000$, $r=.501$), respectively. Furthermore, there was a statistically significant correlation between the PPTs' epistemological beliefs and their NoS views ($p=.000$, $r=.357$). A multiple linear regression analysis was conducted to predict the joint contribution of the two independent variables on the dependent variable, and the PPTs' epistemological and NoS views were found to predict their science teaching attitudes at a rate of 47%. Accordingly, it is concluded that sophisticated epistemic approaches and positive NoS views play an important role in shaping science teaching attitudes.

With the proposed TACO model, a topological model of the PPTs' science teaching attitudes was constructed based on their epistemological and NoS views. This model revealed a reduced altitude that started from the nature of scientific knowledge of the epistemological beliefs and continued throughout all dimensions of NoS. In addition, the developmental appropriate dimension of science teaching attitudes possessed a structure that had a negative effect on the topological agreement. After the transformation operation for converting the 3D topological map to the coordinate system, it was observed that the slope value of the science teaching attitude curve ($m=-.28$), especially in the developmental appropriateness sub-scale threatened the topological agreement of epistemological and NoS views at approximately 30%. In other words, the low effect of epistemological and NoS views on the developmental appropriateness sub-scale was observed. Furthermore, the predictive coefficient obtained from TACO was the same as the value ($R^2=.47$) produced by the regression analysis, which can be considered as the proposed modeling and analysis technique being reliable to provide analytical and practical solutions for holistic approaches including all variables. We believe that TACO, with its holistic assessment structure that includes all the variables in the study, has the potential to be an alternative analysis method for further research on teacher views on the NOS and their epistemological beliefs that impact their science teaching in pre-schools.

Limitations and Implications

The data collection tools measuring only quantitative constructs moving away from qualitative-based techniques, such as observations and interviews can be considered as a limitation concerning the methodological structure of this study. It is also considered that it would be beneficial to examine other variables contributing to the PPTs' science teaching attitudes (e.g., motivation, self-efficacy, and field knowledge). Research investigating similar variables can be undertaken to examine preschool children's attitudes to science learning and the relational dimensions of children's epistemic cognition, NoS views, and conceptual development of science. Finally, the topological agreement percentage of TACO used in the research was interpreted based on the results of the application by the researchers. It is recommended that comparative studies are carried out with different samples to theoretically present the critical values to ensure topological agreement.

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Appendix A: Algorithm of TACO

Theoretical Foundations and Modeling Steps of TACO

TACO modeling is based on the holistic surface/topological mapping and interpretation of correlational tendencies between the sub-scales of a dependent variable(s) (science teaching attitudes in this research) and those of an independent variable(s) (epistemological and NoS views in this research). The modeling process was carried out following the steps below including an example from the current research.

1) The correlations between the sub-scales of the dependent and independent variables are calculated (Pearson's correlation analysis).

Example:

A correlation analysis was performed between the dependent variable; i.e., sub-scales of science teaching attitudes (coded as s_1, s_2, s_3 and s_4) and independent variables; i.e., sub-scales of epistemological and NoS views (coded as e_1, e_2 and e_3, and n_1, n_2, n_3 and n_4, respectively).

The results of the correlation analysis between the sub-dimensions of science teaching attitudes and epistemological and NoS views

		Epistemology			NoS			
Science teaching attitudes		e_1	e_2	e_3	n_1	n_2	n_3	n_4
s_1	r	.419**	.432**	.307**	.400**	.448**	.291**	.299**
s_2		.543**	.538**	.406**	.412**	.404**	.375**	.435**
s_3		.419**	.405**	.343**	.355**	.302**	.317**	.293**
s_4		.593**	.635**	.429**	.370**	.266**	.293**	.356**

Note. **p = .000.

2) The sub-scale mean scores of the dependent variable are added to the correlation table created to examine the variation according to independent variables. A matrix is constructed for the mean score rates of the dependent variable and the correlational coefficients of the independent variables. The reason for taking the mean score rates into account is that due to the different item number/scale interval values, all variables are analyzed based on the same percentage system to overcome a standardization problem in the modeling process.

Example:

In the current research, the percentage values of the mean sub-scale scores of science teaching attitudes were calculated as s_1=.53; s_2=.55; s_3=.54, and s_4=.47 (results obtained from Table 2 in main text). The locations of these scores in the matrix table are shown below.

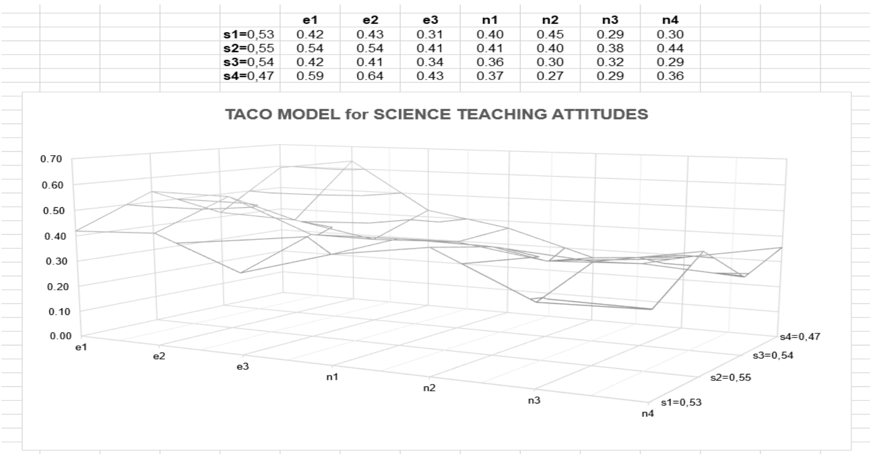
The mean scores and correlational coefficients matrix

	Epistemology			NoS			
Science teaching attitudes mean score percentages	e_1	e_2	e_3	n_1	n_2	n_3	n_4
s_1=.53	.419**	.432**	.307**	.400**	.448**	.291**	.299**
s_2=.55	.543**	.538**	.406**	.412**	.404**	.375**	.435**
s_3=.54	.419**	.405**	.343**	.355**	.302**	.317**	.293**
s_4=.47	.593**	.635**	.429**	.370**	.266**	.293**	.356**

Note. **p = .000.

3) Based on the matrix table, a surface/topological map is drawn to demonstrate the changes in the mean score rates of the sub-scales of the dependent variable according to the sub-scales of the independent variable.

Example:



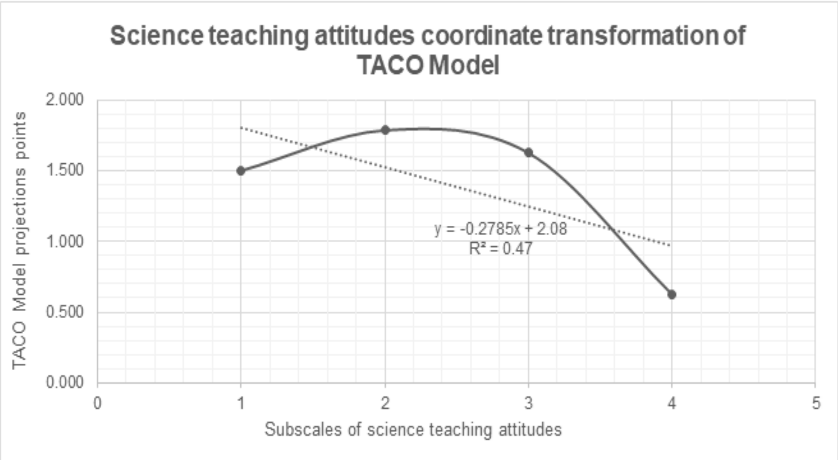
***This figure represented as "Figure 1" in main text.**

4) The 3D topological model is converted to the xy plane. This process; i.e., transformation of the 3D model to the coordination system, aims to obtain a graph revealing the changes in the sub-scales of all variables included in the model. This allows the mathematical interpretation of the curve equation formed by the correlations between the variables in the analytical plane.

The following steps of the analysis
The projection of all sub-scales (vectors) of the independent variable on the plane of the 3D model is calculated. The entire surface area covered by the topological map is determined as a projection corresponding to each sub-scale of the dependent variable. This projection represents the scalar product size of all sub-scales; i.e., vectors of the independent variables that constitute the model (the mean score rates of sub-scales are the scalar sizes of the vectors).
The point of projection is found by multiplying the scalar sizes (mean score rates) of all vectors that constitute the topological 3D model. Then, the scalar sizes of the vectors are calculated (the mean score rates of sub-scales used from Table 2 in this research) and the projection point of the topological model is calculated as $e_1 \times e_2 \times e_3 \times n_1 \times n_2 \times n_3 \times n_4 = .59 \times .54 \times .54 \times .44 \times .47 \times .52 \times .45 = .008$
The dependent variable vectors must exhibit seven vector-like behaviors for seven sub-scales (vectors) of the independent variables. The main reason for this logic is the principle of one-to-one correspondence for the formation and detection of correlational tendencies of each vector in topological map modeling. Thus, the projections formed by the dependent variable vectors against the integral and single projection of the independent variables (vectors) constituting the 3D model are calculated using the formula of vector$^{n \text{ (total number of sub-scales of independent variables)}}$. In this research, this was determined as:
$s_1^7 \rightarrow .53^7 \approx .012$
$s_2^7 \rightarrow .55^7 \approx .015$
$s_3^7 \rightarrow .54^7 \approx .014$
$s_4^7 \rightarrow .47^7 \approx .005$
The ratio of the dependent variable projections to the topological model projection reveal the distance between the two in the xy coordinate system and point to the location of the projections in the analytical system.
s_1 projection/TACO projection=.012/.008=1.500
s_2 projection/TACO projection=.015/.008=1.785
s_3 projection/TACO projection=.014/.008=1.625
s_4 projection/TACO projection=.005/.008=0.625
Locations of the 3D topological projection points in the xy coordinate system:

x	y	(x; y)
1	1.500	(1; 1.500)
2	1.785	(2; 1.785)
3	1.625	(3; 1.625)
4	0.625	(4; 0.625)

After assigning the projection points in the xy coordinate system, the coordinate transformation graph and equation of the TACO projections is obtained.



***This graph represented as "Figure 2" in main text.**