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An Assessment into Pre-service Biology Teachers' Approaches to the Theory of Evolution and Nature of Science

Biyoloji Öğretmen Adaylarının Evrim Teorisi'ne ve Bilimin Doğasına Bakış Açıları Üzerine Bir Araştırma

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Abstract

This study explores how a group of pre-service biology teachers view the nature of evolutionary theory and how their views about nature of science affect their approaches to the theory of evolution. A total number of 75 pre-service teachers participated in the study. Participants' perceptions of nature of science and the theory of evolution were assessed by a questionnaire and a semi-structured, face-to-face interviews. The results revealed that the participants generally had negative attitudes toward the nature and status of the theory of evolution. Furthermore, a detailed analysis of participants' accounts with regard to the nature of science and the examination of the association of these accounts with their views about the theory of evolution implied a potential relationship.

Keywords nature of science, the theory of evolution, pre-service biology teachers

Öz

Bu çalışma, biyoloji öğretmen adaylarının Evrim Teorisi'ni nasıl algıladıklarını ve bilimin doğasına ilişkin görüşlerin bu algıyı nasıl etkilediğini araştırmaktadır. Çalışmaya toplam 75 öğretmen adayı katılmıştır. Katılımcıların Evrim Teorisi ve bilimin doğasına ilişkin görüşleri bir anket ve yüz yüze yapılan yarı-yapılandırılmış görüşmeler ile araştırılmıştır. Sonuçlar katılımcıların genel olarak Evrim Teorisi'nin doğası ve status konusunda olumsuz görüşlere sahip olduğunu göstermektedir. Katılımcıların bilimin doğasına ilişkin görüşleri ve bu görüşlerin Evrim Teorisi'ne bakışlarına etkisi üzerine yapılan detaylı çözümlemeler, bu iki bilgi alanı arasında potansiyel bir ilişki olduğunu ortaya koymaktadır.

Anahtar Sözcükler Bilimin Doğası, Evrim Teorisi, biyoloji öğretmen adayları.

Summary

Purpose

The theory of evolution is accepted as the unifying paradigm in biological sciences and, in broad terms, the science community is committed to evolution as both an appropriate and essential aspect of science curriculum. Despite the importance of the theory of evolution as the foundation of biology, it is clear that the theory is far from its desired status in the public sphere as it continues to evoke controversy in many countries, including Turkey. Without doubt, elements of school science, especially biology teachers who are primarily responsible for the teaching of evolution, are the most critical factors in educating future generations that have a thorough understanding of the theory of evolution. To this end, this study explores how a group of pre-service biology teachers view the nature of evolutionary theory. By focusing on this, the study also ad-

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dresses the role that understanding about nature of science (NOS) plays in shaping these views.

Results

A detailed analysis of the items in the questionnaire showed that a significant group of the participants presented negative attitudes towards evolutionary theory and its scientific status. The findings pointed out that, in general, the participants of the study did not find the theory of evolution as a reliable theory in biological sciences. For example, 44% of the participants thought that the idea of biological evolution has a speculative nature and do not rely on valid scientific evidence collected through scientific observations and experiments. Sixty-eight percent of the participants did not think or not convinced about that the theory of evolution is supported by adequate scientific evidence. Only 20% of the participants perceived that the available evidence clearly support biological evolution. The fact that the participants of this study did not find the theory of evolution as a scientific theory affected their ideas and approaches about the validity of the theory. Indeed, only around half of the participants saw the theory as a valid scientific theory.

The study also revealed that the majority, if not all, of the participants in this study also held some inadequate and inconsistent conceptions about NOS. Overall group percentages with regard to certain aspects of NOS were extremely low. The most problematic aspects of science for the participants were the role of indirect evidence in science, the relationship between scientific theories and laws, and the inferential nature of most theories.

Discussion

The implications of the findings are not encouraging. Biology teachers who have negative attitudes toward the nature and status of the theory of evolution will inevitably hesitate to teach this theory to their students and will never be able to inspire students in a subject that is intrinsically difficult to come to grips with. Thinking the significant role of the theory of evolution in understanding and relating various biological explanations and concepts, it may also be argued that the vast majority of students of such teachers would complete their education with unclear and unexamined conceptions of the theory of evolution and a deep understanding of biology. This would inevitably jeopardize the promotion of scientific and biological literacy in society.

On the other hand, the detailed analysis of the selected participants' accounts with regard to NOS and examination of the association of these accounts' with their views about the theory of evolution implied a potential relationship. This relationship is especially obvious when the participants with positive attitudes about the theory of evolution expressed informed views about the nature of scientific theories and the role of direct evidence in science. Clearly, such one-to-one connections support the existence of a conceptual level relationship between the two belief systems and display how specific beliefs regarding NOS influence individuals' conceptualizations of the theory of evolution. The fact that the participants with positive attitudes toward the theory of evolution expressed relatively more informed ideas about various aspects of science further supported this relationship.

Conclusion

These results point out that more effective education should be given to pre-service biology teachers with regard to the theory of evolution. As an informed understanding of NOS appeared as a prerequisite for understanding the theory of evolution, any course design intended to teach evolution should pay a special attention to NOS. Without a doubt, biology teachers with differentiated and integrated understanding of NOS and the theory of evolution will have greater ability than those whose understanding is limited and inconsistent, to plan and deliver lessons that help students develop deeper and adequate understandings with respect to biology's prime paradigm.

Introduction

The theory of evolution is accepted as a unifying paradigm in biological sciences; so much that Dobzhansky (1973) went so far as to say that 'nothing in biology makes sense except in the light of evolution' (p.125). In broad terms, the science community is committed to evolution as both an appropriate and essential aspect of the school science curriculum (National Research Council, 1998; Smith, 2010) as one sees in the quote from Dobzhansky. Indeed, many curriculum documents highlight evolution as one of the most important biological concepts to be taught in schools. Despite the importance of the theory of evolution as the foundation of biology, it is clear that the theory is far from its desired status in the public sphere and continues to evoke controversy in many countries. Indeed, the beliefs, attitudes, and knowledge of many different populations have been investigated; all are characterized by low levels of understanding and acceptance of evolution, as well as the occurrence of many misconceptions (Dagher & BouJaoude, 1997; Nehm, Kim, & Sheppard, 2009; Smith, 2010).

Without a doubt, school science emerges as one of the most critical factors affecting individuals' approach as it has the primary responsibility in educating future generations that have a thorough understanding of the theory of evolution. There has been extensive research regarding students' perceptions of the theory of evolution. Reviewing the research on students' conceptions of the theory of evolution is beyond the scope of this research. However, it is important to note that investigations by many researchers (Deniz, Donnelly, & Yilmaz, 2008; Hokayem & BouJaoude, 2008; Kampourakis & Zogza, 2007; Nehm, Kim, & Sheppard 2009; Peker, Comert, & Kence, 2010) on different student populations and in different contexts have revealed a strong objection of students' towards the theory. Science education research has revealed that one or more of the following arguments are utilized by students in their objections to the theory of evolution: a) conceptual difficulties b) extra scientific explanations (e.g. Aristotelian ideas), c) faulty understanding of nature of science, and d) religious beliefs (Dagher & BouJaoude, 1997).

Such disappointing results have led to an explosion of research concerning the teaching and learning of evolution in schools and, with this movement, science teachers' views of the theory of evolution have become the focus of attention. Research has pointed out that despite overwhelming agreement in science and science education communities, teaching evolution remains a problematic subject in schools. The results of this research revealed that large percentages of science teachers - close to a majority in many samples -reject or are uninformed about evolutionary theory (Nehm & Schonfeld, 2007). This situation, of course, has been perceived as the major barrier in evolution education. Clearly, science teachers who are knowledgeable about and who have a comprehensive understanding of the theory of evolution play a central role in promoting a thorough understanding of the theory of evolution in society. The importance of teacher education programmes in preparing teachers for this challenge is well recognized. There have been many implementations in developing both in-service and pre-service science teachers' conceptions of the theory of evolution. Although new courses and materials have been developed and some success has been reported, research indicates that that it is very difficult to bring conceptual change about evolution in spite of formal instruction and learning materials designed for that purpose (Demastes, Good, Sundberg, & Dini, 1992; Settlage, 1994).

For some researchers, the failure in efforts to manage conceptual change with respect to evolution stems from the failure of the recognition of the conceptual ecology of individuals, which requires recognizing the whole set of ideas one carries with him or her to the classroom. Epistemological beliefs about science constitute a part of the conceptual ecology of individuals and it is argued that there is a critical relation between individuals' conceptions of nature of science (NOS) and their views of the theory of evolution (Hokayem & Boujoude, 2008).

NOS has been defined in many ways in science education literature. The most cited definition of NOS is that by Lederman and Zeidler (1987) in which they refer to the values and beliefs inherent in scientific knowledge and its development. More specifically, McComas, Clough, and

Almozroa (1998) define NOS as

> . . . a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours. (p. 4)

Accordingly, science is more than just facts, laws, and theories. Although science includes facts, laws, and theories as a human activity, it is also composed of scientists doing investigations, the attitudes and beliefs these scientists hold, the processes they use, the community within science, and so on. In its contemporary meaning, science emerges as a special way of knowing. It is accepted that there are methods and standards in science, but that they can vary from science to science and can, within science, be changed, and changed for the better (Chalmers, 1999). One of the central aspects of science is that all scientific knowledge, including "facts," "theories," and "laws," is tentative. Reasons for this stem from several other aspects, such as (a) scientific knowledge has a basis in empirical evidence, (b) empirical evidence is collected and interpreted based on current scientific perspectives as well as personal subjectivity due to scientists' values, knowledge, and prior experiences, (c) scientific knowledge is the product of human imagination and creativity, and (d) the direction and products of scientific investigations are influenced by the society and culture in which the science is conducted (Schwartz & Lederman, 2002, p. 207).

Today, many researchers accept NOS as a fundamental component of scientific literacy. Lederman (1999), for example, claims that 'an understanding of the nature of science will enable students to be more informed consumers of science, which will empower them to make more informed decisions when scientific claims and data are involved.' (p.916). McComas and others (1998) approach the issue from a very similar perspective. They state that despite the enormous effect of developing science in the last century, few individuals in society have an elementary understanding of how scientific enterprise operates. They believe that this lack of understanding is potentially harmful, particularly in societies where citizens have a voice in science funding decisions, evaluating policy matters and weighing scientific evidence provided in legal proceedings. They argue that at the foundation of many illogical decisions and unreasonable positions are misunderstandings of the character of science.

Investigations dealing with the relationships between aspects of NOS and understanding the theory of evolution are still in their beginnings. However, limited research in this domain has revealed some positive correlation between individuals' understanding of these two concepts. Sharmann and Harris (1992), for example, integrated the history and nature of science and content about the theory of evolution in their intervention with secondary teachers. Results of this study revealed more tolerance towards the theory of evolution. Dagher and BouJaoude (2005) found that most students considered experimentation rather than historical evidence as a necessary tool in arriving at scientific knowledge. Moreover, Brickhouse, Dagher, Letts and Shipman (2000) showed that even when an astronomy professor explicitly addressed NOS in his course, empirical evidence remained the priority in identifying knowledge as scientific by the students and rarely did anyone consider the historical non-demonstrative evidence as valid. Although there are some other studies that are promising and documented some positive correlation between understanding of the nature of evolutionary theory and NOS (e.g. Lederman, 2007; Smith, 2010; Smith & Scharmann, 2008) research on the effect of epistemological beliefs on accepting the theory of evolution remains an open question (Hokayem & Boujoude, 2008) and there is still need for further empirical studies which will reveal the details and nature of this relationship.

To this end, this study presents a further attempt to explore the nature of this relationship. It aims to assess this relationship in the context of pre-service teacher education. Without a doubt, biology teachers have the primary responsibility in educating future generations that have a thorough understanding of the theory of evolution. This necessarily requires well equipped and informed teachers with regard to the theory of evolution. Therefore, assessing teachers' views about

the theory of evolution and the factors affecting their approaches are of paramount importance. This assessment is especially critical in initial teacher education level, where pre-service teachers develop necessary knowledge and understanding that will guide them throughout their professional lives. Therefore, this study explores how a group of pre-service biology teachers view the nature of evolutionary theory. By focusing on this, we also address the role NOS understanding plays in shaping their views. Such an assessment will inform us about how the content of a typical teacher education program should include to develop pre-service teachers' views about the theory of evolution and how, if it does, understanding about NOS affect perceptions about the theory of evolution.

Method

Research Sample

This investigation was undertaken in spring 2008 semester, at a major teacher education institution in Istanbul. A total number of 75 pre-service teachers participated in the study. Of these participants, 39 were at the fourth and 36 were at the final year of their five-year biology teacher education program. The reason for including both fourth and fifth year students in the sample was the fact that both these groups had completed their studies in the content (biology) part of their program and were taking courses on pedagogy only. Therefore, both these groups, theoretically at least, at the similar knowledge and experience level in biology content. Participants' perceptions of NOS and the theory of evolution were assessed by a questionnaire and semi-structured, face-to-face interviews. The participants' perceptions with regard to these domains were analyzed seperately first, then the relationship between the two analyzed in later stages of the study.

Instruments of the Study

The Questionnaire

Participants' acceptance of and approaches to the theory of evolution was assessed by the Measure of Acceptance of the Theory of Evolution (MATE) developed by Rutledge and Warden (1999). The measure consists of 20 items and was designed to assess the participants' views about *the reliability and validity of evolutionary theory, the nature of evidence about evolution and, the variety of life.* Since its development, the measure has been used by many researchers in many contexts (e.g. Rutlage & Warden, 1999; 2000), including Turkey (e.g. Deniz, Donnelly, & Yilmaz, 2008; Peker, Comert, & Kence, 2010). In these studies, the researchers reported high levels of internal consistency (.92 and .91 respectively). Before its administration, the measure was translated into Turkish by the researchers. To make the Turkish version of the MATE more context-relevant, 5 items which specifically refer to the age of the earth and Bible were removed as the participants in the Turkish context were not familiar with such concepts. At the end of such process, the Turkish version of the MATE consisted of 15 items. A panel of experts compared and revised the translated version and concluded that the Turkish version of the measure correctly reflected the original version. The Cronbach's alpha value for the internal consistency of the Turkish version of the MATE was found to be .87. The participants recorded their responses to the items on a five-point Likert-type frequency response scale. The categories in this scale ranged from 'strongly disagree' to 'strongly agree'. The responses to the items were analyzed through descriptive statistics.

Interviews

Participants' understanding of NOS was assessed through interviews. Towards this end, purposive sampling strategy was utilized as the aim of this stage of the study was to explore the potential relationship between attitudes towards the theory of evolution and understanding NOS. In this sampling strategy, the researcher actively selects the most productive sample to answer the research question (Marshall, 1996). To this end, in light of the analysis of the responses

to the measure, 5 participants (all females) who emerged as having the most positive attitudes towards the theory of evolution in the sample (individual mean values between 3.53 and 3.87) and 5 participants (2 males and 3 females) who identified as having the most negative attitudes towards the theory of evolution (individual mean values between 1.00 and 2.13) were invited for interviews. Semi-structured interviews with these 10 selected participants were conducted in order to assess their understandings of NOS in detail. The questions of the Views on Nature of Science Questionnaire – Form C (Abd-El-Khalick, Lederman, & Schwartz, 2001) were utilized as guiding interview questions. The original form of the VNOS questionnaire was developed by Lederman and O'Malley (1990) and consisted of seven open-ended questions. It was used in conjunction with follow-up individual interviews to assess high school students' views of the tentative nature of science (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001). In 1998, the questionnaire was modified twice and the final form (Form C) based on 10 questions was developed by Abd-El-Khalick et al. (2001). Although the original questionnaire was developed as a paper-and-pencil instrument, the questions were also appropriate for use in interviews since they were open-ended (Irez, 2006). Through these questions, the participants' views about several aspects of NOS were assessed. These aspects included, for example, the empirical and tentative nature of scientific knowledge, the nature of scientific method and scientific theories, the creative and imaginative nature of science, the subjective nature of scientific knowledge, and social and cultural influences on scientific knowledge. The significance of these aspects is that they, when considered together, cover much of what is central to the description of what NOS is and, therefore, helped reveal a complete picture of the participants' beliefs about NOS.

Interviews lasted between one to one-and-half hours. In these interviews, participants' views about various aspects of science, such as the tentative nature of scientific knowledge, the nature of scientific theories and laws and, scientific method, were assessed with special reference to the theory of evolution. That is; when the participants expressed their views about an aspect of science, the following question was about if their perspectives were the same in the case of the theory of evolution. The interviews were audio-recorded and then transcribed verbatim. In order to provide anonymity, pseudo names were used to represent the participants in this study.

Results

Participants' views about the theory of evolution

The overall analysis of the participants' responses to the items in the questionnaire reveals that the mean value was 2.99, indicating that the group presented an 'undecided' position with regard to the nature and the status of the theory of evolution. However, the detailed analysis of the items in the questionnaire showed that significant part of the participants presented negative attitudes towards evolutionary theory and its scientific status.

Table 1 presents the distribution of the participants' responses to the questionnaire items. The four dimensions by which the participants' attitudes toward the theory of evolution are presented are placed on the left column of the table. The questionnaire items related to these dimensions are presented in the middle column and the distribution of the participants' responses to these items is on the right column of the table.

The first dimension in this framework was about the reliability of the theory of evolution. As seen in the table, almost half of the participants (48%) disagreed with the statement that the theory of evolution is based on speculation rather than valid scientific observations and experiments (Q2). On the other hand, 44% of the participants thought that the idea of biological evolution has a speculative nature and do not rely on valid scientific evidence collected through scientific observations and experiments. This finding was further supported by the participants' responses to the Q7. Only 32% of the participants viewed that the theory is supported by a significant body of data. %37.6 of the participants, however, did not agree with this statement and 30.4%

presented an undecided view. When we add up these numbers, it can be concluded that 68% of the participants did not think or not convinced about that the theory of evolution is supported by adequate scientific evidence. Another question in this dimension was about the quality of the available evidence with regard to the theory of evolution. Strikingly, only 20% of the participants perceived that the available evidence clearly support the biological evolution. In contrast, half of the participants found the available evidence unclear and ambiguous and, 28% were undecided about the quality and the nature of available evidence supporting the theory. These findings point out that, in general, the participants of the study, that is biology teachers of the next generation, did not find the theory of evolution as a reliable theory in biological sciences.

Perhaps, the fact that the participants of this study did not find the theory of evolution as a scientific theory affected their ideas and approaches about the validity of the theory (M: 2.98). Indeed, as a response to the questions 1 and 8, which were assessed participants' views on whether the theory of evolution is a valid scientific theory, only around half of the participants (44% and 54.8% respectively) provided positive responses. Although there were around 10% differences between the responses to these similar questions, which might be an indication of the existence of undecided participants within this group, the results point out that around half of the participants did perceive

Table 1.

The distribution of the participants' responses to the questionnaire items

Dimension	Items	Agree %	Disagree %	Undecided %
The reliability of the theory of evolution (M: 2.84)	Q2 The theory of evolution is based on speculation and not valid scientific observation and testing	44	48	8
	Q7 There is a considerable body of data that supports evolutionary theory.	32	37.6	30.4
	Q14 The available evidence is ambiguous as to whether evolution actually occurs.	52	20	28
Scientific validity of the theory of evolution (M: 2.98)	Q1 Evolution is a valid scientific theory.	44	36	20
	Q4 Much of the scientific community doubts if evolution occurs.	49.4	26.6	24
	Q8 Evolution is not a valid scientific theory.	32	54.8	13.2
	Q9 Most scientists accept evolutionary theory to be a scientifically valid theory.	32	45.3	22.7
	Q15 Current evolutionary theory is the result of sound scientific research and methodology.	32	46.7	21.3
The nature of evidence (M: 3.26)	Q5 The theory of evolution is incapable of being scientifically tested	38.7	41.3	20
	Q10 Evolutionary theory generates testable predictions with respect to the relationships of living things	56	22.7	21.3
	Q11 Evolutionary theory is supported by factual, historical, and laboratory data.	62.7	25.3	12
Variety of life (M: 2.92)	Q3 Organisms existing today are the result of evolutionary processes that have occurred over millions of years	54.7	32	13.3
	Q6 Modern humans are the product of evolutionary processes that have occurred over millions of years.	29.3	53.4	17.3
	Q12 Humans exist today in the same form in which they always have.	54.4	36.3	9.3
	Q13 The theory of evolution brings meaning to the diverse characters and behaviors observed in living things	52.7	32.5	14.8
Overall (M: 2.99)				

the theory as a valid scientific theory (36% for the Q1 and 32% for the Q8) or were skeptical about its validity (20% for the Q1 and 13.2% for the Q8). The participants' negative or skeptical views about the validity of the theory of evolution might be linked to their perceptions of scientific community's reception of the theory. As response to the questions (Q4 and Q9) assessing the participants' perceptions of scientific community's reaction to the theory of evolution, almost half of the participants (49.4%) believed that much of the scientific community doubts if evolution occurs and a significant part (45.3%) believed that most scientists did not accept evolutionary theory as a scientifically valid theory. Further, the percentages of the participants who were undecided about these two questions were not insignificant (24% and 22.7% respectively). Another factor contributing to the participants' negative approaches to the validity of the theory of evolution might be related to their perceptions of the methodological approaches utilized in evolutionary studies. The results indicated that the majority of the participants either did not accept the methods of evolutionary biology as valid and reliable or undecided about the validity of methodological approaches. Only 32% accepted that the knowledge produced in this domain is a result of sound scientific research and methodology.

The participants presented unclear views about the third dimension, which was the nature of the evidence in evolutionary biology. Somewhat inconsistent with the views declared to the other questions with regard to the validity and reliability of the theory of evolution as a scientific theory, the majority of the participants (62.7%) articulated that the theory of evolution is supported by factual, historical and, empirical data. Similarly, 56% of the participants viewed that the predictions generated by evolutionary theory with regard to the relationships of living things are testable. By looking at these results, one may infer that the majority of the participants had an informed understanding of the nature of evidence in evolutionary theory. However, in response to a similar question (Q5), only 38.7% of the participants declared that the theory of evolution is capable of being scientifically tested. An explanation to the controversy between the responses of the participants might be that while the majority of the participants perceived some knowledge in evolutionary biology, such as the relationship amongst living things as scientifically valid, they were skeptical about some of the explanations that the theory of evolution suggested. Support to this tentative conclusion might be found in the responses of the participants to the questionnaire items in the last dimension.

Indeed, the participants' responses to the items in the dimension related to the variety of life indicated that the participants did not grant the same value to all explanations of the theory of evolution. Consistent with the responses provided in the previous dimension, more than half of the participants (54.7%) accepted one of the main claims of the theory of evolution that organisms existing today are the result of evolutionary processes that have occurred over millions of years (Q3). Hence, a significant part of the participants (52.7%) agreed that the theory of evolution brings a meaning and explanation to the diversity of characters and behaviors observed in living things (Q13). On the other hand, results pointed out an objection (%53.4) to the claim that modern humans are also products of evolutionary processes (Q6). Those who believed that humans that exist today are in the same form in which they always have make up 54.4% of the participants.

Analysis of the participants' understandings about NOS

As it was explained above, semi structured interviews were conducted with 10 of the participants (five with negative attitudes and five with positive attitudes) in order to assess their understanding of NOS. At the end, any potential relationship between their approaches to the theory of evolution and understanding of NOS was examined. In this section, the participants' views about NOS are presented first, then, the discussion will then proceed to the examination of any potential relationship between their approaches to the theory of evolution and understanding of NOS.

The interviews yielded rich data about the participants' views about NOS. The findings concerning the participants' beliefs about NOS are summarized in Table 2. This table presents the participants' conceptions about different aspects of science in relation to each other. It also al-

lows making comparisons across the individuals regarding their understandings. In the left-hand column of the table are the themes and statements that have been frequently cited by science education reform documents (e.g., AAAS, 1993) and researchers in various studies (e.g., Abd-El-Khalick et al., 2001; McComas & Olson, 1998; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003, Irez, 2006). These themes and statements are considered as adequate statements reflecting and highlighting at least some aspects of science. Using these statements and themes, a holistic summary of the participants' understandings of NOS was constructed. The participants are placed at the top row. The '■' symbol in each participant's cell corresponding to each theme or statement shows the participant's agreement with the theme or statement in consideration. If there is no symbol then it means that the participant disagreed with that statement. The last column on the right-hand side gives the total number and percentage of the participants agreeing with the theme or statement. By looking at these percentages, one can identify the problematic areas within the group. The last row at the bottom of the table, in Table 2 other hand, reveals the total individual scores. The reader can see each individual's rate and percentage of agreement with all the themes and statements presented.

Table 2.
Overall analysis of the participants' beliefs about NOS

NOS Aspect	Negative attitude toward evolution					Positive attitude toward evolution					Total
	Rıdvan	Emrah	Ayse	Pelin	Sema	Turkan	Eylul	Hulya	Seda	Cigdem	
Description of Science											
Science as a way of knowing			■	■		■	■	■			5 (50%)
The empirical NOS											
Does not rely solely on direct evidence						■				■	2 (20%)
Scientific method											
No single scientific method						■		■	■		3 (30%)
Is not a step-wise procedure								■	■		2 (20%)
The tentative NOS											
Scientific knowledge is tentative		■		■		■	■			■	5 (50%)
Theories and laws											
Theories are well sustained		■				■	■	■	■	■	6 (60%)
Theories may change		■		■		■				■	4 (40%)
Due to new evidence	■	■									2 (20%)
Reconsidering existing evidence		■		■		■	■				4 (40%)
Laws may change	■	■					■				3 (30%)
No hierarchical relationship											0 (0%)
Inference and theoretical entities											
Inferential nature of some theories						■				■	2 (20%)
Creativity and imagination in science											
Involves imagination and creativity				■			■		■		3 (30%)
Total	2 (15%)	6 (46%)	1 (8%)	5 (38%)	0 (0%)	8 (62%)	6 (46%)	4 (31%)	4 (31%)	5 (38%)	41/130 (32%)
	14/65 (26%)					27/65 (42%)					

Research literature clearly indicates that students, teachers, lay people and even scientists do not possess adequate conceptions about many aspects of NOS (Lederman, 1992; McComas, 1998). This research revealed that the majority, if not all, of the participants in this study also held some inadequate and inconsistent conceptions about NOS.

As seen in the table, there are 13 statements about various aspects of science. Analysis of the interviews revealed that the group's performance was 41/130, which is 32%. It is important to note that the total percentages of the participants' agreed with the related themes and statements did not exceed 60% on any of these aspects of science. Overall group percentages with regard to certain aspects of NOS were extremely low and need careful analysis.

The table reveals that only 2 participants indicated that science *'does not rely solely on direct evidence'*. These participants, Turkan and Cigdem, emphasized that scientists make use of indirect evidence in producing explanations about natural phenomena:

You need evidence for scientific claims; you need to show it to others, if you are unable to show it directly then you need to use indirect evidence. There may be some phenomena that cannot be observed directly, but they might be explained using indirect ways. Consider the explanation about space for example; people were able to understand the spherical shape of the earth using indirect evidence. (Turkan)

A similar approach was presented by Cigdem. Her example was that the nature of evidence supports the theory of evolution:

We see [understand] evolution indirectly, there is a lot of indirect evidence and we bring them together… One day enough evidence could be accumulated and the theory of evolution might become a scientific law. (Cigdem)

No doubt that, one striking statement in Cigdem's explanation, apart from her explanation about the role of indirect evidence, was about the relationship between scientific theories and laws. Many researchers reported a common misconception amongst pupils, teachers and lay people (e.g. Aikenhead & Ryan, 1992; Abell & Smith, 1994; Mueller & Wawering, 1999) that scientific theories become laws when proven after repeated testing. This belief was also common amongst the participants of this study. Indeed, the interviews revealed that all participants held a belief that there is a hierarchical relationship between the two:

Theories become laws when they reach a status that no objection against the theory exists in the scientific community. This is why the theory of evolution is still a theory. Of course it is a scientific theory. But it needs to become a law to be accepted as the truth. (Pelin)

… a theory is produced and if it is proven and accepted by everybody, it becomes a law. This is how our knowledge grows. (Sema)

Theories are yet to become laws, that is, they are not supported and accepted by all scientists, they are subject to further investigations. (Turkan)

As can be seen, some participants who hold this view did not only believe that theories become laws depending on the availability of supporting evidence and therefore laws have higher status (Lederman, 1998), but also often fail to appreciate the status of scientific theories, as they believe that only scientific laws represent the 'truth' (McComas, 1998).

Consistent with the groups' naïve ideas about the importance and role of indirect evidence in science and the relationship between scientific theories and laws, analysis revealed that majority of the participants did not appreciate the inferential nature of most theories and the place of theoretical entities in science.

There were other aspects of science about which the participants presented mostly naïve views. As can be seen in the table, the majority (7) believed that there exists a universal scientific method. Further, eight the participants claimed that this method is a stepwise procedure. This finding has been commonly reported in many studies of students' and teachers' beliefs (e.g. Mc-

Comas, 1998; Abd-El-Khalick *et al.*, 2001).

In a similar fashion the majority of the participants expressed inadequate views regarding the tentative NOS. Only five participants acknowledged the tentative nature of scientific knowledge. However, somewhat inconsistent with this finding and showing the inconsistency in participants' depiction of science, the majority (7) believed that laws do not change.

By comparison, the group's percentages were much higher in some statements about science. Five out of ten viewed science as 'a' way of knowing as opposed to 'the' way of knowing. Six participants declared that scientific theories are sustained.

Despite this discouraging picture revealed by the groups' overall performance, analysis revealed that some participants performed better comparing to others. One can see each individual's score by looking at the bottom of the table. This analysis is important, as it will help us analyze the potential relationship between participants' attitudes toward the theory of evolution and their understandings of NOS.

As can be seen in the table, individual percentages varied from 0% to 62%. The participants who performed significantly better comparing to others were Turkan, Eylul, and Emrah, respectively. The analysis of the interviews conducted with Turkan revealed that she reported consistent views with eight of the 13 (62%) statements provided in the table. Eylul and Emrah presented consistent views with six of the 13 (46) statements. Interestingly, one of the participants, Sema, did not present any view that was consistent with the contemporary views about science. She continually presented inadequate conceptions about science such as her belief in science's reliance solely on direct evidence and their understanding of theory as an unsubstantiated idea. Interviews also revealed some crucial misunderstandings in her conceptions, such as her belief in the hierarchical relationship between scientific theories and laws. It is important to note that her score in the MATE was 1, indicating a strong objection to the theory of evolution.

Analysis of the relationship between the attitudes toward the theory of evolution and the understandings of NOS

Table 2 reveals that, in general, the participants with positive attitudes toward the theory of evolution presented relatively more informed ideas with regard to NOS than those with negative attitudes. Overall score of the participants with positive attitudes was 42% (27/65) whereas overall score of those with negative attitudes was 26% (14/65).

The most significant difference between the participants with positive and negative attitudes toward the theory of evolution appeared to be their approaches to the status of scientific theories. Notably, all participants with positive attitudes toward the theory of evolution argued that scientific theories are well sustained and supported by evidence. Even though many of these participants admitted that they did not feel themselves fully knowledgeable about the theory, they appreciated the status of the theory:

No doubt that it is a scientific theory… I do not feel that I have enough knowledge about, but it is a reliable scientific theory, and presents us a framework to understand the nature. (Eylul)

Turkan's views further support that an informed understanding of NOS might be a powerful contributor in appreciating the status of the theory of evolution as a scientific theory:

I see myself insufficient with regard to the theory. I know that I do not posses adequate and sufficient knowledge, but, it is a scientific theory. Because, like all other scientific theories, it is falsifiable. If it is falsified it might be abandoned, but as it is yet to be falsified, it is a valid and well supported scientific theory. (Turkan)

On the contrary, only one of the participants (Emrah) in the opposite group believed that theories are well supported. This indicates that one of the main reasons for refusing the theory of evolution may be the incorrect belief that theories are not adequately sustained or supported. Emrah's views about the status the theory of evolution, on the other hand, once again provide

evidence how misunderstanding the nature of theories affects individuals' approach to the theory of evolution:

It is true that Darwin's theory is a scientific theory, but as I said it is a scientific idea that has not been proven… Therefore I cannot say that evolution occurs… there is a significant difference between a theory and law. (Emrah)

The rest of the participants with negative attitudes toward the theory of evolution claimed that articulation of evolutionary theory as a "theory" clearly proves that the idea is not true:

It [the theory of evolution] might be a scientific theory, but in order to call it 'true' it needs to become a law. (Pelin)

As discussed earlier, the majority of the participants presented naïve ideas about the nature of evidence in science in that they believed that science uses only direct evidence. However, the fact that both the two participants who discussed that science does not solely depend on direct evidence were members of the group with positive attitudes toward the theory of evolution points out a relationship between understanding the role of indirect evidence in science and the validity of the theory of evolution (see earlier quotes by Turkan and Cigdem). The accounts of the participants with negative attitudes further supported the relationship:

It [the theory of evolution] is not scientific. It is not well supported; it neither has validity nor support behind it, because there is no evidence. You need concrete evidence for validity, you need visible evidence. (Ridvan)

Another significant finding was about the participants' views of scientific method. Research evidence point out that individuals may approach some claims as non-scientific if they perceive that the claim did not follow the steps of so-called universal scientific method (hypothesis-experiment-theory-law) (Dagher & Boujaoude, 2005). Similarly, some of the participants in this study claimed that the theory of evolution did not complete all of the steps of the scientific method. Sema, for example, appeared to reject the theory of evolution on this basis:

… there needs to be a hypothesis first, then experiments follow, you prove your claim with experiments and observations. But it [the theory of evolution] is yet to be proven, it is not universal and completed. (Sema)

On the other hand, the fact that the participants who rejected the existence of such a method were the members of the group with positive attitudes toward the theory provide further support for such relationship:

… we can talk about scientific method but every individual scientist might have his/her own approach to the problems… that is; investigations in science does not and should not have boundaries. (Turkan)

Scientific method is not something that, as traditionally considered, you produce a hypothesis and so on. Each scientist has his/her own way… the questions asked and the method used in producing answers are quite individualistic. (Hulya)

Conclusion and Discussion

This study was designed to assess a group of pre-service biology teachers' understandings about the theory of evolution and NOS and, thus, to examine the potential relationship between these two domains. The results revealed that the participants generally had negative attitudes toward the nature and status of the theory of evolution. These results confirm the results of previous research conducted with large segments of the populations surveyed in several countries (e.g. Miller, Scott, & Okamoto, 2006; Nehm, Kim, & Sheppard 2009; Smith, 2010). One can easily anticipate that, amongst all segments of the populations, teachers constitute the most important ones when it comes to teaching the theory of evolution.

When one looks at the results of this research from this perspective, the implications are not encouraging. Biology teachers who have negative attitudes toward the nature and status of the theory of evolution will inevitably hesitate to teach the theory to their students and will never be able to inspire students in a subject that intrinsically difficult to come to grips with. Thinking the significant role of the theory of evolution in understanding and relating various biological explanations and concepts (Smith, 2010), it may also be argued that the vast majority of students of such teachers would complete their education with unclear and unexamined conceptions of the theory of evolution and a deep understanding of biology. Recent research on the teaching and learning of the theory of evolution in Turkey supports such conclusion. A recent research published in the *Science* magazine, for example, revealed that Turkey and the USA are the two countries where the theory of evolution is least accepted (Miller, Scott, & Okamoto, 2006).

One can anticipate that many factors have share in Turkish public's low support to the theory. It is considered that, for example, one of the reasons of this strong rejection is the religious beliefs. Turkey's population is around 70 million, 99% of the population is believed to be Muslim. Deniz, Donelly and Yilmaz (2008) pointed out that accepting evolutionary theory in this context has deep social and cultural implications. They explain that, generally, evolution is considered as a form of atheism and acceptance of evolutionary theory is equated with the rejection of God. Therefore, many religious people are compelled to reject evolution because they think that acceptance of evolutionary theory and belief in God cannot coexist.

A review of the related literature also points out that formal education has also an important effect of general society's approach to the theory of evolution. Turkey has a highly centralized education system. There is a national curriculum that all teachers need to follow. Therefore, teachers are not allowed to select the content. Science is a compulsory subject in both elementary and secondary education. There is an integrated science approach in the elementary education, whereas physics, chemistry, and biology are taught as separate subjects at each grade throughout the grades 9–12 in the secondary curriculum. The topics related to the origins of life and the theory of evolution are first introduced to students at the 8th grade of primary education. However, the scope of these topics at this level is quite narrow and research acknowledges that 8th grade science textbooks lack adequate conceptual knowledge and framework which is necessary for understand the theory (Somel, 2007). The place and content of the theory of evolution in secondary biology curriculum (and biology textbooks accompanied teaching) has also been criticized by many researchers (Somel, 2007; Peker, Comert & Kence, 2010). "The origins of life" unit is introduced at the 12th grade to those who select science in secondary schools. Peker, Comert and Kence (2010), in their recent study, point out that students who opt to study non-science fields at high school are graduated with only two hours of biology per week at 9th grade with no mention of evolution theory because evolution is covered later in biology which is not part of the non-science course track. Further, 12th grade is a critical grade in a typical Turkish student's life, because the University Entrance Examination takes place at the end of this grade. Rate of absenteeism amongst the students is very high at this grade as students choose to study at home or follow University Entrance Examination preparation courses. This negatively affects evolution education. Peker, Comert and Kence (2010) draw attention to that even students who attend classes have limited access to a scientific perspective on evolution because in the ''The Origin of Life and Evolution'' unit, the curriculum and biology textbooks introduces the creationism as an alternative idea to the evolutionary theory to explain the origin of living things. Furthermore, the evolutionary theory is not taught as unifying theory in biology curriculum, but rather presented as an isolated ''view'' about the origin of life among some other non-scientific views (Peker, Comert, & Kence, 2010).

Research indicates that the situation is not better on the teaching of the theory of evolution. Many biology teachers are uncomfortable teaching evolution because they feel the pressure of communities that oppose the teaching of evolution, and also there are biology teachers who do

not accept the theory of evolution at the first place; and therefore, they are reluctant to teach it (Somel, Somel, Tan, & Kence, 2006; Peker, Comert, & Kence, 2010).

Research acknowledges that the failure of science teacher preparation programs in providing effective courses on evolution is not unique to Turkey. However, the need for deeper understanding of the theory of evolution is now widely recognized and even called for by national science bodies and federal governments as a necessary part of the very practical business of repairing national and global economies (Miller, Scott, & Okamoto, 2006; Smith, 2010). Here, we echo Smith's (2010) call that if universities are to meet the challenge, faculty from diverse departments (Biology education, Biology, Philosophy etc.) must come together to develop curricula that reinforce concepts that have mutual goals of courses on biological evolution. Future pre-service science teacher training must include radically revised coursework in both science and science education departments that is carefully dovetailed and mutually supportive in this area (Smith, 2010). A detailed analysis and account on the teaching and learning of the theory of evolution can be found in a recent paper by Smith (2010).

In a similar fashion, this research revealed that the majority of the participants involved in this study also held some inadequate conceptions about NOS. Again, such results are in line with research literature which clearly indicates that students, teachers, lay people, and even scientists do not possess adequate conceptions about many aspects of NOS (Irez 2006, Lederman, 1992; McComas, 1998). Researchers (e.g., Lakin & Wellington, 1994; Mellado, 1997) explain this situation with a lack of previous reflection regarding NOS. This lack of reflection was possibly the main reason for their inadequate beliefs, their use of clich´es, and their conflicting ideas (Mellado, 1997). Considering that a sound understanding of NOS is necessary for a scientifically literate citizen and science teachers are crucial components of education for scientific literacy, the findings of this research suggest that close attention should be paid to the pre-service preparation of science teachers regarding NOS. A widely accepted view on the nature of such preparation is that such preparation could only be achieved by a separate coursework and reflection should lay at the core of these courses (e.g., Eichinger, Abell & Dagher, 1997). Pre-service teachers enter graduate level programs holding ideas, beliefs, and values (Abell & Bryan, 1997; Lainer & Little, 1986). Therefore, pre-service teachers should be encouraged throughout their studies to explore these preexisting beliefs in order to develop them. Such reflection is especially crucial if pre-service teachers are to improve their understandings of NOS as this requires a critical deliberation of one's own beliefs (Irez, 2006).

On the other hand, detailed analysis of the selected participants' accounts with regard to NOS and examination of the association of these accounts' with their views about the theory of evolution implied a potential relationship. This relationship especially obvious when the participants with positive attitudes about the theory of evolution expressed informed views about the nature of scientific theories and the role of direct evidence in science. Clearly, such one-to-one connections support the existence of a conceptual level relationship between the two belief systems and display how specific beliefs regarding NOS influence individuals' conceptualizations of the theory of evolution. The fact that the participants with positive attitudes toward the theory of evolution expressed relatively more informed ideas about various aspects of science further supported this relationship.

These results point out that education on NOS should be an integral part of the education on the theory of evolution. As an informed understanding of NOS appeared as a prerequisite for understanding the theory of evolution, any course design intended to teach evolution should pay a special attention to NOS. Without a doubt, biology teachers with differentiated and integrated understanding of NOS and the theory of evolution will have greater ability than those whose understanding is limited and inconsistent, to plan and deliver lessons that help students develop deeper and adequate understandings with respect to biology's prime paradigm.

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