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Turkish Adaptation of the Views of Nature of Science-Form C: Validity and Reliability Study*

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Abstract
The aim of this study is to adapt the nature of science questionnaire C form to Turkish in a valid and reliable manner. The questionnaire was developed by Abd-El Khalick (1998) and further amendments on the questionnaire were made by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002). The process of adaptation of the questionnaire was carried out in five steps. These are: translating from English to Turkish, back translation from Turkish into English, the implementation of both Turkish and English versions with preservice science teachers, carrying out the pilot research and then the actual research. The items 1 and 4, 6, 7, and 8 after validity and reliability study were revisited and each question was separated into two and indicated as a and b (e.g. 1-a and 1-b). The questionnaire is frequently used in the nature of science research and it was previously adapted to German, Portuguese, Thai, Swedish, Vietnamese and Korean. It is hoped that the Turkish adaptation will contribute to the studies in nature of science in Turkey.

Keywords
Nature of science, VNOS-C, Turkish Adaptation, validity, reliability

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Introduction
The nature of science is used to express integration of science, philosophy, history, sociology, and psychology to understand the core values and assumptions that play an active role in the development of scientific knowledge (Lederman, 1992; McComas, Clough & Almazroa, 1998; Abd-El-Khalick & Lederman, 2000a; Özcan, 2013). The focus here is not the relationship between disciplines of philosophy, history, sociology, and psychology, but the interrelationship and intersection of the nature of science with these disciplines. As a matter of fact, a direct definition of what is the nature of science can be easily understood by knowing the elements and relevant myths that constitute it (Özcan, 2013). An important point that should not be forgotten is that the student or even the teachers have misconceptions about the nature of science (Lederman, 1992; Thye & Kwen, 2004). In this sense, assessment and evaluation of the nature of science understanding is as important as the identification and acquisition of these understandings. Assessment and evaluation is a stage where learning outputs become meaningful. When the literature is examined, there are various questionnaires developed by many researchers from 1954 to 2017. They aimed basically to probe views about the nature of science (see **Appendix A**) (Lederman, Bartos & Lederman, 2014; Buckland, 2015; Walls, 2016; Burniston, 2017). Some of these scales are the Likert type, some include open-ended questions, and some have multiple choice and/or multi-choice questions or interview questions. Aikenhead et al. (1987) proposed the following conclusions in his work on the evaluation of these 4 techniques:

> *Likert type scales:* The answers gathered with this scale only suggest an estimate of student beliefs. The chances of finding a correct assessment is very low. Uncertainty is around 80%.
>
> *Scales consisting of paraphrased open-ended questions:* The uncertainty for answers received at this scale is between 35% and 50%. This presents a better situation than a Likert type scale. The uncertainty here is that some students tend to write incomplete or incomprehensible paragraphs.
>
> *Scales consisting of multiple choice questions:* Options at this scale are the results of experimental studies and the uncertainty with responses from students' ranges between 15% and 20%.
>
> *Interviews:* Interviews are one of the evaluations which provide presumably the easiest way to understand and to obtain the closest true data. However, a lot of time is needed to collect and analyze the data. Uncertainty in interviews is about 5%.

Lederman (2007) and Schwartz, Lederman, and Crawford (2004) also emphasize that true-false, multiple-choice and Likert-type data collection tools are not appropriate in determining the nature of science. Instead of forcing students to choose an option, open-ended questionnaires which allow them to explain their ideas with examples are more suitable to identify nature of science concept. In this sense, both studies support Aikenhead et al. (1987) explanations of evaluation techniques. According to Aikenhead et al. (1987), interview technique provides data that is the closest to the truth. Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) also adopted interview techniques and they stated that, in addition to questionnaires, some semi-structured, supportive and elaborative interviews should be conducted with some individuals chosen from the sample. In this context, the scope of this study was to adapt the Views of Nature of Science-Form C (VNOS-C) questionnaire into Turkish. VNOS-C consists of 10 open-ended questions in English. It allows the sample to express their in-depth opinions and ideas on the nature of the science. VNOS-C has a great deal of scale features that are recommended for the nature of science (Aikenhead et al., 1987, 1987; Schwartz, Lederman & Crawford, 2004; Lederman, 2007); it is reliable and therefore, it is preferred to other nature of science scales (Hofheinz, 2008; Porra, Sales & Silva, 2011; Özcan, 2013).

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VNOS-C

VNOS-C was first prepared by Lederman and O'Malley (1990) under the name of VNOS-A to address the concerns of paper-pencil test evaluation methods and to include students' comments. The first version of this survey consisted of 7 questions. Semi-structured interviews would be conducted at the end of this questionnaire with students and they would be analyzed. According to the results of the analysis, it was revealed that 3 questions were not clear, and they were difficult to understand. Following the first revision in VNOS-A, VNOS-B, a second form for evaluating teachers' views on the nature of science, was developed (Lederman and O'Malley, 1990; Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). The implementations of the questionnaire improved understanding of students and teachers around 15% -20%. VNOS-C was formed with the adaptation of 3 items of the VNOS-B by Abd-El Khalick (1998), the replacement of items 1, 2, 5 and 7 and introducing 5 new items. These nine items were amended in a panel of five university professors (Abd-El-Khalick & Lederman, 2000b). Three science educators, one science historian, and a panel of scientists have carried out internal and external validity studies of VNOS-C, and the questionnaire was extensively developed. (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). The final questionnaire includes 10 items. VNOS-C, which is frequently used in the literature, has many aspects of the nature of science. **Table 1** shows the relationship of the VNOS-C questionnaire with the nature of science, while **Table 2** explains why each item is included in the questionnaire (Abd-El Khalick, 1998; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). We contacted Professor Norman Lederman via email to obtain his consent and approval for us to adapt VNOS-C questionnaire into Turkish.

Table 1. The relationship between the nature of science aspects and VNOS-C items

Nature of science aspects	VNOS-C Items
Scientific knowledge is tentative	1, 6, 7, 9, 10
Scientific knowledge is empirically-based	1, 2, 3, 6, 7, 9
Scientific knowledge is based on evidence and observation.	6, 7, 9
Theories and laws are different kinds of scientific knowledge	5
Scientific knowledge is theory-laden.	6, 9
Scientific knowledge involves imagination and creativity.	1, 4, 6, 7, 8, 9
Scientific knowledge is embedded in social and cultural context.	1, 9, 10

Method

Turkish Adaptation of VNOS-C

The questionnaire consists of 10 open-ended questions in English and it aims to identify respondents' views regarding the nature of science. Below we outline the procedure that was applied during the adaptation process in five steps.

Step 1: VNOS-C was translated into Turkish by academics who have earned Ph.D. degrees in science education from universities in the US and UK. Subsequently, back translations were performed by academics who have expertise in the field of nature of science. Then, researchers gathered with two Turkish language experts to discuss the translations. The percentage of agreement between translations was calculated as 83%, indicating a high degree of agreement between translations (Roid & Haladyna, 1982). The translations were examined by the academics and they discussed the differences in the language and the appropriateness of the translation to Turkish culture. Necessary amendments were made on the questionnaire (Roid & Haladyna, 1982; Regmi, Naidoo & Pilkington, 2010).

Step 2: VNOS-C was back translated into English. This was also carried out by researchers. They came together again and exchanged ideas on translation. The translations are compared to the original form of the questionnaire. It was seen that the questionnaire was compatible with the expressions in its original form (Prieto, 1992; Geisinger, 1994; Behling & Law, 2000)

Step 3: Both the Turkish version and the original English version of VNOS-C were implemented with 50 preservice science teachers studying at an English-instructed Turkish university. Since the relationship between the translations of two different forms (English and Turkish versions of the questionnaire) is important, the follow-up is tracked by the numbers given to the forms. In this way, the relationship between the contents of each form (Turkish and English form) filled by the same person was examined. A positive relationship was found between the two forms. This indicates that the questionnaire form was sufficiently meaningful (Behling & Law, 2000; Regmi, Naidoo & Pilkington 2010).

Step 4: Pilot study of the Turkish form was conducted with 65 preservice science teachers who were taking nature of science course. Students were studying at a Turkish-instructed university. The purpose was to test the intelligibility of survey items. Some of the questions that were found to be difficult by the preservice science teachers were revisited in the light of the feedback provided by preservice science teachers and the opinions of science education academics (Roid & Haladyna, 1982; Hansen, 1987; Prieto, 1992; Geisinger, 1994; Behling & Law, 2000; Regmi, Naidoo & Pilkington 2010).

Step 5: After all the amendments and corrections made on the questionnaire, the study was conducted with 50 (39 f, 11 m) preservice science teachers who were studying at a Turkish instructed university and taking nature of science course.

Table 2. VNOS-C Items and item descriptions

Items	*Item descriptions*
1	This question aims to assess respondents' views regarding science as a discipline to address questions about the natural world, the role of science in providing explanations for natural phenomena, and the role that empirical evidence plays in science that separates science from other "ways of knowing." Responses to this question often reveal a common misconception regarding the use of the "Scientific Method" as an objective process by which the knowledge is discovered. Such a view is often presented as an explanation for how science differs from other disciplines of inquiry.
2, 3	[Questions #2 and #3 are used in combination to assess respondents' views of investigative processes in science. Question #3 elicits responses regarding the existence of multiple methods of investigation (such as experimentation involving controlled variables, correlational studies, and descriptive investigations) that do not all follow the traditional "Scientific Method" or set of pre-established logical steps requiring a testable hypothesis. Responses to Question #2 clarify respondents' ideas of "experiment," as often this term is defined differently. Question #3 is then interpreted in relation to the provided description of "experiment." Question #3 also may elicit views of subjectivity and creativity in science.
4	This question refers respondents to a concept from the physical sciences to assess their understandings of the role of human inference and creativity in developing scientific explanations and models based on available data, and the notion that scientific models are not copies of reality.
5	This question assesses respondents' views of the development of and relationship between scientific theories and laws. The common misconception of the existence of a hierarchical relationship is often revealed. This misconception is presented by the explanation of a progression from scientific theory to law with the accumulation of more and more evidence until the theory has been "proven true" at which time it becomes a law. Views regarding distinctions between observation and inference are also commonly elicited. Additional ideas are often expressed by respondents as they attempt to describe the differences between scientific theories and laws.
6	This question assesses respondents' understanding of the tentative nature of scientific theories and reasons why science is tentative. Respondents often attribute change solely to the accumulation of new observations or data and/or the development of new technologies, and they do not consider a change that results from a reinterpretation of existing data from a different perspective. Views of the theory-laden nature of scientific investigations, the notion that the prevailing theories of the time impact the direction, conduct, and interpretation of scientific investigations, are assessed through the explanation of the role of theories in science. Additionally, responses often indicate views of the role of subjectivity, creativity, inference, and the sociocultural embeddedness of the scientific endeavor, as well as the interdependent nature of these aspects.
7	This question refers respondents to a concept from the biological sciences to assess their understanding of the role of human inference, creativity, and subjectivity in science. Desired responses describe the idea that "species" is defined by scientists to explain observed and inferred relationships, and that definitions, as well as concepts in science, are created by scientists to be useful for their endeavors. Additionally, this question elicits responses concerning the role of models in science and that scientific model are not copies of reality.
8	This question assesses respondents' views of the role of human creativity and imagination in science and the phases of scientific investigations at which respondents believe these aspects play a role. Often creativity is described relative to design only, and usually in regard to resourcefulness necessary to set up and conduct investigations (such as the design of new trapping methods in the wild). Respondents are less likely to recognize the role of creativity in question development, data analysis, and interpretation. Ideas of "discovery" versus "created patterns" are elicited.
9	This question assesses respondents' understandings of reasons for controversy in science when scientists use the same available data. Ideas of subjectivity, inference, creativity, social and cultural influences, and tentativeness are often elicited. The question aims to assess respondents' beliefs about what influences data interpretation including personal preferences and bias (personal subjectivity) to differing theoretical commitments and impacts of social and cultural values.
10	This question assesses respondents' views of the impact of social and cultural values and expectations on the scientific endeavor. Naive views are often indicated by responses describing science as "value-free" and stating

Validity and reliability studies of the questionnaire

The data obtained from the pilot study of VNOS-C questionnaire were used to compare the procedures explained below and to control the consistency. The deficiencies in the previous adaptations in Turkey have also been considered here (Doğan-Bora, 2005; Küçük, 2006; Ayvacı, 2007; Çil, 2010). The procedures followed in a translation of VNOS-C were directly related to validity-reliability studies. In addition, the validity and reliability of the questionnaire were carried out with a necessary amendment in questions to improve the quality. Some of these processes have been carried out in five steps indicated in the adaptation of VNOS-C, and the procedures can be summarized as follows:

- Researchers and academics in the field of science education were involved in the translation process and the agreement between them was taken into consideration.
- In the last section, the feedback given by the preservice science teachers during the pilot study was meticulously examined.
- After the implementation process, semi-structured interviews were conducted with students as suggested in the literature review.
- In addition to observation and interviews, data triangulation was used in the analysis of the data by three researchers.
- Researchers can access and use the data if needed.

Findings and Results

VNOS-C questionnaire includes 10 open-ended questions. After the pilot study, both the answers given by the preservice science teachers and the written feedback they provided at the end of the questionnaire or the verbal feedback provided at the time of the study were noted by the researchers. In this context, preservice science teachers have stated that the questionnaires were too long and the questions were difficult to answer as they were not clear. In particular, the views of preservice science teachers (PST) who share their views on the lengths of questions 1, 4, 6, 7, 8, and 10 are given in the following direct citations.

- In the fourth question, the expression of "*How certain are scientists?*" implies that "*in fact, they should not be sure*" (PST 7, 13, 17, 30, 45, 46).
- The sub-question of "is there a difference" in question 5 is not neutral and directs the readers (PST 4, 7, 11, 14, 23, 27, 41, 45).
- I understand that the phrase "*How certain are scientists?*" in question seven is very difficult to understand. I understand these questions asks us to "*provide a measure of certainty*" and to "state a certainty percentage" (PST 2, 7, 14, 21, 28, 39).
- In the seventh question, the phrase of "*what specific evidence*" in the question of "*What specific evidence do you think scientists used?*" asks if the evidence I think of is specific or not (PST 1, 5, 13, 15, 19, 22, 37, 45).
- As noted in question nine, the question "*How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?*" is contradictory. In sum, I think that we cannot get different conclusions if we are using the same set of data (PST 4, 11, 19, 22, 32, 33, 43).
- In question ten, why do the expressions of "*science reflects social and cultural values*" and "*universal*" appear contradictory and why do I have to choose one of these? (PST 1, 4, 14, 19, 35, 40, 47).

Some corrections and adjustments have been made in the process of adapting VNOS-C to Turkish. These changes can be listed as follows:

- The first question is divided into 1-a and 1-b because it is too long to include multiple questions, and some participants responded to the first part of the problem in the pilot study and did not respond to the second part.
- The "*science*" word in the 1-a question is the focus of the statement and therefore it is written in bold.
- The "*different*" phrase in the 1-b question is written in bold because it is the focus of the statement.
- The "*experiment*" word in the second question is written in bold because it is the focus of the statement.
- The words of "*yes*" and "*no*" in probing questions of question three were written in bold for emphasis.
- The fourth question is divided into 4-a and 4-b because it is too long, includes multiple questions and some participants responded the first part of the problem in the pilot study whereas they did not respond to the second part.
- The expression of "*how certain are scientists?*" in question 4-a is replaced with "*how can they be certain?*"
- The expressions of "*how certain*" and "*what types of evidence*" in question 4-a is written bold and they form the focus of the question.
- The expression of "*is there a difference?*" in question 5 is replaced with "*is there a relationship?*"
- The expression of "*is there a relationship*" is written in bold as it is the focus of the expression.
- The sixth question is divided into 6-a and 6-b because it is too long, includes multiple questions, and some participants responded to the first part of the problem in the pilot study and did not respond to the second part.
- The expressions of "*do not change*" and "*ever change*" are written in the bold as they are the focus of the questions 6-a.
- The expression of theories are written in bold in questions 6-b.
- The seventh question is divided into 7-a and 7-b because it is too long, includes multiple questions, and some participants responded to the first part of the problem in the pilot study and did not respond to the second part.
- The expression of "*how certain are scientists?*" in question 7-a is replaced with "*how can they be certain?*"
- The expression of "*how can they be certain?*" in question 7-a is written in bold as it is the focus of the question.
- The expression of "*how certain*" and "*what types of evidence*" in question 7-b is written bold and they form the focus of the question.

- The expression of what types of evidence in question 7-b is written in bold as it is the focus of the question.
- The question eight is divided into 8-a and 8-b because it is too long includes multiple questions, and some participants responded to the first part of the problem in the pilot study and did not respond to the second part.
- The expression of "*their imagination and creativities*" is written in bold as it is the focus of the question 8-a.
- The words of "*yes*" and "*no*" in question 8-a were written in bold for emphasis.
- The expressions of "*yes*" and "*their imagination and creativity*" in 8-b is written in bold as they are the focus of the statement.
- The sub-question of "*How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?*" in question 9 is replaced with "*why are there different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?*"
- The expression of "same" and "difference" are written in bold as they are the focus of the statement.
- Question 10 is changed as follows: *Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values and intellectual norms of the culture in which it is practiced. If you think that science is infused with social and cultural values, please explain with examples. If you think science is not infused with social and cultural values, please explain with examples.*
- The expression of "*is not infused with social and cultural values*" are written in bold because it is the focus of the statement.

The Turkish version of VNOS-C is given in **Appendix B**. All the changes made from the original to the Turkish adaptation process are shown in **Table 3** (Özcan, 2013).

Table 3. Changes in VNOS-C questionnaire items

Type of Questionnaire	Number of Items	Number of Questions	Divided Items	Qualitative Changes	Stylistic Changes
Original Questionnaire	10	10	-	-	-
Pilot Questionnaire	10	15	1, 4, 6, 7, 8	1, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Implemented Questionnaire	10	15	1, 4, 6, 7, 8	1, 4, 5, 6, 7, 8, 9, 10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Discussion Conclusion and Suggestions

The VNOS-C questionnaire was adapted to German, Portuguese, Swedish, Vietnamese, Korean and Thai and used with different samples (Hofheinz, 2008; Kim & Nehm, 2011; Porra, Sales & Silva, 2011; Todt, 2014; Yuenyong & Thao-Do, 2015; Pattamapongsa, Pongsophon & Suwanwong, 2016; Leden, 2017). We encountered similar difficulties with the aforementioned adaptation studies. First of all, like Chen (2006) and Hofheinz (2008), we think that the participants were not given enough time during the implementation. For this reason, they should have open-ended time (or at least flexible) when answering questions. Some questions are too long and this causes difficulties in understanding, which leads to inexplicable answers. For this reason, separating questions into two as we did in our work by discussing the questions with experts will significantly increase the meaningful responses to the questionnaire. This is also preferred by Hofheinz (2008) and Porra, Sales, and Silva (2011).

It is also important to ensure the adapted questionnaire also aligns with the grammar adaptation and cultural aspects of the country as adaption also has a cultural dimension. For example, when question 10 is translated into Turkish, the meaning sounded as if science reflects social and cultural values and it conflicts with universal values (Özcan, 2013). However, in Turkish culture, science can be infused with both social-cultural values and be universal. At this point, the difference between the direct translation of the questionnaire and the adaptation to be made with scientific processes can be seen. In the Vietnamese adaptation study conducted by Yuenyong and Thao-Do (2015), the element concept is better known in Vietnam than the species concept, so the use of elements instead of species can be given as another example in this respect. In the field of VNOS-C adaptation studies, it is also possible to discuss the terms used on the daily basis, to avoid confusion, to simplify the questions and to reduce the number of questions (Hofheinz, 2008; Kim & Nehm, 2011; El Khoury, Boujaoude & El Hage, 2014; Pattamapongsa, Pongsophon & Suwanwong, 2016).

The VNOS-C questionnaire can be adapted to other languages by carrying out its validity and reliability study. It is also possible to use the questionnaire for different age groups. Even by using cross-age study, it can be compared between age groups. New versions of the VNOS-C can also be developed to adopt it to today's conditions. In this regard, we think that adding visuals to the questionnaire and enriching the samples with latest scientific developments will give positive results. Again, giving a flexible time to fill out the survey will increase the depth and quality of the answers given to the questionnaire. It is also very important that the VNOS-C questionnaire is supported by interviews. We also recommend that meta-analysis studies of VNOS-C adaptations, which are not limited only to VNOS-C use or international comparison can be conducted.

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APPENDIX A

Year	Abbr. Name	Instrument	Author(s)
1954	SAQ	Science Attitude Questionnaire	Wilson
1961	TOUS	Test on Understanding Science	Cooley & Klopfer
1967	NOSS	Nature of Science Scale	Kimball
1969	TSAS	Test on the Social Aspects of Science	Korth
1974	SI	Science Inventory	Hungerford & Walding
1975	NOST	Nature of Science Test	Billeh & Hasan
1975	VOST	Views on Science and Technology	Hillis
1976	NKSKS	Nature of Scientific Knowledge Scale	Rubba
1978	TOSRA	Test of Science-Related Attitudes	Fraser
1981	COST	Conception of Scientific Theories Test	Cotham & Smith
1987	VOSTS	Views on Science-Technology-Society	Aikenhead, Ryan & Fleming
1990	VNOS-A	Views of Nature of Science A	Lederman & O'Malley
1993	TBA-STS	Teachers' Belief About Science-Technology-Society	Rubba, & Harkness
1998	VASS	Views About Science Survey	Halloun
1998	VNOS-B	Views of Nature of Science B	Abd-El-Khalick, Bell & Lederman
2000a	VNOS-C	Views of Nature of Science C	Abd-El-Khalick & Lederman
2002	VNOS-D	Views of Nature of Science D	Lederman & Khishfe
2004	VNOS-E	Views of Nature of Science E	Lederman & Ko
2006	VOSE	Views on Science and Education Questionnaire	Chen
2006	SUSSI	Student Understanding of Science and Scientific Inquiry	Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer
2008	VOSI	Views of Scientific Inquiry	Schwartz, Lederman & Lederman
2008	NOSS	Nature of Science Survey	Khishfe
2010	NSS	Development of Nature of Science Scale	Koksal, & Cakiroglu
2011	NSKAS	Nature of Scientific Knowledge and Attitudes Survey	Young
2011	MOSQ	Myths of Science Questionnaire	Buaraphan
2012	SBANOS	Students Beliefs and Attitudes About the Nature of Science	Spady
2013	KS4NS	Knowledge Structures for Nature of Science and Scientific Inquiry Questionnaire	Bartos
2013	SINOS	Students' Ideas About Nature of Science,	Chen, Chang, Lieu, Kao, Huang & Lin
2013	TBNOS	Teacher Beliefs About Science	Belo
2014	NOSI	Nature of Science Instrument	Hacıeminoğlu, Yılmaz-Tüzün, & Ertepınar
2017	VENCCE	Students' Views on The Nature of Science by Way of Contextualization in Ecology	Azevedo
2018	NOSvs	Nature of Science View Scale	Temel, Şen & Özcan

APPENDIX B

Bilimin Doğası Hakkında Görüşler Anketi (BDHGA)

Sevgili öğretmen adayları, aşağıda yer alan sorular bilimin doğasına ilişkin görüşlerinizi belirlemek amacıyla hazırlanmıştır. Anketi samimiyetle cevaplandırmanızı bekler, araştırmaya katkınızdan dolayı teşekkür ederiz.

1-a) Size göre Bilim nedir?

1-b) Bilimi (ya da Fizik, Kimya, Biyoloji gibi bir bilimsel alanı) diğer araştırma alanlarından (örneğin, din ve felsefe) **farklı** kılan nedir?

2) Deney ne demektir?

3) Bilimsel bilginin gelişmesi için deneyler gerekli midir?

- Eğer cevabınız **evet** ise neden böyle düşündüğünüzü bir örnekle açıklayınız.
- Eğer cevabınız **hayır** ise neden böyle düşündüğünüzü bir örnekle açıklayınız.

4-a) Fen kitapları genellikle atomu; protonlardan (pozitif yüklü parçacıklar) ve nötronlardan (nötr parçacıklar) oluşan merkezdeki bir çekirdek ile çekirdek etrafında dolaşan elektronların (negatif yüklü parçacıklar) oluşturduğu bir şey olarak ifade etmektedir. Bilim insanları atomun yapısı hakkında **nasıl emin** olabilmektedirler?

4-b) Bilim insanlarının atomun neye benzediğine karar verebilmek için **ne tür kanıtlar** kullandıklarını düşünüyorsunuz?

5) Bilimsel teori ile bilimsel kanun arasında **bir ilişki var mıdır**? Cevabınızı bir örnekle açıklayınız.

6-a) Bilim insanları bilimsel bir teori geliştirdikten sonra (örneğin; atom teorisi, evrim teorisi) bu teori hiç değişebilir mi? Eğer bilimsel teorilerin **değişmeyeceğine** inanıyorsanız nedenini örneklerle açıklayınız. Eğer bilimsel teorilerin **değişeceğine** inanıyorsanız: teoriler niçin değişir? Açıklayınız.

6-b) Teorileri **değişir ise;** teorileri öğrenmek için neden bu kadar çaba sarf ediyoruz? Cevabınızı örneklerle açıklayınız.

7-a) Fen kitapları tür kavramını genellikle benzer özelliklere sahip, üreyebilecek yavrular oluşturmak için kendi aralarında çiftleşebilen organizmaların oluşturduğu bir grup olarak tanımlamaktadır. Bilim insanları bir türün ne olduğuna ilişkin tanımlamalarından **nasıl emin** olmaktadırlar?

7-b) Sizce bilim insanları bir türün ne olduğuna karar vermek için **ne tür kanıtlar** kullanırlar?

8-a) Bilim insanları, ileri sürdükleri sorularına yaptıkları deneyler ve araştırmalar ile cevap bulmaya çalışırlar. Sizce bilim insanları bunu yaparken **hayal güçlerini ve yaratıcılıklarını** kullanırlar mı?

- Eğer cevabınız **evet** ise bilim insanlarının neden hayal gücü ve yaratıcılıklarını kullandıklarını örneklerle açıklayınız.
- Eğer cevabınız **hayır** ise neden böyle düşündüğünüzü bir örnekle açıklayınız.

8-b) Eğer cevabınız **evet** ise sizce bilim insanları **hayal güçlerini ve yaratıcılıklarını** araştırmalarının hangi aşamasında/aşamalarında (planlama, araştırmayı kurgulama, veri toplama ve veri toplama sonrası vb.) kullanırlar?

9) Dinozorların yaklaşık 65 milyon yıl önce neslinin tükendiğine inanılmaktadır. Bilim insanları tarafından dinozorların neslinin tükenmesini açıklayan iki önemli hipotez diğerlerine göre daha fazla kabul görmektedir. Bir grup bilim insanı tarafından oluşturulan birinci hipotez; 65 milyon yıl önce büyük bir meteorun dünyaya çarptığını ve bu durumun dinozorların neslinin tükenmesine neden olan bir dizi olaya sebep olduğunu öne sürer. Diğer bir grup bilim insanı tarafından oluşturulan ikinci hipotez ise; büyük ve şiddetli bir volkanik patlamanın, dinozorların neslinin tükenmesine neden olduğunu öne sürer. Her iki gruptaki bilim insanları da **aynı** olay için **aynı** verileri kullandığına göre, olaya ilişkin olarak yaptıkları açıklamalar neden **farklılıklar** içermektedir?

10) Bazı insanlar, bilimin; toplumsal, sosyal ve kültürel değerlerden etkilendiğini iddia etmektedirler. Yani bilim, uygulandığı kültürün; toplumsal ve politik değerlerini, felsefi varsayımlarını ve üretildiği kültürün akla uygun normlarını yansıtmaktadır. Diğer insanlara göre ise bilim; ulusal ve kültürel sınırları aşmaktadır. Sosyal, politik ve felsefi değerlerden ve üretildiği kültürün akla uygun normlarından etkilenmemektedir.

- Eğer bilimin, **sosyal ve kültürel değerleri yansıttığını** düşünüyorsanız, örnekler vererek açıklayınız.
- Eğer bilimin **sosyal ve kültürel değerleri yansıtmadığını** düşünüyorsanız, örnekler vererek açıklayınız.