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Epistemological Predictors of Prospective Biology Teachers' Nature of Science Understandings

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The purpose of this study was to investigate epistemological predictors of nature of science understandings of 281 prospective biology teachers surveyed using the Epistemological Beliefs Scale Regarding Science and the Nature of Science Scale. The findings on multiple linear regression showed that understandings about definition of science and objectivity in science were negatively predicted by beliefs in inborn learning ability (ILA) and requirement for time in learning (RTL), while understandings about tentativeness was positively predicted by the same belief factors. Also, understandings of characteristics of scientific knowledge were positively predicted by beliefs in ILA and RTL, and hierarchy between laws and theories were negatively predicted by beliefs in ILA, RTL and development of learning ability with opportunity and support.

Keywords: epistemological beliefs, nature of science, prospective biology teachers, science teacher education.

INTRODUCTION

Epistemological beliefs are composed of beliefs regarding to the origin, nature, limits and methods of human knowledge. Studies of epistemological beliefs in education are not new; Perry (1968) opened the gate by studying on the intellectual development of college students about moral subjects. Subsequently, studies of women's ways of knowing, epistemological reflection and reflective judgment came onto the scene (Belenky, Clinchy, Goldberger & Tarule, 1986; King & Kitchener, 1994; Magolda, 1992). All of these studies accepted epistemological beliefs as uni-dimensional, connected and developmental. But Schommer (1994) approached epistemological beliefs from a different angle. According to Schommer's conceptualization, epistemological beliefs should be considered as a system of independent epistemological beliefs, or personal epistemologies, which include five distinct aspects of epistemological beliefs (Hofer & Pintrich, 1997; Schommer-Aikins, 2002; Hofer, 2002). Schommer-Aikins (2002) named these five independent belief aspects as structure of knowledge, stability of knowledge, source of knowledge, control, and speed of knowledge acquisition. However, empirical studies supported four of these aspects as Certain Knowledge, Quick Learning, Simple Knowledge, and Fixed Ability (Hofer, 2001). These four aspects were frequently used to explain epistemological beliefs of students. Similar to epistemological beliefs, nature of science (NOS) understandings are also related to nature of knowledge and science in general. But NOS involves science-specific beliefs. NOS refers to "the epistemology and sociology of science, science as a way of knowing, and the values and beliefs inherent to scientific knowledge and its development" (Lederman, 1992, p.331). Importance of NOS in science education is related to its contribution to five aspects; usefulness in life, democratic participation, scientific ethic, learning

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State of the literature

- Epistemological beliefs and nature of science understandings of prospective biology teachers are theoretically associated but there is no enough empirical evidence about this association in the literature.
- Moreover it is shown that epistemological beliefs of teachers affect their approach to teaching hence teaching for changing NOS understandings and learning NOS aspects require having appropriate epistemological beliefs.
- For making a teaching on NOS aspects more active and student-centred, there is a need to find epistemological predictors of NOS understandings.

Contribution of this paper to the literature

- Findings of this study provided an empirical support for the idea that epistemological beliefs and nature of science understandings of prospective biology teachers are theoretically associated.
- The results showed that designing an epistemologically sound NOS teaching process in biology teacher education requires taking into account beliefs regarding quick learning, innate ability to learn and improvement of learning science with support and opportunity.
- This result provided important epistemological components regarding NOS understandings of prospective biology teachers; it is an important point for teacher educators in designing their courses

science content and appreciation of science as a human culture (Lederman, 2007). Four aspects of epistemological beliefs are also theoretically associated with nature of science (NOS) (Cho, Lankford & Wescott, 2011). Hence investigation of their relationship by using predictive method and by providing empirical evidence might inform instruction of NOS to prospective teachers.

Importance of the Study

Studies suggested that students' epistemological beliefs have a direct and indirect effect on learning in general (Brownlee et al., 2014; Schommer-Aikins, 2002; Topcu & Yilmaz-Tuzun, 2008; Viholainen, Asikainen & Hirvonen, 2014; Vries, Grift, & Jansen, 2014; Walker et al., 2012). In particular epistemological beliefs have importance in learning science since epistemological beliefs are associated with science achievement (Topcu & Yilmaz-Tuzun, 2008), attitudes toward science (Ozkal, 2007), conceptions of learning science (Liang & Tsai, 2010), and nature of science (NOS) (Cho, Lankford & Wescott, 2011). Especially relationship between nature of science and epistemological beliefs takes attention due to their close theoretical association. The theoretical relationship between epistemological beliefs and NOS understandings was explained by some researchers (Cho, Lankford & Wescott, 2011), but the empirical evidence for this relationship was not enough to suggest epistemologically sound instructional practices for changing the NOS understandings. NOS subject is important in science education since NOS comes to mind when science curricula and education reforms are considered (AAAS, 1990, 1993; NRC, 1996; Ministry of Education [Venezuela], 1990; National Center for Educational Research and Development [Lebanon], 1997). The meaning of NOS includes "the epistemology and sociology of science, science as a way of knowing, and the values and beliefs inherent to scientific knowledge and its development" (Lederman, 1992, p.331). NOS has several aspects: Tentativeness (scientific knowledge is tentative), evidence and observation based science, relationship between laws and theories (without hierarchy), roles of laws and theories, theory-laden science, role of culture and social life on science, myth of one way to do science, creativity and imagination in science, subjectivity and definition of science (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; McComas, 1998). NOS as emphasized in science curriculums should be taught by teachers using appropriate teaching methods such as explicit-reflective teaching (Khishfe & Lederman, 2006; Khishfe & Lederman, 2007). However, teachers' teaching practices or their conceptions on learning and teaching are affected from beliefs regarding knowledge and learning (Hashweh, 1996; Chan & Elliott, 2004; Chan, 2004). Therefore, successful implementation of NOS teaching requires appropriate epistemological beliefs for making instruction more active and student-centred. Cleminson (1991) asserted a need to establish an epistemological base for science teaching to provide connection between theory and practice in teaching. Prospective teacher education programs are the main environments in which inappropriate epistemological beliefs can be changed and beliefs can be made more consistent with expected beliefs for teaching informed understandings of NOS, since the prospective teachers are still in an active education process and they are taking courses regarding NOS. At the same time they will be responsible to teach NOS to their students. Hence we have to determine NOS understandings of prospective teachers and to find epistemological roots of their NOS understandings for suggesting sound instructional ways to teach NOS.

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Rationale of the Study

Teaching biology involves rich examples of hypotheses, theories, laws and models including cell membrane models, gene theory of inheritance, cell theory and Mendel's laws but beliefs on some of them, such as evolution theory, have controversial dimensions and are related to individuals' misunderstandings of NOS (Southerland & Sinatra, 2003; Lombrozo, Thanukos & Weisberg, 2008; Gencer, 2014). Prospective biology teachers are cases for change, as might be expected, for improving their NOS understandings and for making NOS teaching more effective in the future. But the literature shows that prospective teachers do not have adequate understandings regarding nature of science (Liu & Lederman, 2007; Lin & Chen, 2002). They believe in objective science and hierarchical relationship between theories and laws while they do not believe in involvement of imagination in science and empirical nature of scientific knowledge (Liu & Lederman, 2007). Also prospective science teachers believed in objective science and no place for creativity in theory production (Lin & Chen, 2002). The factors related to these inadequate understandings are not clear. For example, academic variables such as college grade point average, number of science courses or experience in teaching are not related to the inadequate understandings of the prospective science teachers (Billeh & Hasan, 1975; Lin & Chen, 2002; Carey & Stauss, 1970). Another possible factor in explaining NOS understandings involves epistemological beliefs associated with the understandings about NOS. Unfortunately Tsai (2002) showed that science teachers preferred to teach science in traditional positivistic perspective that is disadvantageous for learning NOS aspects. This situation gives clue about previous insufficient educational background of prospective teachers. For changing insufficient understandings of prospective teachers we have to analyse epistemological correlates of NOS understandings. Also the possible epistemological nature of certain NOS aspects (for example, scientific knowledge is tentative) leads us to look at the epistemological roots of NOS understandings to make suggestions about more epistemologically sound NOS teaching to prospective teachers. Therefore, determining the relationship between epistemological beliefs and NOS understandings of prospective biology teachers might provide a basis for future epistemologically sound instruction on NOS in teacher education programs. Before making suggestions about the instruction of NOS, there is a need to investigate epistemological predictors of NOS understandings in prospective biology teachers. But as stated by Pajares (1996), epistemological beliefs should be measured by considering their domain-specific nature, so domain-specific measurement of epistemological beliefs of prospective teachers might provide detailed understanding on the relationship between NOS aspects and epistemological beliefs. In this study domain-dependence of epistemological beliefs was taken into account whereby measurement of epistemological beliefs was made by focusing on the science domain. Previous studies took epistemological beliefs as a domain or discipline-free construct (Schommer-Aikins, 2004). However, researchers showed that epistemological beliefs are associated with domain (Buehl & Alexander, 2001; Hofer, 2000; Lofstrom & Pursiainen, 2015). Pajares (1996) stated the importance of domain on epistemological beliefs by saying that if the beliefs are assessed at a domain-specific level, they will be more predictive of the behaviour of individuals. Hence, the aim of this study is to examine domain-dependent (science) epistemological predictors of NOS understandings of prospective biology teachers.

METHODS

In this study, 281 prospective biology teachers were surveyed using two different instruments. Of the 281 participants, 242 were female and 39 were male. In Turkey, biology teacher education programs are five-year undergraduate programs which include science content courses, pedagogy courses and school applications. The distribution of the participants by educational level was 49 freshmen, 67 sophomores, 62 junior, 52 senior and 51 upper-senior. The unit of analysis for this study includes all participants. The study was conducted by using a correlational study approach including PCA (principle component analysis) and regression analysis. For the data collection on epistemological beliefs, Epistemological Beliefs Scale Regarding Science adapted from Schommer's Epistemological Beliefs Questionnaire (Schommer, 1990) by Deryakulu and Buyukozturk (2002) into Turkish, was used by changing wording content for science domain. The instrument consisted of 35 items regarding to epistemological beliefs related to science. The scale was a Likert type instrument (strongly agree, strongly disagree). In spite of the previous evidence on reliability and validity, both reliability and validity analyses were conducted because of the change in wording and application to a new group in this study. As a second instrument, the Nature of Science Scale was developed by the researchers forming an item pool. The items were determined by searching for previous studies (McComas, 1998, p. 53-70; Lederman et al., 2002; Liang et al., 2008; Aikenhead & Ryan, 1992). Based on the literature search, the initial form of the instrument included a total of 60 items. The items were directly translated into Turkish by the researchers and were put into the instrument form in a Likert type scaling

(absolutely true, absolutely false). Reliability and validity evidence was also collected by applying the instrument to prospective biology teachers in this study.

Results on Instrument Development

Development of Nature of Science Scale

The NOS scale included 18 items loaded on four factors (definition of science and objectivity in science [F1]; characteristics of scientific knowledge [F2]; hierarchy between laws and theories [F3]; tentativeness [F4]). In developing the scale, an item pool which included 60 items was established. Principal Component Analysis with Varimax rotation was then undertaken. Assumptions (normality, KMO [Kaiser-Meyer-Olkin value] and Bartlett's test) of principal component analysis were tested before conducting the analysis. Skewness and kurtosis values were investigated and found to be lower than 1.0 as a cut-off score to provide a normality assumption. Then KMO and Barlett's test were done to check factorability. KMO and Bartlett's test values were also found to be sufficient (KMO = .84, Bartlett's test chi-square = 1828.10, df = 153, $p<.0001$) (Sharma, 1996; Tavsancil, 2002). Finally, principal component analysis and analysis of Cronbach alpha reliability were completed. The majority of the items were eliminated because of different insufficiencies. The reasons for the eliminations are explained in Table 1.

The remaining items (n=18) were found to be appropriate for inclusion in the subsequent analysis and were included in the scale with four factors. The items and factors are represented in Table 2.

After the analyses, a four-factor solution was reached. The factors explained 60.57% of the total

Table 1. Reasons for Elimination of the Items after Principal Component Analysis and Reliability Analysis

Reasons for Elimination
Decreasing the reliability of the scale
Lower factor loadings than 0.40
Only one item loaded on one factor
Only two items loaded on one factor
Negatively loaded on factors

Table 2. Example Items of the Scale and Their Corresponding Factors

No	Factor	Items	Scale				
1.	F1	Scientists are objective, open-minded and unbiased	AT	THP	U	FHP	AF
2.	F1	Science is theories, laws and principles which explain the world we live in.	AT	THP	U	FHP	AF
3.	F2	Scientific knowledge, like religion and philosophy, depends on individual ideas	AT	THP	U	FHP	AF
4.	F3	Laws are more absolute than theories and hypotheses	AT	THP	U	FHP	AF
5.	F4	Existing scientific knowledge might be changed by adding new evidence	AT	THP	U	FHP	AF

(Note: AT= Absolutely True, THP=True with High Probability, U= Undecided, FHP=False with High Probability, AF= Absolutely False)

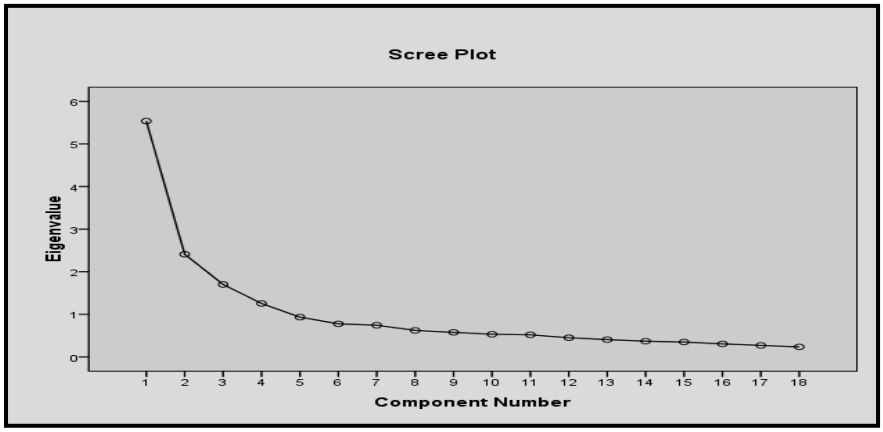

Figure 1. Scree plot for the four-factor solution of the Nature of Science Scale

variance (F1 = 30.76%, F2 = 13.39%, F3 = 9.45%, F4 = 6.97%). The scree plot can be seen in Figure 1. Table 3 shows that the factor loading of 18 items and the Cronbach alpha reliability of each factor.

Development of Epistemological Beliefs Scale Regarding Science (EBSRS)

The Epistemological Beliefs Scale Regarding Science included 14 items loaded on four factors (belief in inborn learning ability [F1]; belief in learning with time [F2]; belief in development of learning ability with opportunity and support [F3]; belief about resource of knowledge [F4]). For developing the scale, the re-worded items in the Epistemological Beliefs Questionnaire were used. Principal component analysis by Varimax rotation was then executed due to the fact that the group and content of the scale were new for studying epistemological beliefs regarding science. Assumptions of principal component analysis, similar to the NOS scale development process; (normality, KMO and Bartlett's test) were tested before conducting the analysis. Skewness and kurtosis values were also found to be lower than 1.0 as a cut-off score to provide a normality assumption. Then KMO and Barlett's test were done to check factorability. KMO and Bartlett's test values were also found to be sufficient in using the data for principal component analysis (KMO = .77, Bartlett's test chi-square = 847,611, degrees of freedom = 91, p<.0001) (Sharma, 1996; Tavsancil, 2002). Finally, principal component analysis and analysis of Cronbach alpha reliability after negative items were inverted were completed. The majority of the items were eliminated because of different inappropriateness. The reasons for the elimination of the items can be seen in Table 4.

The remaining items (n=14) were found to be appropriate for inclusion in the subsequent analysis and were included in the scale with four factors. Meanwhile it is a requirement that negative items were excluded due the fact that all of the items were written in positive wording style. The items and factors are represented in Table 5. After the analyses, a four-factor solution was

Table 3. Factor Loadings of 18 Items and Cronbach Alpha Reliability of Each Factor

ITEM NO	FACTORS			
	Definition of science and objectivity in science	Characteristics of scientific knowledge	Hierarchy between laws and theories	Tentativeness
1	.732			
2	.719			
3	.690			
4	.689			
5	.676			
6	.647			
7	.615			
8		.799		
9		.790		
10		.784		
11		.667		
12		.612		
13			.821	
14			.805	
15			.783	
16				.813
17				.789
18				.769
Cronbach Alpha Reliability (Total=.51)	.82	.81	.77	.76

Table 4. Elimination of the Items after Principal Component Analysis and Reliability Analysis

Elimination Reason
Only two items loaded on one factor
Lower factor loadings than 0.40
Loaded on two factors at the same time
Negatively loaded on factors
Decreasing the reliability of the scale

reached. The factors explained 57.34% of the total variance (F1 = 23.22%, F2 = 18.08%, F3 = 8.38%, F4 = 7.66%). The scree plot can be seen in Figure 2. Table 6 represents the factor loading of each item and the Cronbach alpha reliability of each factor.

Analysis

In the analyses of the data, multiple linear regression (standard "enter" method) was used. The regression formulas below represent random effects model.

F1 = B0 + B1 Ept1 + B2 Ept2 + B3 Ept3 + B4 Ept4

F2 = B0 + B1 Ept1 + B2 Ept2 + B3 Ept3 + B4 Ept4

F3 = B0 + B1 Ept1 + B2 Ept2 + B3 Ept3 + B4 Ept4

F4 = B0 + B1 Ept1 + B2 Ept2 + B3 Ept3 + B4 Ept4

RESULTS

The results from the descriptive data analysis showed important problems for NOS understandings of the participants. The score of the participants on definition of science and objectivity ($\bar{x}$ = 2.00, sd =.58, min.=1, max.= 4.57) is lower than the mid-point of the scale. This is a sign of naive understanding of the participants in this aspect of NOS. Similarly, they have naive understanding of the hierarchy between law and theory aspect ($\bar{x}$ =1.58, sd=.65, min. = 1, max. =3.67). However, they have higher scores on tentativeness ($\bar{x}$ = 3.95, sd = .66, min. = 1, max. = 5.00) and characteristics of scientific knowledge ($\bar{x}$ = 3.57, sd = .91, min. = 1, max. = 5) aspects than the mid-point of the scale, which is an indication of a developed understanding of these aspects.

The descriptive findings for epistemological beliefs regarding science showed that the participants have neutral beliefs regarding belief in inborn learning ability ($\bar{x}$ = 3.02, sd = .77, min. = 1, max. = 4.80). In other words, they do not strongly believe that learning cannot be improved; it is a stable, inborn characteristic. For the second factor, they are in favour of the belief that learning requires time, it does not occur immediately ($\bar{x}$ = 4.01, sd = .68, min. = 1.67, max. = 5). Similarly, their answers to the items regarding the third factor indicate that they believe that learning ability can be developed by opportunity and support ($\bar{x}$ = 4.23, sd = .57, min. = 2.67, max. = 5.00). For the fourth factor; belief in resource of knowledge, the mean score of the participants shows improved beliefs in favour of the importance of the individual as a resource of knowledge rather than dependence on dominance of authority of the individual ($\bar{x}$ = 3.87, sd = .73, min. = 1, max. = 5).

Results of Multiple Regression Analysis

For the first equation regarding the criterion variable (Factor 1=definition of science and objectivity in science), was significantly related to the epistemological beliefs (R2 = 0.16, F (4; 276) = 13.45, $p<0.001$). The regression equation with weights (Bs) can be seen in the following:

F1 (definition of science and objectivity in science) = 3.95 - .01 Ept1 - .21 Ept2 - .18 Ept3 - .07 Ept4

ZF1 = -.02 ZEpt1 - .25 ZEpt2 - .17 ZEpt3 - .09 ZEpt4

The sample multiple correlation coefficient (R=0.40) shows that 16% of the variation in understandings of definition of science and objectivity in science could be calculated by a linear combination of the predictors. The following investigation of partial correlation displayed that the negative predictors are belief in learning with time (Ept2) and belief in development of learning ability with opportunity and support (Ept3). Ept 2 alone accounted for 6.5% of the variation in understanding related to the first factor, while Ept3 contributed an additional 3.7%. The other factors explained 6.2% of the variation in understandings of definition of science and objectivity in science which was not significant.

The second equation was written for the criterion variable regarding the second factor of the NOS scale (Factor 2=characteristics of scientific knowledge). As a result, the regression equation with all four predictors on epistemological beliefs was extensively related to the second factor of NOS scale (R2 = 0.18, F (4; 276) = 15.19, p = 0.001). The regression equation with weights (Bs) can be seen in the following:

F2 (characteristics of scientific knowledge) = .81 + .16 Ept1 + .30 Ept2 + .09 Ept3 + .05 Ept4

ZF2 = .29 ZEpt1 + .23 ZEpt2 + .07 ZEpt3 + .04 ZEpt4

The sample multiple correlation coefficient (R=0.43) shows that 18% of the variation in understanding of characteristics of scientific knowledge could be calculated by a linear combination of the predictors. The following investigation of partial correlation displayed that the positive predictors are belief in inborn learning ability (Ept1) and belief in learning with time (Ept2). Ept 1 alone accounted for 9% of the variation in understanding related to the second factor, while Ept 2 contributed an additional 5%. The other factors explained 4% of the variation in understanding of characteristics of scientific knowledge which was not significant.

For the third equation regarding the criterion variable (Factor 3=hierarchy between laws and theories), the regression equation with all four predictors of epistemological beliefs was significantly related to the third factor of NOS scale (R2 = 0.19, F

Table 5. Final Items of the Scale after Eliminations and Their Corresponding Factors

No	Factor	Items	Scale				
1.	F1	Somebody is born as smart in science and would be successful in science while the others remain with limited cognitive ability.	5	4	3	2	1
2.	F2	Learning science occurs by accumulation of knowledge in the mind over time.	5	4	3	2	1
3.	F3	Giving separate courses in developing skills in the study of science might be useful.	5	4	3	2	1
4.	F4	Learning amount of students from a science textbook depends on their own abilities.	5	4	3	2	1

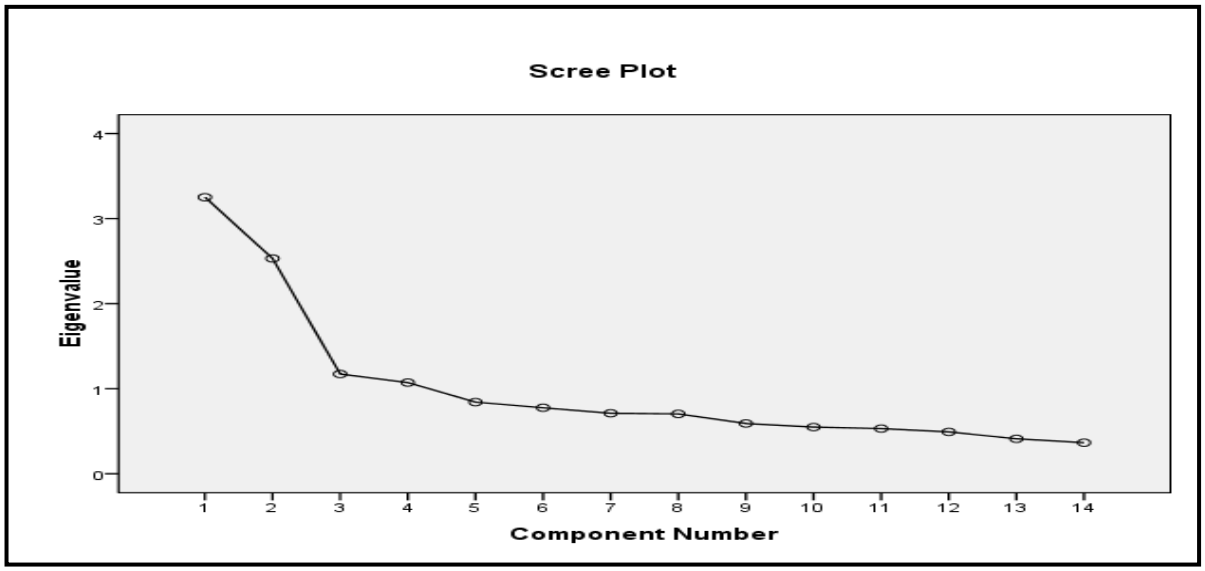

Figure 2. Scree plot for the four-factor solution of the Epistemological Beliefs Scale Regarding Science

(4; 276) = 16.27, p<0.001). The regression equation with weights (Bs) can be seen in the following:

F3 (hierarchy between laws and theories) = 4.04 - .07 Ept1 - .20 Ept2 - .23 Ept3 - .06 Ept4

ZF3 = -.19 ZEpt1 - .21 ZEpt2 - .20 ZEpt3 - .07 ZEpt4

The sample multiple correlation coefficient (R=0.44) shows that 19% of the variation in understanding of hierarchy between laws and theories could be calculated by a linear combination of the predictors. The proceedings investigation of partial correlation displayed that the negative predictors are belief in inborn learning ability (Ept1), belief in learning with time (Ept2) and belief in development of learning ability with opportunity and support (Ept3). Ept 1 alone accounted for 4% of the variation in understanding related to the third factor, while Ept 2 contributed an additional 4.4%. Ept 3 also contributed an additional 4%. The other factors explained 4.6% of the variation in understanding of hierarchy between laws and theories which was not significant.

For the fourth equation regarding the criterion variable (Factor 4= tentativeness), the regression analysis showed that the regression equation with all four predictors of epistemological beliefs was significantly related to the fourth factor of NOS scale (R2 = 0.17, F (4; 276) = 13.81, p < 0.001). The regression equation with weights (Bs) can be seen in the following:

F4 (tentativeness) = 1.72 + .04 Ept1 + .27 Ept2 + .19 Ept3 + .04 Ept4

ZF4 = .10 ZEpt1 + .28 ZEpt2 + .16 ZEpt3 + .04 ZEpt4

The sample multiple correlation coefficient (R=0.41) shows that 17% of the variation in understanding of tentativeness could be calculated by a linear combination of the predictors. The following investigation of partial correlation displayed that the positive predictors are belief in learning with time (Ept2) and belief in development of learning ability with opportunity and support (Ept3). Ept 2 alone accounted for 7% of the variation in understanding related to the fourth factor, while Ept 3 contributed an additional 3%. The other factors explained 7% of the variation in understanding of tentativeness which was not significant.

Table 6. Factor Loadings of Each Item and Cronbach Alpha Reliability of Each Factor in EBSRS

ITEM NO	FACTORS			
	Belief in inborn learning ability	Belief in learning with time	Belief in development of learning ability with opportunity and support	Belief about resource of knowledge
1	.772			
2	.746			
3	.728			
4	.698			
5	.647			
6		.777		
7		.711		
8		.701		
9			.802	
10			.758	
11			.626	
12				768
13				.749
14				.602
Cronbach Alpha Reliability (Total=.75)	.79	.65	.61	.64

DISCUSSION AND IMPLICATIONS

The descriptive findings of this study show insufficiencies in understanding NOS aspects and inappropriate epistemological beliefs. The results on the definition of science and objectivity, and hierarchy between laws and theories aspects highlighted an insufficiency in the understanding of prospective biology teachers of these aspects. However, they had more informed understanding of the tentativeness of scientific knowledge and characteristics of scientific knowledge aspects. Similarly Koksal and Cakiroglu (2010b), by studying 47 science teachers, determined that science teachers had inadequate understandings of the objectivity and hierarchy between laws and theories aspects. The understandings of definition of science aspect are shaped by different factors. By focusing on one of these factors, Bloom (1989) studied 80 prospective teachers and found that prospective teachers define science inappropriately from an anthropocentric point of view. They define science as a "study of the world" by making frequent reference to man. In another study, Koksal and Koksal (2012) showed that medical researchers define science by focusing on study objects such as animals, plants or life. Hence, anthropocentricity might not be the only reason for NOS misunderstandings of definition of science. The misunderstandings of the other two aspects do not have such anthropocentric components, for example Abd-El-Khalick (1998) asserted that participants believing in objectivity in science or hierarchy between laws and theories might not have taken the opportunity to reflect upon and clarify their understandings. Akerson, Abd-El-Khalick and Lederman (2000) supported this assertion that the majority of teacher participants did not have an adequate understanding of the objectivity and hierarchy between laws and theories aspects. They also emphasized a history of reflection in the participants for explaining inadequate understandings of NOS aspects. Actually reflection on NOS aspects is a culture-specific situation, quality and content of making self-assessment vary from culture to culture (Sivak, Soler & Trankle, 1989). So understandings on NOS should also be different in different cultures. Sutherland and Dennick (2002) showed that students from different cultures represented different misunderstandings on NOS aspects. These differences might be related to difference in reflection practices of individuals in different cultures. Non-western cultures have cultural drawbacks involving superstition, to learn about science (Jegede & Okebukola 1991). This drawback might be a reason for insufficient reflection practices, since students have a cultural reason to explain scientific event or science by their cultural beliefs.

As another possible cause of these misunderstandings, namely inappropriate presentation of NOS aspects in biology textbooks has been shown (Irez, 2009). For the aspects of tentativeness and

characteristics of scientific knowledge, the participants had more appropriate understandings than for the first two aspects, but these understandings were near to the mid-point of the scale (neutral). This can be accepted as a transitional phase as stated in Koksal and Cakiroglu (2010b). The authors found that the majority of the participants, including 47 science teachers, had transitional understandings of tentativeness and characteristics of scientific knowledge. These findings on tentativeness and characteristics of scientific knowledge might also be related to the degree of opportunity to reflect upon and clarify the understandings of NOS (Abd-El-Khalick, 1998). In Turkish teacher education programs for biology teachers do not include explicit courses or units on NOS aspects, the prospective biology teachers establish NOS understandings implicitly. Therefore, there are no application including reflection, clarification and use of appropriate materials such as textbooks in biology teacher education programs.

The epistemological beliefs regarding science in this study had four aspects; belief on inborn learning ability, learning with time, learning ability can be developed by opportunity and support and belief in resource of knowledge. Beliefs in inborn learning ability lie at the mid-point of the scale, so the participants' beliefs are neutral for this epistemological aspect. Unal Coban, Ates and Kaya Sengoren (2011), in studying 147 prospective science teachers, also found that beliefs of prospective science teachers were neutral regarding the beliefs in inborn learning ability aspect. Koksal (2011) also studied 411 prospective teachers and reached the same conclusions that prospective teachers' beliefs are neutral with regard to accepting effect of inborn ability on learning. For the other three factors, the participants agreed that learning with time, it does not occur immediately and also that learning ability can be developed by opportunity and support, since the resource of knowledge is the individual's self. In parallel to the findings of this study, Sunger (2007) showed that prospective teachers in his sample (n=68) positively believed in learning with time, it does not occur immediately and the resource of knowledge is individual's self. For the learning improvement with support and opportunity aspect, Cheng, Chan, Tang and Cheng (2009) found similar findings with the current study. They studied 228 prospective teachers and found that prospective teachers believed in improvement of learning ability with support and opportunity.

The predictors of different NOS aspects show that the NOS understandings and epistemological beliefs are shaped by different factors, as stated by Schommer (1994) and Schommer-Aikins (2002), epistemological beliefs are partially independent factors. In the findings of this study, it was found that NOS aspects related to characteristics of knowledge were predicted by two epistemological factors in expected direction. This might be associated with direct emphasis on characteristics of knowledge in these epistemological factors; beliefs in learning with time and improvement in learning with support and opportunity. For the other NOS aspects, there was no direct emphasis on characteristics of knowledge; the results showed the predictors negatively predicted them. These findings represented independent nature of the epistemological factors and their differing associations with the same NOS aspects.

The relationship between the factors of the epistemological beliefs and NOS was found to be significant in this study. When the predictors of NOS aspects were investigated, it was found that being informed about definition of science and place of subjectivity in science was related to belief in quick learning, and limited and stable capacity for learning science in spite of support and opportunity. This relationship might be explained that the participants' experiences on the definitions of science and objectivity, and learning process of them are coming from different resources in spite of their association. There are some resources including insufficient depiction of science, they are media, school textbooks and journals (Song & Kim, 1999; Irez, 2009). Learning science might be confused with stereotyped learning of scientists depicted as a quick learning process (e.g. immediate sparkling when something is learnt) in resources or minds when scientists learn about the unknown (Irez, 2009; Koksal & Koksal, 2012; Meyers, 2007). Hence, scientists are depicted as quick learners. Moreover, it is believed that they have a higher and stable ability, and they do not need additional opportunity and support to learn (Dogan-Bora, Arslan & Cakiroglu, 2006; Koksal & Koksal, 2012). Koksal and Koksal (2012) found that graduate students believed in being quick and intelligent (a stable characteristic) in learning is a characteristic of scientists. Therefore, science knowledge and objectivity in science are associated with a naive understanding of learning science over time and a need for support and opportunity for improving learning ability.

On another finding, it was found that being informed about characteristics of scientific knowledge is associated with being informed about improvable learning ability and learning with time. For this aspect, there is an emphasis on dependence of scientific knowledge upon evidence and observation. Hence, the existence of a developmental observation process and evidence collection makes production of scientific knowledge a time-requiring and change-driven process. In these characteristics, learning is seen as a continuous process which improves with time, and at the same time, learning occurs over time. Kolstø and Mestad (2005) designed a study to provide more appropriate experiences regarding scientific research and they

showed that improvement in knowledge about scientific processes and characteristics of scientific knowledge decreased the use of words such as "proof" and "facts" that were signs of a quick learning process and a final point in learning. Evidence collection is a continuous process and its end-point cannot be called "proof" and "facts" due to the tentative nature of scientific knowledge (Lederman, 2007). Irez (2009) showed that step-by-step learning in the scientific process is emphasized in biology textbooks; this might be a reason for the fixed learning ability belief in science. Since even graduate level students believe in following a step-by-step process to learn about scientific problems (Koksal & Koksal, 2012). Therefore, accepting scientific knowledge production including observation and evidence as a learning type is a significant base to see learning as a time-requiring and improvable process with support and opportunity. Thus, knowing more about the characteristics of scientific knowledge is in line with being informed about improvable learning ability and learning with time.

When looked at the misunderstanding on hierarchy between law and theory, belief in quick learning, belief in innate ability to learn and belief in improvement of learning science with support and opportunity negatively predicted the related NOS aspect. This means that being informed about no hierarchy between law and theory is associated with believing in a requirement for innate ability to learn science, quick occurrence of learning and no improvement in learning with support and opportunity. This relationship might be explained by knowing about differences between laws and theories, but considering scientists when learning process on laws and theories is case. Inappropriate depiction of science in media, school textbooks and journals might be reason of this understanding (Song & Kim, 1999; Irez, 2009). A step-by-step procedure of knowledge production in science is frequently depicted in science textbooks (Irez, 2009; Meyers, 2007) and a quick, stable (intelligence) learning ability of scientists is also believed by students (Dogan-Bora, Arslan & Cakiroglu, 2006; Koksal & Koksal, 2012). All of these depictions and representations might stimulate a fixed innate ability, quick learning and fixed learning beliefs in spite of knowing about the no hierarchy between laws and theories aspect of NOS.

Finally, the tentativeness aspect of NOS is positively predicted by beliefs in learning with time and improvement in learning with support and opportunity. The tentativeness aspect includes believing in change of scientific knowledge, so that learning about scientific knowledge is not seen as a step-by-step truth seeking process and the change in any direction is accepted as natural. In the tentativeness aspect, there is an emphasis on the learning process in which it is acknowledged that learning is a continuous process and takes time. Over time, learned knowledge can be changed according to different conditions. The positive relationship between the tentativeness aspect and beliefs in learning with time and improvement in learning with support and opportunity might be related to the nature of tentativeness shaped by a higher-order learning process with support and accumulation over time.

The most important problems in this study are associated with the low reliability of the instruments. The low reliability might be related to the nature of the topic including epistemological beliefs and NOS because previous studies have also shown low reliability values regarding epistemological beliefs and NOS measurements (Liang et al., 2008; Koksal & Cakiroglu, 2010a; Topcu & Yilmaz-Tuzun, 2009; Schommer-Aikins, Duell & Hutter, 2005). Overall, low reliability is a sign of weak association among the factors of the instruments, but the reliabilities regarding the factors might be an effective starting point for making statistical decisions. In addition, Hatcher and Stepanski (1994) stated that a Cronbach alpha value as low as 0.55 could be considered for statistical consideration in social studies. As another point, Gardner (1975) also emphasized using only factor reliabilities rather than overall reliability in advocating internal consistency of the instruments; he stated that we cannot establish a "dining table index" by only measuring the length of the table legs.

Based on the findings of this study, it can be suggested that designing an epistemologically sound NOS teaching process in biology teacher education requires taking into account beliefs regarding quick learning, innate ability to learn and improvement of learning science with support and opportunity. If implementers consider complementary parts of NOS aspects and related epistemological beliefs in science courses for biology teachers, NOS teaching might be more effective. At the same time, the epistemological roots of misunderstanding of NOS aspects should also be checked for expected change in NOS teaching to prospective biology teachers, due to the fact that the relationships shown in this research highlight the importance of epistemological factors for NOS aspects in the NOS teaching process.

In this research, we have investigated the possible relationship between factors of NOS understanding and epistemological beliefs regarding science of prospective biology teachers. However, our sample is limited to 281 participants from two large-scale universities located in the capital city of Turkey. Therefore, generalizations of the study should be made by considering this situation. As another limitation, total-scale reliability of the NOS scale is low, while the factors of the scale have high reliability values. Finally, it should be said that our study is limited to four factors of NOS aspects and four factors of epistemological beliefs; there is a need to

investigate other aspects of NOS and epistemological beliefs by using more valid and reliable instruments.

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