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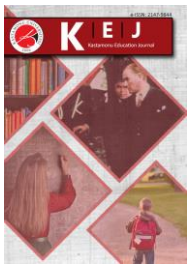

| Research Article / Araştırma Makalesi |

Pre-service Science Teachers' Epistemological Beliefs: A Q Method Study

Fen Bilgisi Öğretmen Adaylarının Epistemolojik İnançları: Bir Q Metot Çalışması

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Keywords

1.Epistemological beliefs

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Abstract

The purpose of the study is to investigate pre-service science teachers' epistemological beliefs and the possible causes of these beliefs. This study is theoretically framed by using Schommer's multi-dimensional Epistemological Beliefs Model. This study is designed using the Q-method, which aims to reveal subjective structures, attitudes and perspectives from the viewpoint of the individuals. The sample of this study consists of 12 pre-service science teachers. Data are collected using the Epistemological Beliefs Inventory throughout interviewing with each participant separately, and all interviews are audio recorded for Q analysis. Within thirty-two items in the nine ranges of intervals, all the factors are determined by centroid factor analysis in PQ-method software. According to the analyses, participants have informed understandings about tentativeness of scientific knowledge, subjectivity, learning differences, and they mostly deny the existence of omniscient authority. It is also found that courses are taken in college, personal experiences and observations, and socio-cultural structure are effective in forming the epistemological beliefs of the pre-service science teachers. It is assumed that this study with Q-method might contribute valuable insights and have implications for research in science education and allow this method to be used more frequently in future studies.

Öz

Bu çalışmanın amacı, fen bilgisi öğretmen adaylarının epistemolojik inançlarını ve bu inançların olası nedenlerini incelemektir. Çalışmanın teorik çerçevesini Schommer'in çok boyutlu epistemolojik inanç modeli oluşturmaktadır. Bu çalışma öznel yapıları, tutumları ve bakış açılarını bireylerin bakış açısından ortaya çıkarmayı amaçlayan Q yöntemi kullanılarak tasarlanmıştır. Çalışmanın örneklemini 12 fen bilgisi öğretmen adayı oluşturmaktadır. Veriler, Epistemolojik İnanç Envanteri kullanılarak her katılımcı ile görüşmeler yapılarak toplanmıştır ve tüm görüşmeler Q analizi için kaydedilmiştir. Dokuz yığın aralığındaki otuz iki maddede tüm faktörler PQ-metodu yazılımında centroid faktör analizi ile belirlenmiştir. Bulgulara göre, katılımcıların bilimsel bilginin değişebilirliği, öznellik ve öğrenme farklılıkları ile ilgili gelişmiş görüşlere sahip oldukları ve her şeyi bilen bir otoritenin varlığını reddettikleri sonucu bulunmuştur. Öğretmen adaylarının epistemolojik inançlarının oluşumunda temel olarak üniversitede aldıkları derslerin, kişisel deneyim ve gözlemlerinin ve içinde bulundukları sosyokültürel yapının etkili olduğu görülmüştür. Q-metodu kullanılarak yürütülen bu çalışmanın fen bilgisi eğitimi araştırma yaklaşımlarına önemli bir değer katabileceği ve bu yöntemin gelecekteki çalışmalarda daha sık kullanılmasına olanak sağlayacağı öngörülmektedir.

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INTRODUCTION

Epistemology, originally derived from the Greek words epistēmē (knowledge) and logos (science), is one of the subsections of philosophy and examines the structure and validity of human knowledge (Erçel, 2014). According to the widely accepted definition, epistemological beliefs are the beliefs that people have about knowledge and knowing/learning (Hofer & Pintrich, 1997).

Although epistemology and epistemological beliefs mainly were subjects of research in the fields of philosophy and developmental psychology in the past, epistemological beliefs and the variables related to these beliefs have also attracted the attention of educational researchers (Kessels, 2013). Findings of research revealed that epistemological beliefs are related to many variables such as the ability to understand and interpret texts (Kardash & Scholes, 1996), problem-solving skills related to complex issues (Schraw, Dunkle, & Bendixen, 1995), attitudes towards studying (Önen, 2011), motivation towards learning (Paulsen & Feldman, 1999), achievement goals (Braten & Stromso, 2004, 2006), self-efficacy perceptions (Köse & Dinç, 2012) and school achievement (Trautwein & Lüdtke, 2006; Schommer-Aikins & Easter, 2006; Yılmaz- Tüzün & Topçu, 2013).

In this respect, the development of epistemological beliefs has been directly or indirectly given a place among the goals of education programs. For example, in the current science curriculum of Turkey (Ministry of National Education [MoNE], 2018), helping students understand the processes related to the development of scientific knowledge is listed among the science education objectives of the country. Similarly, it is seen that epistemological beliefs are directly included in the content of the "Nature of Science" course, which is offered to pre-service teachers in the Science Teacher Education undergraduate program (Higher Education Council [YÖK], 2018). Epistemology is a term that is used to define and explain the concept of "Nature of Science" (NOS) (Lederman, 1992). Therefore, emphasis given to teaching NOS in many science curricula indirectly points to the importance of epistemological beliefs for the learning and teaching of science. Statements in American National Science Education Standards (NRC, 2000) and the Next Generation Science Standards (the NGSS Lead States, 2013) exemplify this situation.

Teachers have crucial roles in achieving the aims of curricula. Teachers first must have the necessary qualifications to help their students reach the targeted educational goals. The importance of developing in-service and pre-service teachers' epistemological beliefs can be understood better when the influences of epistemological beliefs on the time, effort and energy spent to understand any subject and perform an activity (Schommer, 1990) are considered. Similarly, teachers' abilities to successfully implement teaching strategies that are most appropriate for their students are thought to be linked to their awareness about their own epistemological beliefs as well as epistemological beliefs of their students (Chai, Khine, & Teo, 2006; Schommer-Aikins, 2004; Yılmaz-Tüzün & Topçu, 2013). This situation reveals the necessity of examining the epistemological beliefs of in-service and pre-service teachers. There are two different approaches utilized in the study of epistemological beliefs. One of these approaches is the one-dimensional approach, which was more frequently used in the early years of epistemological belief research (e.g., Perry, 1981; Baxter Magolda, 1987, King & Kitchener, 1994). According to this approach, people's epistemological beliefs develop in successive stages from simple to more advanced. The other approach is the multidimensional approach. This approach was developed by Schommer (1990) and adopted by other researchers such as Hofer and Pintrich (1997) and Conley, Pintrich, Vekiri, and Harrison (2004). According to the multidimensional approach, people's beliefs about knowledge and knowing/learning have more than one dimension, and these epistemological belief dimensions (e.g., beliefs about the structure of knowledge, learning ability, speed of learning, etc.) are more or less independent from each other (Shommer, 1990, 1994). In the extant literature, many researchers (e.g., Hofer, 2002; Zeidler, Herman, Ruzek, Linder, & Lin, 2013) argued that it would be more accurate to consider epistemological beliefs in a multidimensional way and that studies based on this assumption would yield better results and inferences for the science education community.

In her epistemological beliefs model, Schommer (1990) proposes five dimensions of epistemological beliefs: "the structure, certainty, and source of knowledge, and the control and speed of knowledge acquisition" (p.498). Two of these dimensions are epistemological beliefs about the structure of knowledge (knowledge is simple [simple knowledge], knowledge is specific [certain knowledge]). Two other epistemological belief dimensions' address beliefs about how learning occurs (learning ability is innate [innate ability], learning occurs quickly [quick learning]). Another dimension (the source of knowledge is the omniscient authority [omniscient authority]) examines people's beliefs about the source of knowledge.

Examination of the extant literature on epistemological beliefs reveals that the studies carried out with pre-service teachers mainly utilized quantitative research designs. These studies generally measured epistemological beliefs of pre-service teachers with Likert type scales to reveal factor structures of their epistemological beliefs through factor analyses and/or examine relationships of the obtained epistemological belief dimensions to other variables such as grade level, gender, academic achievement, pedagogical content knowledge (e.g., Efilti & Coklar, 2016; Jena, 2013; Yalcin & Yalcin, 2017). However, to the best of the researchers' knowledge, no study directly straightforwardly investigated the factors that underlie pre-service teachers' epistemological beliefs.

In their study, Chai, Khine, and Teo (2006) found that pre-service teachers in Singapore emphasized the necessity of effort for learning to take place and tended to accept evaluations of experts as correct. The researchers interpreted these findings as implications for the influence of culture on epistemological beliefs. Yılmaz-Tüzün and Topçu (2013) examined the relationships of gender and science achievement to the epistemological beliefs of Turkish pre-service science teachers. Both variables were found to be related to epistemological beliefs. Inconsistency between the findings of Yılmaz-Tüzün and Topçu's (2013) study and some

other studies conducted in western cultures, which did not result in any relationship between gender and epistemological beliefs (e.g., King and Kitchener, 1994; Kuhn, 1991), was attributed to the differences in eastern and western cultures.

Research studies conducted in Turkey generally reveal that pre-service teachers exhibit more sophisticated beliefs in the Quick Learning epistemological belief dimension (e.g., Saylan Kirmizigul & Bektas, 2019; Topçu, 2011). Similarly, emphasis on the necessity of hard work and effort for learning to take place (Unlu & Dokme, 2017) and propensity for perceiving authority figures such as experts as the source of knowledge (Efilti & Çoklar, 2016) are among the typical findings of research that examined epistemological beliefs of Turkish pre-service (science) teachers. On the other hand, concerning the epistemological beliefs about the Certainty of Knowledge, while findings of some of the research studies (e.g., Topcu, 2011) indicate sophistication of pre-service teachers' beliefs in this dimension, some others reveal the existence of pre-service teachers who support the view that there is only one truth (Yenice, 2015). Findings of studies are also inconclusive regarding pre-service teachers' beliefs in Simple Knowledge (Ozturk & Yilmaz-Tuzun, 2017; Yilmaz-Tuzun & Topcu, 2008, 2013) and Innate Ability (Ozturk & Yilmaz-Tuzun, 2017; Saylan Kirmizigul & Bektas, 2019; Yilmaz-Tuzun & Topcu, 2008) epistemological belief dimensions.

This study differs from similar studies in the literature regarding the research method used. The Q method, which belongs to a mixed research design, was used in the study (Stephenson, 1955). The essential feature of the Q method is that the participants sort the judgment statements presented to them within themselves. In other words, instead of stating the extent to which they agree with each statement, as in the classical Likert-type scales, the participants rank the judgment statements from the statements that they most agree with to the statements that they agree with the least. During the sorting process, participants are asked to think aloud and explain their sorting. With this method, additional findings such as what is more important and less necessary for the participants and the groups the participants are gathered are obtained. In this respect, the Q method focuses on the different perspectives of the participants and the underlying reasons for these different perspectives. Therefore, this study made it possible to obtain more in-depth findings of the sophistication of pre-service science teachers' epistemological beliefs and interpret the obtained findings based on their statements. The research questions that guided the study are:

1. What are the epistemological beliefs of pre-service science teachers?
2. What factors are influential on pre-service science teachers' epistemological beliefs?

METHOD

This study was conducted by using the Q-method (Stephenson, 1955). In studies carried out by driving the Q-method, data are collected and analyzed quantitatively, but the results are mostly interpreted by supporting with qualitative data (Ramlo & Newman, 2011). The Q method was defined by William Stephenson as the measurement of subjectivity (Stephenson, 1955). The Q-method allows participants to reveal their feelings, thoughts and beliefs about a topic by sorting the statements. The selected statements are called Q sentences. Despite its mathematical background, the purpose of the Q-method is to present participants' subjective structures, attitudes and perspectives from their own line of vision (Brown, 1996).

Participants

The sample of this study consists of 12 (6 female; 6 male) pre-service science teachers (PSTs) (average age: 21) on their 3rd and 4th year at a state university in the Eastern Black Sea region of Turkey. The purpose of including the 3rd and 4th year pre-service teachers in this study was that these pre-service science teachers have taken the basic science education courses (e.g., physics, chemistry, biology, introduction to educational sciences, educational psychology, etc.). The participants of this study also took the *"Inquiry-Based Science Teaching"* and *"Nature of Science"* courses given by the authors of the study, thus gaining familiarity with the concept of epistemological belief. As a result, it was supposed that the 3rd grade (3 female, 3 male) and 4th grade (3 female, 3 male) pre-service teachers included in the study could better express themselves about the concepts such as science, knowledge, and ways of obtaining knowledge. While showing the findings of the study, each pre-service teacher was coded to indicate their grade level and gender (e.g. TF for a female participant in the 3rd year; FM for a male participant in the 4th year). In order to ensure maximum diversity (Creswell, 2007), it was ensured that the pre-service teachers who voluntarily participated in the study had a homogeneous distribution in terms of gender and grade level. A pre-interview for sampling purposes or a measurement tool for readiness was not conducted. Since the aim of a Q study is to identify typical representations of different viewpoints and to reveal how different viewpoints are represented, rather than to find the proportion of individuals with certain viewpoints (Akhtar-Danesh, Batunann, & Cordingley, 2008; Simons, 2013), the small number of participants in such studies does not pose any disadvantage (McKeown & Thomas, 1998; Valenta & Wigger, 1997).

Data Collection Tool

The Epistemological Beliefs Inventory (EBI) developed by Bendixen, Schraw and Dunkle (1998) was used as the data collection tool in the study. The Epistemological Beliefs Inventory is theoretically based on Schommer's (1990, 1994) epistemological beliefs model. In this context, the 32 items that make up the inventory (7 of them are reverse items) consist of statements containing judgments that will reveal the respondents' beliefs in five epistemological belief dimensions (*simple knowledge, certain knowledge, innate ability, quick learning, and omniscient authority)*. Studies show that the inventory allows to obtain reliable and valid data (Bendixen et al., 1998; Schraw et al., 1995). The Turkish version of the inventory (Tuncay-Yüksel, 2016; Tuncay-Yüksel, Yılmaz-Tüzün, & Zeidler, 2015) gives the desired results in terms of its psychometric properties. According to these studies, it was

determined that the data obtained from the inventory were gathered under five factors in accordance with Schommer's (1990, 1994) Epistemological Beliefs Model, and the reliability values of these factors (mean inter-item correlation: .20 to .28) were in the desired range (Pallant, 2007). The Epistemological Beliefs Inventory was presented to the participants through open-ended interviews. In the interviews, in accordance with the nature of the Q method, it was aimed to collect data about how the participants sorted the statements in the scale, the reasons behind these sorting, and how they made these sorting.

Data Collection Process

In this study, each pre-service teacher was asked to sort the Q statements (32 epistemological belief statements in the Epistemological Beliefs Inventory (Bendixen et al., 1998)) as shown in Figure 1, from most agree (+4) to least agree (-4). The Q set consisting of 32 statements in the Epistemological Beliefs Inventory was given to the pre-service science teachers as randomly numbered cards. The pre-service science teachers first divided the random cards into three groups as "I agree", "I do not agree" and "I am undecided", and then they sorted the statements in each group according to their most agreeing to least agreeing. As a result of these sorting, a distribution as in Figure 1 was obtained. During the ranking process, participants were reminded that they were free to change their sorting at every stage of the process. In this way, pre-service teachers made changes in their sorting along with their justifications. While the pre-service teachers were sorting the statements, the researchers asked the participants to explain the statement they put in each range and tried to reveal the reason(s) underlying this sorting by asking why the statement was in that order. All interviews were audio-recorded for further analysis.

-4	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**
25	29	21	17	26	4	22	2	6
	28	19	10	13	3	30	20	
	23	16	8	14	11	32	24	
		27	9	7	12	18		
			31	15	5			
				1				

Figure 1. Example of classification scheme for a Q sorting technique with 32 expressions

Data Analysis

Q sorting data for all participants were entered into PQMethod (Schmolck, 2014), a program designed explicitly for Q analysis. After the obtained Q types were sent to factor analysis, the factors were obtained using the centroid factor analysis (CFA) (Brown, 1980; Schmolck, 2008; Stephenson, 1955) method, which is a factor extraction method is frequently used in the Q method studies. Principal component analysis (PCA) was performed for the rankings in this study, but no statistically significant aggregation was achieved. In Q studies, PCA extracts unrelated linear combinations of observed Q-varieties. Generally, this method analyzes all variance in variables (Q-kind). The use of centroid factor analysis in the Q method and its full explanation were made by Brown (1980). CFA is an approximation of principal axis factor analysis (PAF) in other statistical programs. However, the technical difference between them is that in PAF, the sum of squares of "loads" is maximized, whereas in CFA, the average of "loads" is maximized. Geometrically, while PAF provides a set of orthogonal factors, while factors extracted using CFA do not need to be orthogonal (Akhtar-Danesh, 2017). CFA is the only method that extracts non-orthogonal factors.

Unlike PCA and PAF, CFA is not included in major statistical programs (such as SAS, SPSS, Stata, and R), while it is available to Q method users through the PQMehtod program. For this reason, it was used as factor analysis in this study. The significance of the factors was revealed by using graphical rotation and Varimax rotation analysis.

As a result of the analyses, tables were created for each factor. Among these tables is a representative Q-rank for each factor. In these tables, the Q ranking values (columns indicated by Q) indicate to what extent the pre-service teachers in the relevant factor agree with the corresponding item within the range of -4 (strongly disagree) to +4 (strongly agree); Z-score values (columns indicated by Z) represent standardized score lines of the respective Q values. In addition, the proportion of expressions representing consensus and disagreement among the factors was also reported in the outputs of the Q analyzes (values expressed by the explanation variance (%) in the Tables) (Brown, 1980; McKeown & Thomas, 1988). Each factor obtained in the Q method represents a different perspective within the group. While every Q ranking is subjective, the factors identified in the Q are based on concrete behavior and are typically reliable and repeatable (Brown, 1980). The audio-recorded interview data was used to help interpret the factors obtained from the Q analysis. All interview transcribes were coded by making content analysis in the Hype-research program. The researchers named the factors using the dimensions in Schommer's (1990, 1994) Epistemological Beliefs Model, the Q-rank values corresponding to the minimum and maximum factor loads in the outputs, the Z-score values, the specific items, and the statements of the participants in the interviews. The validity and reliability of the research in the Q method, which is a mixed-method, is considered different from the quantitative research methods. There are no external criteria to evaluate an individual's point of view (Friedman & Wyatt, 1997). The rankings made by each individual are accepted as a valid expression of their views (Brown, 1996).

FINDINGS

According to the results of the Q analysis, the factors determined as a result of the centorid factor analysis were rotated in a graphical rotation and only one factor, namely the common factor (Tentativeness of knowledge: Relativity of truth) was determined. As seen in Table 1, 11 out of 12 pre-service teachers (except the TF_9 coded pre-service teacher) were loaded in this factor in a meaningful way. The common factor explained 47% of the common epistemological belief views of the pre-service science teachers (Table 1).

Table 1. Factor matrix with an X indicating a defining sort

Participants	Common Factor
FM_1	0.6153 X
FF_2	0.8012 X
TF_3	0.5008 X
FF_4	0.8819 X
FF_5	0.8961 X
TM_6	0.5997 X
FM_7	0.6167 X
FM_8	0.7935 X
TF_9	0.4479
TM_10	0.5574 X
TF_11	0.6235 X
TM_12	0.7120 X
(%) Expl. Var.	47

Mean: .00; St. Dev: 2.032

* F: 4th grade pre-service teacher; T: 3rd grade pre-service teacher; M: Male; F: Female (e.g.; FM_1: Coded 1, 4th grade male pre-service teacher)

When the factors obtained as a result of the centroid factor analysis were rotated in Varimax rotation, a model was formed in which the participants were distributed into 3 factors. The three factors that emerged as a result of the Varimax rotation (these subgroups refer to the coexistence of the participants in terms of similar views) reflect the epistemological belief statements of the pre-service teachers in which they accumulate statistically significant. These factors explain 22%, 20% and 19% of all pre-service teachers' common epistemological belief views, respectively (Table 2). As a result of this rotation, 3 pre-service teachers (FF_2, TM_6, TF_11) loaded in factor 1 (Learning ability: Relationship between success and intelligence); 5 pre-service teachers (FM_1, TF_3, FM_5, TM_10, and TM_12) loaded in factor 2 (Source of knowledge: Suspicion against authority); and 4 pre-service teachers (FF_4, FM_7, FM_8, and TF_9) were included in factor 3 (Simplicity of knowledge: Desire and effort in learning) (Table 2).

Table 2. Factor matrix with an X indicating a defining sort

	Factors		
Participants	1	2	3
FM_1	0.3834	0.5596 X	0.1131
FF_2	0.8680 X	0.2732	0.3065
TF_3	0.1690	0.4541 X	0.2298
FF_4	0.5307	0.3503	0.6516 X
FF_5	0.4595	0.6517 X	0.4079
TM_6	0.6478 X	0.2810	0.1340
FM_7	-0.0974	0.5610	0.6958 X
FM_8	0.4906	0.3055	0.5828 X
TF_9	0.2142	0.0758	0.5256 X
TM_10	0.2177	0.6086 X	0.1355
TF_11	0.6923 X	0.2734	0.3211
TM_12	0.2445	0.6432 X	0.4123
(%) Expl. Var.	22	20	19

Mean: .00 ; St. Dev: 2.032

Common Factor: Tentativeness of Knowledge: Relativity of Truth

This factor, which emerged as a result of the graphical rotation, includes the most and least accepted epistemological belief statements on which 11 out of 12 pre-service science teachers (Table 3).

Table 3. The Common Factor: Four most and least agreed to statements by all pre-service teachers

EBI items	Statements	Grid position	Z score
2	Truth means different things to different people	+4	1.984
6	Absolute moral truth does not exist	+3	1.725
24	The more you know about a topic, the more there is to know	+3	1.646
20	Children should be allowed to question their parents' authority	+3	1.50
...	.....	...	...
28	People who question authority are trouble makers	-3	-1.264
21	If you haven't understood a chapter the first time through, going back over it won't help	-3	-1.309
23	The moral rules I live by apply to everyone	-3	-1.629
25	What is true today will be true tomorrow	-4	-1.978

As a result of the analysis, almost all of the pre-service teachers argued that there is no single truth both scientifically and morally. They thought that a knowledge that is correct today may change in the future and that moral rules should be different for everyone. While the pre-service teachers expressed their views on the tentativeness of knowledge, they especially emphasized the effects of the *"Inquiry-Based Science Teaching"* and *"Nature of Science"* courses they took on their epistemological beliefs.

> *"Social or scientific things that are considered true today may change in the future. For example, while it was accepted that girls should not go to school in the past, today, on the contrary, women have become the leaders of society. Or, scientifically, while it was believed that the atom was a sphere, it was later said to be surrounded by electrons, with neutrons and protons inside. Maybe in the future this will change and they will bring another explanation. In short, as we often repeat in nature of science course, there is no single truth and what is considered true today may change in the future." (FF_5)*

> *"The effect of social and cultural life on moral rules is quite high. Thus, what's right for me may not be right for someone else. In fact, everyone creates their own rules." (FM_1)*

> *"As we said in our lesson, scientific knowledge, whether it is theories or laws, may change in the future with the effect of the development of technology in the light of new data and evidence. For example, the laws and theories of classical physics, especially known after Einstein's research, changed and formed the basis of modern physics." (FF_2)*

Pre-service teachers also stated that learning never stops and that there are new things to be learned and discovered throughout life. In addition, they thought that a person's rapid or slow learning of something may depend on many factors. Pre-service teachers argued that people have different backgrounds and learning abilities, and that things that cannot be learned at first can be learned later. They stated that these views were formed by their personal experiences and observations.

> *"Learning is a lifelong process. No one can say that "I know everything", on the contrary, the more they learn about a subject, the more they realize how much more there is to learn. So, the more you know about a subject, the more you realize how much you don't actually know. At least that's how I've experienced it in my own life." (FM_8)*

> *"The ability to learn is different in every living thing. There are many factors that affect this. Some people understand immediately when they first read it, while others need to read more than once to learn. For example, I have two younger brothers and they are completely different from each other when they learn something. In fact, their perception levels are different. While some people are easy to learn visually, others learn better during physical activities. Therefore, I think that generalization should not be made on this subject." (TF_3)*

In addition, almost all of the pre-service teachers argued that both adults and children should criticize and live more freely instead of accepting the authority established on them. They thought that authority often harms people and restricts children's critical thinking and creativity in particular.

> *"Having authority over someone and making him do whatever you want causes that person to lose self-confidence and not be able to think creatively and critically. I don't do anything that someone who considers himself to be an authority says. I inquiry first and only then do it if I'm convinced it's true." (FM_7)*

> *"If a parent who has authority over their child wants them to do whatever they say without question, it creates a generation that is oppressive, distorted, unquestioning and uncritical. This will negatively affect both their school, work and social life in the future and prevent them from being successful." (TF_3)*

Factor 1: Learning Ability: Relationship between success and intelligence

In this factor, in which the FF_2, TM_6 and TF_11 coded pre-service teachers are loaded in a statistically significant way, the statements most and least agreed with by the pre-service teachers are given in Table 4. Just like in the common factor, the pre-service teachers in this factor stated that there are no definite moral truths, that moral rules can vary from one society to another society, from one religion to another, from one family to another family and even from one person to another. They argued that it should be respected.

Table 4. For factor 1, four most and least agreed to statements by pre-service teachers

EBI items	Statements	Grid Position	Z score
6	Absolute moral truth does not exist	+4	1.843
2	Truth means different things to different people	+3	1.697
32	Some people are born with special gifts and talents	+3	1.571
4	People should always obey the law	+3	1.445
...	.....	...	...
29	Working on a problem with no quick solution is a waste of time	-3	-1.445
25	What is true today will be true tomorrow	-3	-1.571
23	The moral rules I live by apply to everyone	-3	-1.591
15	How well you do in school depends on how smart you are	-4	-1.697

"I don't think there is a single moral right. In other words, what is considered true may differ from society to society, and even from family to family. For example, some societies think that it is immoral for girls to wear short skirts due to their religion, but I think that morality is not about people's clothing. If the societies respect differences, they can develop more." (FF_2)

The pre-service teachers who loaded in this factor stated that although some people are born with special abilities and skills, they did not agree that students' success at school is directly related to how smart they are.

"We need to separate the concept of success from the concept of intelligence. There are many factors that affect success. Being smart is often equated with success in exams and school in our society. However, although some people are very intelligent, they who have anxiety in exams, whose psychology is broken because they cannot find enough peace in their family, or who fail because they do not study a lot are seen as stupid. Although some people are born with special abilities, success is something that can change with environmental factors." (TM_6)

"Many people who I believe to be smart, who can think quickly and make decisions, fail in school. I think that in order to be successful in school, it is necessary to be hardworking rather than smart." (TF_11)

Table 5 shows the views that statistically distinguish pre-service teachers in factor 1 from pre-service teachers in other factors according to their epistemological beliefs. Accordingly, it was observed that the pre-service teachers did not agree with the view, which especially pre-service teachers which loaded in other factors were undecided, that how successful they were at school was related to how smart they were. Also, it was seen that the pre-service agreed with the view, which pre-service teachers who loaded in other factors were mainly undecided, that all people should always obey the law.

Table 5. Distinguishing Statements for Factor 1

		Factor 1		Factor 2		Factor 3	
EBI Items	Statements	Q	Z	Q	Z	Q	Z
4	People should always obey the law	3	1.45*	0	-0.21	0	-0.19
20	Children should be allowed to question their parents' authority.	2	0.80	4	1.85	3	1.65
15	How well you do in school depends on how smart you are	-4	-1.70*	0	-0.01	-1	-0.31

(P < .05 ; Asterisk (*) Indicates Significance at P < .01)

Both the Factor Q-Sort Value (Q) and the Z-Score (Z) are Shown

"Laws are the things that help keep society alive. Laws are made to keep people away from committing crimes, infringing on other people's rights or disturbing the peace of society and to bring society to modern levels. So everything would be better if people obeyed the law." (FF_2)

Factor 2: Source of Knowledge: Suspicion Against Authority

In this factor, where FM_1, TF_3, FF_5, TM_10, and TM_12 coded pre-service teachers are included in a statistically significant way, the most and least accepted expressions by the pre-service teachers are given in Table 6. As a result of the analyzes, the pre-service teachers who loaded in this factor stated that people should not bow unquestionably to any political, cultural, religious or family-established authority. Also, they argued that people should stand upright and question the pressure of the authority.

> *"Whatever someone in authority tells me, I do the opposite. Because I am a free-spirited person who wants to do what I believe and want. When someone forces me to believe or want me to do something, it makes it disliked and I don't do it. I think everyone should stand up for their own ideas and life. Even if it's my dad I'll ask why, if it makes sense I'll do it." (TM_10)*

> *"People should question everything and accept nothing blindly without researching it. I think we live in a very oppressive society. In particular, the pressure and authority, who the principal in the school, the teacher in the classroom, or the words of the parents at home, that society puts on people, should not be accepted without question. Of course, respectfully..." (FF_5)*

Table 6. For factor 2, four most and least agreed to statements by pre-service teachers

EBI items	Statements	Grid Position	Z score
20	Children should be allowed to question their parents' authority.	+4	1.852
2	Truth means different things to different people	+3	1.571
6	Absolute moral truth does not exist	+3	1.459
24	The more you know about a topic, the more there is to know	+3	1.456
...	.....	...	...
19	If two people are arguing about something, at least one of them must be wrong	-3	-1.236
27	When someone in authority tells me what to do, I usually do it	-3	-1.675
25	What is true today will be true tomorrow	-3	-1.747
28	People who question authority are troublemakers	-4	-1.950

The pre-service teachers loaded in this factor thought that there are no definite moral truths, just like in the common factor, that the truths known today may change in the future, and that the concepts defined as truth may mean different things for different people.

> *"In fact, before I took the nature of science and inquiry-based science teaching course, I believed there was only one answer to everything. But I don't think there is such a thing as "true" anymore. "True" is a relative concept, it varies from society to society, culture to culture, and even person to person. Even scientific theories and laws can change over time in the light of new data, although they are based on very strong evidence. That's why I believe what is true today may change in the future." (FF_5)*

Table 7 shows the statements that statistically distinguish pre-service teachers in factor 2 from pre-service teachers in other factors according to their epistemological beliefs. Accordingly, the pre-service teachers in this factor agreed with the view that intelligent people are naturally intelligent, which is a view generally rejected by the pre-service teachers in the other factors. They stated that they made these views by observing the people living around them. Also, on the contrary to the view that the pre-service teachers loaded in the other factor mostly disagree with the view that too many theories make things complicated, the pre-service teachers in this factor argued that more theories are needed to understand the universe because the theories are the explanations of observable and unobservable events.

Table 7. Distinguishing Statements for Factor 2

		Factor 1		Factor 2		Factor 3	
EBI items	Statements	Q	Z	Q	Z	Q	Z
26	Smart people are born that way	-2	-0.65	1	0.63*	-2	-0.80
10	Too many theories just complicate things	1	0.52	-2	-1.05*	1	0.48
27	When someone in authority tells me what to do, I usually do it	0	-0.13	-3	-1.68*	-2	-0.71
28	People who question authority are troublemakers	-1	-0.52	-4	-1.95	-2	-1.24

(P < .05 ; Asterisk (*) Indicates Significance at P < .01)

Both the Factor Q-Sort Value (Q) and the Z-Score (Z) are Shown

"I believe intelligence is an innate trait. For example, I see around me that children whose parents are smart are also smart." (FM_1)

"Theories are explanations of observable or unobservable phenomena or laws. In order to understand the universe and the natural world around us, we need explanations that scientists put forward with long efforts and strong evidence. These explanations make things clearer rather than complicating them." (TM_12)

Factor 3: Simplicity of Knowledge: Desire and Effort in Learning

In this factor, in which the FF_4, FM_7, FF_8, and TF_9 coded pre-service teachers are loaded in a statistically significant way, the statements the most and least agreed with by the pre-service teachers are given in Table 8. As a result of the analyses, the pre-service teachers loaded in this factor emphasized that learning continues throughout life. Also, they stated that when faced with a situation such as not being able to learn or not learning quickly, people should not lose hope, this is a normal situation, therefore, it is necessary to effort to learn.

Table 8. For factor 3, four most and least agreed to statements by pre-service teachers

EBI items	Statements	Grid Position	Z score
24	The more you know about a topic, the more there is to know	+4	2.014
2	Truth means different things to different people	+3	1.898
20	Children should be allowed to question their parents' authority.	+3	1.647
14	I like teachers who present several competing theories and let their students decide which is best	+3	1.508
...	.....	...	...
16	If you don't learn something quickly, you won't ever learn it	-3	-1.508
21	If you haven't understood a chapter the first time through, going back over it won't help	-3	-1.615
25	What is true today will be true tomorrow	-3	-1.623
23	The moral rules I live by apply to everyone	-4	-1.759

"Learning new things is like an endless ocean. The more you learn new things, the more you want to learn and it never ends." (FM_7)

"Learning is not something that happens immediately. The important thing is to ensure permanent learning. If we don't learn something right away when we read it, I think we should try and try our best to learn it. I think anyone can learn anything if they try enough." (FM_8)

"In a book I have read, it said that human beings only know 1% of the universe. As scientists find something new, it actually opens the door to other unknown things. There is much more to learn." (FF_9)

The pre-service teachers loaded in this factor underlined that, just like other pre-service teachers loaded in other factors, there is no single truth and that the scientific knowledge that we accept as correct today may change in the future.

"Scientific theories and laws that are known to be true today may change in the future. For example, it was believed that the earth was flat for many years, then it was said that the earth was round and as a result of the observations, it was stated that it was in the form of an ellipse. Just like the studies on the shape of the atom." (FM_8)

Table 9 shows the statements that statistically distinguish pre-service teachers in factor 3 from the pre-service teachers in other factors according to their epistemological beliefs. Accordingly, on the contrary to the pre-service teachers who loaded in the other factors, the pre-service teachers who loaded in this factor stated that the really smart students should study at least as much as the other students, and they argued that studying is more important than intelligence. Another distinctive view is that the pre-service teachers who loaded in this factor were undecided about the view that parents should teach their children everything about life, which is the view the other pre-service teachers usually agreed with. Accordingly, the pre-service teachers stated that a person can learn many things from his/her family, as well as from books, teachers, friends, television or through her own experiences.

"To be successful in school, it is necessary to study regularly rather than being smart. If a student who is very smart does not study, I think it is impossible for him/her to be successful in school." (FM_8)

"Although family education is very important, children actually learn many things from their friends, teachers, television, internet, or books. I do not agree with the view that parents should teach children everything." (FF_9)

Table 9. Distinguishing Statements for Factor 3

		Factor 1		Factor 2		Factor 3	
EBI items	Statements	Q	Z	Q	Z	Q	Z
6	Absolute moral truth does not exist	4	1.84	3	1.46	1	0.44*
3	Students who learn things quickly are the most successful	-2	-1.17	-1	-0.28	1	0.40
1	It bothers me when instructors don't tell students the answers to complicated problems	-2	-0.92	-1	-0.68	0	0.18
7	Parents should teach their children all there is to know about life	2	1.17	2	0.78	0	-0.17*
8	Really smart students don't have to work as hard to do well in school	1	0.65	1	0.67	-2	-0.91*
16	If you don't learn something quickly, you won't ever learn it	-2	-0.65	-1	-0.55	-3	-1.51

(P < .05 ; Asterisk (*) Indicates Significance at P < .01)

Both the Factor Q-Sort Value (Q) and the Z-Score (Z) are Shown

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

In the present study, pre-service science teachers' epistemological beliefs and the factors underlying those views were examined using the Q-method. The results of the Q analysis and the findings obtained through the interviews showed that the pre-service teachers who participated in the study generally had advanced epistemological beliefs, as can be understood from their Z scores. In particular, when the common factors obtained through the graphical rotation were examined, it was determined that most of the pre-service teachers agreed on the tentativeness of knowledge. The PSTs stated that they strongly agreed with the statements reflecting the relativity of truth. In parallel, the participants showed a common stance that they disagreed with the statements referring to the certainty of knowledge dimension in Schommer's (1990, 1994) Epistemological Beliefs Model. Results showed that pre-service teachers gave this epistemological belief dimension the most importance. This finding supports the findings of some of the previous research studies conducted in Turkey (e.g., Efilti & Çoklar, 2016; Topçu, 2011). When the statements of the pre-service teachers that were expressed during the interviews are examined in detail, it might be said that they attributed the tentativeness of knowledge and truth to individual, social and cultural differences and the dynamics brought by time. It is striking that the pre-service teachers often referred to the "Nature of Science" course they took in their undergraduate program to support their views.

Another striking finding of the study was the negative attitude of the participants towards authority. Almost all pre-service science teachers stated that they rejected all kinds of authority (political, cultural, religious, family, etc.) and saw authority figures as a threat to their freedom. At first glance, it can be thought that this opposition of the pre-service teachers to authority and authority figures is a natural feature of the age group they belong to (Sadullah, 2008). However, the findings obtained from the interviews show that these attitudes of pre-service teachers are also related to their epistemological beliefs. That is, as can be seen in the factor obtained through the varimax rotation of the collected data (Source of Knowledge: Suspicion Against Authority), the pre-service teachers stated that they denied the existence of an omniscient authority as the source of knowledge and that any knowledge should be questioned regardless of its source. In addition, the participants tried to support the validity of their arguments by drawing attention to the necessity of the dissemination of questioning for achieving healthy individuals and societies.

The pre-service teachers who drew attention to the importance of questioning to acquire knowledge also emphasized the importance of desire and effort in the learning process. Their responses reflected more sophisticated beliefs in the Simple Knowledge epistemological belief dimension proposed in Schommer's (1990, 1994) Epistemological Beliefs Model. More specifically, the participants stated that knowledge is not a collection of facts independent of each other. On the contrary, each piece of knowledge is related to each other, and the phenomenon called knowledge exhibits a complex structure. Therefore, every piece of knowledge opens the door to another unknown. Notably, the pre-service teachers who were factorized under the "Simplicity of knowledge: Desire and effort in learning" factor emphasized the importance of lifelong learning. These pre-service teachers stated that there is no single source of knowledge and that knowledge is not only transmitted from a source such as family but also obtained through individuals' own lives (e.g., reading books, friendships, individual experiences, etc.). It is also possible to see the emphasis put on the importance of desire and effort in the learning process in the epistemological beliefs of the pre-service teachers about learning ability. Remarkably, the pre-service teachers included in the "Learning Ability: Relationship between success and intelligence" factor offered a consensus that success cannot be equated with intelligence. Although these pre-service teachers agreed that some people are born with unique abilities and skills, they stated that success could not be seen as a direct result of intelligence. Instead, the participants emphasized that many factors affect success, including success in school/university. According to these pre-service teachers, learning ability is a phenomenon that can be developed.

Similarly, the teacher candidates stated that everyone could learn anything if enough effort was required. Considering that the study participants were science teacher candidates in their junior and senior years, the findings seem to support previous studies

(e.g., Sutton et al., 1996), which show that epistemological beliefs of pre-service teachers increase as they approach graduation. Based on our findings, we can claim that the epistemological beliefs of the PSTs about knowledge and knowing/learning were promising for their future pedagogical applications. However, of course, it is necessary to carry out studies about the reflection of epistemological beliefs on (pre-service) teachers' pedagogical practices in order to be able to make more accurate inferences.

The present study's findings revealed an interesting situation regarding the attitude of the pre-service teachers towards authority. Contrary to the findings of previous studies (Efilti & Çoklar, 2016), the participants generally took a common stance against religious, political, cultural and social (e.g., family, principal, teacher, etc.) authority. However, they kept laws out of this situation. The participants stated that they saw laws as a necessity for the healthy functioning of society and the protection of individual rights. In line with this view, they stated that everyone should obey the laws. In the literature, epistemological beliefs are proposed to have a cultural basis (Hofer, 2008). For instance, Pye and Pye (1985) concluded that authority figures, including laws, are perceived as an acceptable and even necessary phenomenon for social and personal security in many Asian countries. Findings of the present study, when taken together with Tuncay-Yüksel's (2016) study in which epistemological beliefs of 1524 pre-service science teachers studying in different provinces of Turkey reveal that Pye and Pye's argument may also be valid for the Turkish culture.

When the statements given by the pre-service teachers during the interviews were examined, it was seen that the courses they took at the university, their personal experiences and observations, and the country's socio-cultural structure were mainly effective in the formation of their epistemological beliefs. When these factors are examined according to the Epistemological Beliefs Model (Schommer, 1990, 1994), which constitutes the theoretical background of the study, it is seen that the courses taken by the pre-service teachers at the university were predominantly effective in the formation of their epistemological beliefs about the structure of knowledge (i.e., specific knowledge, simple knowledge). Moreover, the participants frequently expressed the positive effects of the "Inquiry-Based Science Teaching" and "Nature of Science" courses on their views on the source of knowledge and its tentative nature. In parallel with Lederman's (1992) definition of the nature of science, this situation supports the close relationship between views on the nature of science and epistemological beliefs and, thus, can be considered as a clue showing that development of views on the nature of science also supports the development of more sophisticated epistemological beliefs. Moreover, based on the relationships of epistemological beliefs to views about learning and teaching and pedagogical knowledge and practices (Chai et al., 2006; Schommer-Aikins, 2004; Yılmaz-Tüzün and Topçu, 2013), it is suggested that epistemological beliefs should be explicitly and reflectively included in NOS courses offered in education faculties.

The study's findings revealed that personal experiences and observations were more effective in forming epistemological beliefs related to learning (i.e., ability to learn, speed of learning). The pre-service teachers often gave examples from their personal lives while justifying their views about the epistemological belief statements, which were presented to them during the interviews. As stated previously, most of the participants frequently emphasized the importance of hard-working work and effort for learning to occur.

Finally, it can be argued that the socio-cultural features of the country that the participants belong, which includes religion and traditions, were influential in shaping their epistemological beliefs about the source of knowledge. The pre-service teachers drew attention to the authoritarian feature of their society and stated that this should change, and all types of authority should be questioned. This situation supports the predictions concerning the effect of socio-cultural life on epistemological beliefs as put forward by Zeidler et al. (2013).

This study will make significant contributions to the literature by revealing underlying factors of pre-service science teachers' epistemological beliefs. At this point, it should be cautiously acknowledged that the conclusions mentioned above are the inferences made based on the statements of our participants. However, given that no study in the extant literature will enable researchers to decide which factors are more influential on which epistemological belief dimensions, inferences drawn from the present study have significance. It is suggested that future studies should be designed to examine the factors underlying epistemological beliefs in more depth and fill the gap in the literature.

Another critical point that distinguishes this study from similar studies in the literature and makes it valuable is the research method used. The Q method includes the benefits of both qualitative and quantitative research by revealing aspects of a subjective phenomenon that will emerge in a way that reflects individuals' points of view (Dennis & Goldberg, 1996). Considering the advantages of the Q method and the fact that it is a new approach in science education research, it is anticipated that this study will add significant value to science education research approaches and allow this method to be used more frequently in future studies. In addition, applying the data collection tool to larger samples and conducting more detailed interviews with subgroups selected from the samples may be recommended for future studies.

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Statements of publication ethics

We hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Researchers' contribution rate

The study was conducted and reported with equal collaboration of the researchers.

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