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THE MIDDLE SCHOOL STUDENTS' REASONINGS ABOUT MULTIPLE RESPONSES FOR THE SAME SCIENTIFIC QUESTION

MASTER'S THESIS

Ayşe Nur KESKİN

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ORTAOKUL ÖĞRENCİLERİNİN AYNI BİLİMSEL SORU İÇİN ÇOKLU CEVAPLAR HAKKINDAKİ MUHAKEMELERİ

YÜKSEK LİSANS TEZİ

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Önsöz

'İlim tercüme ile olmaz, tetkikle olur.' diyen **Gazi Mustafa Kemal ATATÜRK**'ün bu sözünü eğitim hayatım boyunca kılavuz edindim. Bu çalışmayı onun eğitimde gerçekleştirdiği reformlara borçluyum, onu saygı, sevgi, minnet ve rahmetle anıyorum.

Yüksek lisans eğitimim boyunca bana her zaman ve her konuda destek olan, kıymetli fikirlerini benden esirgemeyen tez danışmanım saygıdeğer Prof. Dr. Ahmet KILINÇ'a sonsuz teşekkür ederim.

Araştırmanın her aşaması TÜBİTAK 115K492 nolu 'Fen Bilimleri Öğretmenlerinin Sosyobilimsel Konuların Öğretimi konusunda, yetiştirilmesi: Bir Profesyonel Öğrenme Topluluğu Çalışması (FESKÖK) projesi kapsamında yürütülmüştür. Sağladığı imkan ve olanaklardan dolayı Türkiye Bilimsel ve Teknolojik Araştırmalar Kurumu (TÜBİTAK)'na teşekkürlerimi sunarım.

Eğitim hayatım boyunca maddi ve manevi desteklerini benden esirgemeyen çok kıymetli aileme ve sevgili eşim Cihat KESKİN'e çok minnettarım.

Ayşe Nur KESKİN

Sevgili oğlum Ali Arslan KESKİN’e...

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ORTAOKUL ÖĞRENCİLERİNİN AYNI BİLİMSEL SORU İÇİN ÇOKLU CEVAPLAR HAKKINDAKİ MUHAKEMESİ

Fen derslerinde bilimin felsefe, tarih, psikoloji ve sosyoloji gibi alanlarla bağlantısı *Bilimin Doğası* başlığı altında incelenir. 2013 Fen Öğretim Programı'na sosyobilimsel konuların eklenmesiyle birlikte öğrencilerin bu tür konularda karar verirken hangi ölçütleri baz aldıkları ve *bilimin doğası* ile ilgili inançlarından nasıl faydalandıkları araştırılmaya başlanmıştır. Buçalışmada sosyobilimsel konu odaklı Fen öğretiminin etkilerini ortaya çıkarmayı amaçlayan FESKÖK projesi kapsamında, öğrencilere sosyobilimsel bir konu etrafında karar verilmeye çalışılan ve farklı görüşler içeren senaryolar sunulmuştur. Ayrıca bu senaryolar ile ilgili olarak *'Sizce bilimde bir sorunun tek bir cevabı olmaz mı ?'* sorusu yöneltilmiştir. Proje kapsamında eğitim gören 5. ve 8. sınıf öğrencilerinin verileri ön test ve son test olarak incelenmiş, belirtilen açık uçlu soruya verilen cevaplar kıyaslamalı bir tematik analize tabii tutulmuştur. Çalışmanın örneklemini 5. sınıflarda 15, 8. sınıflarda ise 24 öğrenci oluşturmuştur. Bu çalışma, okul öğrencilerinin aynı bilimsel soru için çoklu cevaplar hakkında ya fantezi ya da veri odaklı muhakemeler kullandığını göstermiştir. Ayrıca öğrencilerin verdikleri yanıtlar projenin etkisi bakımından ön ve son test yanıtları göz önünde bulundurularak gelişimsel gruplara ayrılmıştır. Bu gruplar fantazi odaklı muhakemesini değiştirmeyenler, fantazi odaklı muhakemeden veri odaklı muhakemeye gelişim gösterenler ve veri odaklı muhakemesini değiştirmeyenler şeklindedir. Fantezi odaklı muhakemede öğrenciler, değer odaklı inançlar, senaryodaki bilimsel açıklamaların karıştırılması ve dil odaklı mantık mekanizmaları sayesinde kolayca tek bir sonuca varmaktadırlar. Veri odaklı muhakemede ise altı farklı mekanizma ortaya çıkmıştır. Bunlar 1) en iyi argüman epistemolojisi, 2) yanlışlama, 3) koşullu görelilik, 4) çok değişkenli epistemoloji, 5) çok yöntemli epistemoloji ve 6) çoklu yaklaşım epistemolojisidir. Çalışma sonuçları, okul öğrencilerinin aynı bilimsel soru için çoklu cevaplar hakkındaki muhakemelerinin, literatüdeki mevcut muhakeme sınıflandırmalarından daha karmaşık olduğunu göstermiştir. Bu bağlamda, fen eğitimcileri bu sınıflandırmadan rubrik olarak faydalanabilirler.

***Anahtar kelimeler**:* Aynı bilimsel soruya çoklu cevaplar, bilimin doğası, epistemolojik inançlar, sosyobilimsel konular.

Abstract

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Supervisor : Prof. Dr. Ahmet KILINÇ

THE MIDDLE SCHOOL STUDENTS' REASONINGS ABOUT MULTIPLE RESPONSES FOR THE SAME SCIENTIFIC QUESTION

In science classes, the connection of science with fields such as philosophy, history, psychology and sociology is categorized under the title of *Nature of Science*. With the addition of socio-scientific issues to the 2013 Science Education Program, it has been started to investigate which criteria the students take as a basis when deciding on such issues and how they use their beliefs about the nature of science within these contexts. In this study,within the scope of the FESKÖK project, which aims to reveal the effects of science education focused on socioscientific issues, the students were presented the scenarios that try to make them decide around a socio-scientific issue and that contain different views. Besides, regarding these scenarios, the question, "Do you think there is not a single response in science?” was asked to the students. The data of 5th and 8th grade students trained within the scope of the project were examined as pre-test and post-test, and the responses given to aforementioned open-ended question were subjected to a comparative thematic analysis. The participants of the study consisted of 15 students in 5th grades and 24 students in 8th grades. This study demonstrated that school students used either fantasy-based or data-based reasoning about multiple responses for same scientific question. The responses of the students are divided into following developmental groups considering the pre and post test responses in terms of the impact of the project: 1) those who do not change their fantasy-based reasoning, 2) those who develop from fantasy-based reasoning to data-based reasoning, and 3) those who do not change their data-based reasoning. In phantasy-based reasoning, they easily reach a single conclusion thanks to value-oriented beliefs, fusing the scientific explanations up in the scenario, and language-oriented logical mechanisms. In data-based reasoning, six different mechanisms emerged: 1) the best argument epistemology, 2) falsification, 3) conditional relativity, 4) multivariate epistemology, 5) multi-method epistemology, and 6) multi-approach epistemology. Study results have shown that school students' reasoning about multiple responses for the same scientific question is more complex than the current classification of reasonings in the literature. In this context, science educators can benefit from this classification as a rubric.

Keywords: Epistemological beliefs, multiple responses for same scientific question, nature of science, socioscientific issues.

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List of Abbrevations

SSI: Socioscientific issues

NOS: Nature of science

FESKÖK: Educating science teachers on teaching socioscientific issues: A learning community study

Chapter 1

Introduction

1.1. Problem Statement

Science is a human activity that is based on finding the responses for the questions regarding mechanisms behind the natural events (Sanitt, 1996). Within this questioning activity, the process in all of the scientific fields is started by a question and completed by multiple responses (Johntson & Southerland, 2001). These responses are achieved either at the same time or in the course of the time (Johntson & Southerland, 2001). This multiple-response nature of scientific questions has attracted the attention of many philosophers. August Comte (2015), for example, does not believe that one scientific question would have multiple responses. He believes that science includes only the absolute notions that are based on observations and experiments and the diversity within scientific responses stems either from lack of evidence in that specific time or from the theological or metaphysical considerations that are the preliminary stages of scientific knowledge development. In addition, Francis Bacon (2012) has built his notion on the inductivism and he believes that multiple responses may stem either from that fact that scientific approaches experience fundamental renewals due to new findings (i.e., observations and experiments) produced in the course of time or from certain idols preventing the understanding of the nature as it is and being based on limited senses (i.e., tribe idol), schooling (i.e., cave idol), communication and language (i.e., market place idol) and fantasies (i.e., theatre idol).

In the case of Karl Popper (2017), he believes that scientific questions always have multiple responses, the duty of scientists is to decrease the number of these responses by the criticisms of existing responses or falsification process. He believes that scientists produce counter-examples for existing responses in order to reach best responses even if these responses will also undergo same process in the course of time. On the other hand, even if

Imre Lakatos (2014) believes in response pluralism and the importance of falsification process, he considers that science is a cumulative activity. Within this cumulative process, scientists produce new responses in the course of time by protecting important parts/the core of old response.

From a more sociological perspective, Thomas Kuhn (2017) believes that multiple responses stem from multiple paradigms that are based on different camps of scientists with different beliefs, values, methodologies, and metaphysics and that have emerged in the course of time. He believes that, in the course of time, scientific activities consistently experience two follow-up stages: i) normal stage, and ii) revolutionist stage. In the first, paradigmatic knowledge has a cumulative nature and is produced by puzzle-solving like developments. In the latter, emerging uncertainties resist existing paradigm/normal science/response and one another paradigm/response is produced by revising previous one. With a more critical sociological perspective, Paul Feyerabend (2017) argues that science is not a unique way to reaching truth or reality; rather, it is one of many ways such as religion and arts. He believes in pluralistic methodology that is based on comparing ideas with each other, as in other social enterprises, rather than on comparing experiments and observations. From a radical language-based approach, Ludwig Wittgeinstein believes that all human activities including science are language games and multiple-responses may be result of diversity of these games even if they have a nature of family resemblance (Anat & Anat, 2020).

The issue of 'multiple responses for same question' has also been attracted the attention of science educators considering that nature of science (NOS), understanding of science from philosophical and historical perspective, is a critical part of scientific literacy in recent science education reforms and documents (Next Generation Science Standards [NGSS] Lead States, 2013; American Association for the Advancement of Science [AAAS], 1990; Council of Ministers of Education Canada [CMEC], 1997; NRC, 2012). Within these documents and reforms, even if there are still uncertainties regarding how science should be represented and which tenets of science should be taught (Abd-El-Khalick, 2012; Lederman, Abd- El- Khalick, Bell, & Schwartz, 2002; McComas, 2017), we can argue that 'consensus view' of Lederman's team, who tried to fuse aforementioned philosophical considerations up, is the most accepted model (Abd-El-Khalick, 2012). Within this model, the nature of 'multiple responses for same scientific question' is emphasized in different tenets. In the tenet of 'empirical nature of scientific knowledge', for example, the researchers argue that different theoretical frameworks and perceptual situations filter the observations that are main justification components of science, which may result in different responses for same question. In the tenet of 'distinction between scientific theories and laws', theories are particularly described as the inferred explanations for the observed phenomena; therefore, multiple theory/response production might be result of diverse inferences. In the tenet of 'creative and imaginative nature of scientific knowledge', it is believed that scientists' creativity and imagination are as important as the observations and the diversity within such mental tools may result in the diversity within the responses. In the tenet of 'theory-laded nature of scientific knowledge', the researchers argue that scientific investigations include prior works, theories, beliefs and experiences; therefore, the diversity within such historical background may be one of the reasons for multiple responses. In the tenet of 'the social and cultural embeddedness of scientific knowledge', the fact that it is believed that because science is a humanistic activity it is influenced by social and cultural factors (e.g., power structures, socioeconomic factors, religion, etc.) may be one another reason for multiple responses. In the tenet of 'myth of existence of a scientific method', the researchers believe that there is no sequence of scientific activities such as observing, testing, measuring, constructing theories and so on or a single scientific method; therefore, such diversity within the methodologies may result in multiple responses for same scientific question. In the tenet of tentative nature of scientific knowledge, it is argued that scientific claims change as a result of new evidence, advances in the technologies and reinterpretation of data. This situation also contributes to the development of multiple responses (Abd-El-Khalick, 2012; Lederman et al. 2002).

By adopting these tenets, the researchers have developed interview forms in which they have asked the questions about these tenets in order to uncover the participants' beliefs about NOS. They, for example, ask what science is, what makes science different from religion and philosophy, the necessity of experiments for producing scientific knowledge, the changeability of theories over time, the distinction between theories and laws, the certainty of knowledge regarding specific examples (e.g., the structure of atoms, taxonomy of species, etc.), the tentativeness of scientific knowledge (e.g., about dinosour extinction), whether science is influenced by social factors or it is universal and the creative and imaginative nature of investigations. After producing the interview transcripts, the researchers have classified the responses/beliefs for all of the tenets using following two categories: 'naïve' and 'sophisticated'. Sophisticated beliefs have particularly emphasized multiple responses for same scientific question in all of the tenets. These beliefs are based on the arguments explained in the previous paragraph and seem to be produced by data-based reasoning (i.e., sticking with the data production process rather than completing it by value-oriented beliefs). On the other hand, naïve beliefs are based on one clear response for one scientific question. These value-oriented beliefs (prejudices) stem from a fantasy-based reasoning that have particularly emerged due to positivist notions or socioscientific controversies (Sadler, Chambers & Zeidler, 2004). In the case of positivist notions, the students usually use the (scientific) belief that science can respond every question because it can reach the absolute truths by appropriate observations and experimentation in order to complement the incomplete data for reaching one single response (McComas, 1996). In the case of socioscientific controversies, it is observed that students usually use ecological, economic, health-oriented, technology-related and other values in order to reach single response despite lack of complete data (Karpudewan & Roth, 2018; Sadler et al., 2004; Sutter, Dauer, Kreuziger, Schubert & Forbes, 2019).

Perhaps because the NOS researchers have not benefited from the languages such as ‘multiple responses for same scientific question’ and ‘value-oriented beliefs (prejudices)’ that we have used in the present study for approaching the nature of science tenets, the literature about NOS has showed that there are some conflicting evidence regarding school students’ reasonings about NOS aspects. Some studies (Deve & Kucuk, 2016; McComas, 1996; Karpudewan & Roth, 2018; Sadler et al., 2004; Solomon, 1992; Sutter et al., 2019), for example, showed that middle school and high school students had naïve reasonings (naïve beliefs and misconceptions) about NOS, whereas some argued that these students (e.g., Çetinkaya , 2019; Yenice, Tunç, & Yavaşoğlu, 2018) had sophisticated reasonings. Similar confusion also emerges within quasi-experimental studies where the researchers compare the NOS teaching (explicit NOS teaching, SSI-based education, History of science education, etc.) with traditional teaching in terms of students’ reasonings about NOS. Some researchers (Eastwood et al.,2012; Solomon, 1992), for example, did not find any significant difference between control (traditional content teaching) and experiment groups (one of the NOS teaching alternatives: i) explicit NOS teaching, ii) SSI-based teaching or iii) history of science teaching) in terms of students’ reasonings about NOS aspects. On the other hand, some (Çetinkaya, 2019; Doğan & Ozcan, 2010; Deve & Kucuk, 2016; Karpudewan & Roth, 2018) argued that they developed students’ reasonings about NOS aspects in the experiment groups (one of NOS teaching alternatives: i) explicit NOS teaching, ii) SSI-based teaching or iii) history of science teaching) much more than those in the control groups (traditional content teaching).

As mentioned before, even if these conflicting results may stem from methodological reasons, we believe that naming the educational parameter as ‘students’ reasonings about multiple responses for same scientific question’ instead of students’ beliefs about NOS aspects and looking for value-based beliefs/prejudices/fantasies behind ‘one single response’ result, as we have done in the present study, may clear some confusions because such relatively new language is both informed directly by the philosophy of science and indirectly by the consensus view adopted by NOS researchers in science education community. Using this relatively new perspective, in order to uncover school students’ reasonings about multiple responses for same scientific question, we have developed one vignette including an authentic scientific question and scientists’ multiple responses for both Grade 5 and Grade 8 students. In addition, we pursued the development of these reasonings through an SSI-based education.

1.2. Research Questions

Research Question 1. What is the nature of school students’ reasonings about multiple responses for same scientific question?

Explanation: In order to throughly uncover school students’ reasonings about multiple responses for same scientific question, we used SSI-based education as the intervention and compared the development of these reasonings through this education.

1.3. Research Purpose

The purpose of present study was to uncover school students’ (Grades 5 and 8) reasonings about multiple responses for same question.

1.4. Importance

Understanding Nature of Science (NOS) is considered a critical part of scientific literacy because understanding of science from philosophical and historical perspective gained considerable attention in recent educational reform documents (Next Generation Science Standards [NGSS] Lead States, 2013; American Association for the Advancement of Science

[AAAS], 1990; Council of Ministers of Education Canada [CMEC], 1997; NRC, 2012). In the US's Next Generation Science Standards [NGSS] Lead States, (2013), for example, NOS themes are essential components of curriculum and instructional outcomes. In addition, particularly 'the tentative nature of science', one of NOS components, has been emphasized in all of the seven national science standards documents of the USA, Australia, Canada, England/Wales and New Zealand (AAAS, 1990,1993; California Department of Education, 1990; Council of Ministers of Education, 1996; Curriculum Corporation, 1994; Department of Education, 1995; Ministry of Education, 1993; NRC, 1996).

Similar to many countries, in Turkey, the aim of reaching scientifically literate persons is a crucial component of the science curriculum (Milli Egitim Bakanlıgı [MEB], 2017). In the context of NOS, in the Turkish science curriculum, 'competence in science refers to the presence of knowledge for the explanations of world and the ability and desire to utilize methodology in order to identify questions and produce evidence-based results.' (MEB, 2017, pp.6). In addition, one item of the 'special objectives' in the same curriculum emphasises that science education helps students understand how scientists create scientific knowledge and how they use it in new research. One another item is that science education provides students to develop reasoning ability, scientific thinking habits and decision making skills using socio-scientific issues. In addition, in the curriculum, by transferring scientific process skills into the learning environments, it is aimed that students conduct research in order to understand the world and to understand how scientific knowledge develops by directly participating in the scientific process (MEB, 2017, pp.10). Lastly, there are NOS-oriented statements in some learning outcomes in the curriculum. For example, in the seventh grade unit about the atom, the learning outcome F.7.4.1.2. is 'Questioning how the thoughts about the concept of atom change from past to present.' Also, in this same learning outcome, it is emphasised that the scientific knowledge can change over time (MEB, 2017, pp.42).

Even though international and national science education documents emphasize the importance of nature of science education, there are some conflicting evidence regarding students' reasonings about NOS aspects. Apart from some methodological reasons, we believe that a philosophically informed language (multiple responses for same scientific question and value-oriented beliefs/prejudices/fantasies) may clear these confusions at some extent and enable us to better uncover school students' reasonings about nature of science. The present study may contribute to existing (nature of) science education studies adopting this new language and the findings that are based on new terminologies stemming from this language.

1.5. Hypothesis

Because present study has a qualitative nature, there is no any hypothesis.

1.6. Limitations

There are some limitations that were encountered in this study. First limitation stemmed from the reduction of data. In this context, we needed to analyse both pre and post-test results in order to uncover changes and developments in the students' reasonings. However, some students did not participate in both of the tests. Therefore, some datas were not included in the analysis. Second, because some students' responses were short and limited, we excluded them. The last limitation was about creating new developmental categories. Because we analysed students' responses by using new terminologies, when new categories were created, we needed to revize previously determined classfications in order to reach clear categorical groups.

1.7. Descriptions

Science: Science is acquiring knowledge and studying the natural world and the laws governing it (Mirable Dictionary, 2007).

Nature of Science: NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992)

Reasoning: The process of thinking about something in a careful way (Mirable Dictionary, 2007).

School Students: The students studying in pre-university state schools.

Chapter 2

Literature

The purpose of present study was to uncover school students' (Grades 5 and 8) reasonings about multiple responses for same scientific question. For this purpose, in this section, first the philosophical approaches about multiple responses for same scientific question was presented and then the previous research particularly focusing on science education studies including the data about school students' reasonings about nature of science and scientific knowledge was shared.

2.1.Philosophical Background

Looking at the philosophy of science, seven prominent contributions were used to explain the issue of 'multiple responses for same scientific question' even if they approached the issue from different angles.

2.1.1. Auguste Comte. In the first half of the twentieth century, Vienna Circle attempted to overcome metaphysics problem via positivist notion by adopting the empiricism (i.e., if a hypothesis is verified by observations and experimentations, it will be scientific.) to explain the natural phenomena. Positivists' analytical thinking was based on logical and mathematical truths. They depended on the naive semantic theory.

Auguste Comte is the founder of this mainstream. He considered that science comes closer and closer to truth without reaching it. He thought that human thinking was based on one single law: The knowledge develops through three stages: the theological (imaginative), the metaphysical (abstract), and the positive (scientific). These three stages are ordered by developmentally. In the theological stage, human minds are interested in causes of the phenomena and anomalies in the universe and explain them using supernatural powers. In the metaphysical stage, there are abstract entities providing explanations about observations by connecting each observed circumstances with personalized abstraction. In the positive stage, absolute notions replaced relative ones. He advocated that truth knowledge was based only on observed events and experimentation. In this stage, the aim of human is making absolute innovations constraint by scientific methods. He said that eventual stage of the human mind was positive philosophy (Comte, 2015).

2.1.2. Francis Bacon. Bacon thought that science was possible only if the nature was interpreted correctly and the laws of nature were known. He advocated that scientific development could be provided by the correct method. In this regard, Bacon criticized accumulation of knowledge and methods of acquiring scientific knowledge before his period because they were parallel to Renaissance sprit (i.e. The deduction method of Aristotle to acquire a scientific knowledge). He suggested that the only source of knowledge acquisition was inductivism. He thought that science did not progress by doing prolepsis in knowledge and putting new knowledge on previous one (i.e., cumulative). Rather, he believed that sciences needed fundamental renewals (Bacon, 2012). He advocated that when the inductivism was applied, observations and experiments should be used effectively (Topdemir, 1999). However, it is not easy to apply such research method because human have some preconceptions or *'idols'* for interpreting the nature. He described that the 'idols' were arbitrary abstraction (i.e., imagination) and they could prevent someone to understand nature as it was. In addition, he considered that the intellect should be purified from such idols. He divided these idols into following four types: "tribe," "cave," "marketplace," and "theater"

a. Tribe idols: All humans have these idols and they work like a crooked mirror in the human mind. They cause distorted interpretation of external world because of limited senses and experience.

b. Cave idols: Individuals develop cave idols due to character, structure of the mind and body, relationships with other people, education and such things. In these idols, the human have some conceptions and doctrines preventing them to give evidence of the truth.

c. Marketplace idols: These idols derive from human connections. Human thinks that their minds guide words; rather, the words guide their minds. Language and words that are tools for the connections surround the mind and react on understanding.

d. Theatre idols: Human understands the nature by the fantasies and imitates the world. These idols stem from tradition, dogmatic philosophy, wrong rules of demonstration, astrology and magic activities (Bacon, 2012, pp.19-24).

2.1.3. Karl R. Popper. In contrast to Vienna's positivist movement (i.e., verification of hypothesis), Karl Popper put forward a new way of thinking about science by discovering a new term 'falsifiability of theories'. According to Popper's falsifiability, science and scientists do not try to verify theories (i.e., to prove that theories are right); rather, they try to falsify theories by creating counterexamples (i.e., to show that theories are false) (Romero-Maltrana et al., 2019). He considered that the verification could not be provided by observation and experimentation because in order to generalize one example, many observations should be made based on the inductive principles. This leads to infinite regress (Popper, 2017). According to him, science was developed by criticizing existing laws (Özsoy, 2018).

2.1.4. Imre Lakatos. Lakatos advocated that scientific developments were cumulative by protecting the important parts of old laws to improve new ones (Özsoy, 2018). Lakatos developed *methodology of scientific research programs* (Lakatos, 2014). He argued that his evaluation standard was isolated by not only one hypothesis or conjunction of them but also the scientific research program. It consists of the series of developing laws and these developing series have a structure. For example, in Newton's research program, three laws of motion and the law of gravitation create only the '*core'* of program. '*Protecting belt'* which includes helping hypothesis protects this *'core'* from refutations. The program has '*heuristic'* which is the machine of the strong problem solving. In Newtonian program example, this *heuristic* consists of the sophisticated mathematical apparatus, including differential and integral equations and the theory of convergence. This heuristic digests anomalies and replaces them with positive evidences. Anomalies refute some of the hypothesis in the *protective belt* and this hypothesis is constantly changed, developed and complicated; therefore, the hard *core* of the program remains intact (Lakatos, 2014). Moreover, Lakatos tries to answer the question '*How can one distinguish a scientific or progressive program from a pseudoscientific or degenerating one?*' According to him, *respective* and *progressive* program predict novel facts that have been undreamt and contradicted by previous or other rival programs. In the example of Einstein's program, he predicted that if distance between two stars was measured during the day and in the night, two measurements would differ from each other. Nobody thought such an observation before Einstein. In the *degenerating* programs, he advocated that theories were asserted in order to accommodate known facts. The example of these programs was Marxism which had some unsuccessful predictions. In addition, he justified Popper by supporting that the hallmark of the scientific programs was not trivial verifications (Lakatos, 2014). His explanation to the question 'Is there only one answer in science/to scientific question?' was that fact that ***'theoretical pluralism'*** was better than '*theoretical monism'* (Lakatos, 2014).

2.1.5. Thomas S. Kuhn. After the half of the twentieth century, Kuhn provided 'anti positivist' thinking to scientific philosophy. He responded following question by a sociology-based view: 'What is the criterion that allows us to determine which is more valid when we encounter contradictory scientific explanations?' He thougth that there was no universal criterion and this was provided by '*paradigm*' which had political, economic, cultural and sociological aspects. Paradigm is described as accepted model by the relevant scientific community and covers their shared theoretical beliefs, values, instruments, methods, and even metaphysics. (Kuhn, 2017). According to Kuhn, science has ‘normal’ and ‘revolutionary’ phases. ‘Normal’ science is described as ‘puzzle solving’, that is; it does not aim to create any changes and it is cumulative picture of a scientific activity with certain boundaries (Kuhn, 2017). In ‘revolutionary’ science, however, uncertainties are experienced. Such uncertainties always resist anticipated results in ‘normal’ science (Kuhn, 2017). Therefore, scientific revolution requires revision of existing scientific beliefs (Bird, 2018).

2.1.6. Paul Feyerabend. Feyerabend downgraded the problem of demarcation between science and pseudo science. He argued that there was no ‘rational’ criteria for the methodological rule of science governing scientific progress. He undermined science’s privileged position within the culture. In this regard; he described himself as ‘epistemological anarchist’. He emphasized, in the *Against Method*, that ‘Science is fundamentally an anarchist attempt. Theoretical anarchism is more humanistic than their alternatives predicting laws and order and it encourages progress more’ (Feyerabend, 2017, pp.35). He advocated that the science was not the unique way to truth and reality; it was one of many pathways (Feyerabend, 2017). He considered that scientist should adopt ‘pluralistic’ methodology and ideas should be compared with other ideas rather than the experiments (Feyerabend, 2017). He thought that science was not independent from religion, metaphysics, sense of humor, and even language and he believed science was a field like religion, art, astrology (Feyerabend, 2017).

2.1.7. Ludwig Wittgenstein. Wittgenstein emphasized the relationships between thought and language by showing application of logic to metaphysics via language. According to him, the philosophy is an activity to clarify the thought and criticize the language. At this point, he incorporated new terms into philosophy such as ‘language-games’ and ‘family resemblance’. At the beginning; he explained ‘language-games’ as a form of life. Such games contain nature of human activity and they do not have general rules. He downplayed general explanations and definitions; that is, instead of ‘craving for generality’ of philosophers, he defined ‘family of resemblance’ as a term to connect particular uses of the same word (Anat & Anat, 2020).

2.2. Previous Research

2.2.1. Nature of Science (NOS) and Scientific Knowledge in Science Education Research. In the science education research, science’s relationship with philosophy, sociology, history and psychology is called by the concept of Nature of Science (NOS). The researchers consider that learning science from philosophical and historical perspective helps students gain scientific literacy. NOS enables students to learn how science works, how scientific knowledge is created and how to distinguish science from non-science (Abd-El-Khalick, 2012; Lederman et. al. 2002; McComas, 2017). Since 1960s, K-12 students’ and their teachers’ understandings about NOS are one of the significant research topics in science education. However, in this research, there is still no common definition of what science and scientific knowledge is (e.g. Irzik and Nola, 2011; Allchin, 2011; Dagher & Erduran, 2016; and Matthews, 2012).

Abd-El-Khalick (2012) and Lederman et al. (2002), for example, put forward a ‘consensus view’ that has seven tenets about NOS: (1) the empirical nature of scientific knowledge (i.e., Science is based on observations and the observations are filtered by perceptual apparatus and theoretical framework etc. Students should be able to distinguish between observation and inference.), (2) the distinction between scientific theories and laws (i.e., Whereas laws are descriptive statements of relationships among observable phenomena, theories are inferred explanations for those phenomena), (3) the creative and imaginative nature of scientific knowledge (i.e., Contrary to what is known in the development of scientific knowledge, human creativity and imagination are as important as observations) (4) the theory-laden nature of scientific knowledge (i.e., Scientific investigations include prior works, theories, beliefs, experiences etc., all historical background plays an important role in the development of science), (5) the social and cultural embeddedness of scientific knowledge (i.e., Because science is a human enterprise, it is affected by social and cultural factors such as, power structures, politics, socioeconomic factors, philosophy, and religion), (6) myth of the existence of a scientific method (i.e., Although scientists observe, compare, measure, test, hypothesize, create ideas, and construct theories and explanations, there is no single sequence of these activities and no single scientific method), (7) the tentative nature of scientific knowledge (i.e., Scientific claims change as a result of new evidence, advances in technology, reinterpretation of data, etc.) (Abd-El-Khalick, 2012; Lederman et al. 2002). These researchers have developed open-ended tests in order to uncover students' beliefs about NOS. Views of Nature of Science Questionnaire (VNOS), for example, is popular one in this area and measures effectiveness of aforementioned NOS aspects and students' NOS views. In addition, when analyzing these tests' results, responses of learners are usually divided into two categories under the heading of NOS aspects as 'more naive views' and 'more informed views'.

Some researchers (e.g. Irzik & Nola, 2011; Allchin, 2011; Dagher & Erduran, 2016; and Matthews, 2012) developed alternative approaches against the consensus view of NOS in order to reduce its shortcomings and weaknesses. In this regard, Irzik and Nola (2011), for example, replaced the terminology of 'nature of science' with 'family resemblance approach' which was originated from Wittgenstein. In the definition of the family resemblance approach, members of a family show similar characteristics in some respects but not in others. They do not believe that consensus view of NOS is valid for all of the sciences. They advocate that sciences have similar cognitive-epistemic system in terms of (1) activities, (2) aims and values, (3) methodologies and methodological rules, and (4) products but in some respect. Secondly, science covers social-institutional system including four categories: 'professional activities', 'scientific ethos', 'social certification and 'dissemination of scientific knowledge', and 'social values of science' (Irzik & Nola, 2014). These researchers believe that the family resemblance approach fits better with the history of scientific development and is more dynamic and open-ended than the consensus view. By adopting this approach, Dagher and Erduran (2016), added following three categories to Family Resemblance Approach (FRA): 'social organizations and interactions', 'political power structures' and 'financial systems' because these were considered as other important aspects influencing scientific discipline. They introduced 'FRA Wheel' covering 'cognitive-epistemic' and 'social-institutional' aspects of science. They emphasized that FRA Wheel may be seemed complex by science teachers and students at the beginning and specific activities to promote metacognitive thinking of science should be added.

In addition, Allchin (2011) suggested a new understanding to nature of science by emphasizing limitations of consensus view. In his study, he argued that science should be seen as 'whole science', not refined in order to adapt consensus view. He characterized that consensus view was insufficient to develop functional scientific literacy, because reliability in scientific practice was absent. He proposed that scientifically literate person should have understanding about how evidence works, error types, peer review, role of funding, validation of new methods, and so on (Allchin, 2011). In addition, questions which are presented in VNOS-C does not provide students to make social and personal decisions. He criticized consensus view in terms of lack of philosophical perspective.

In addition, Matthews (2012) criticized the tenets of NOS, because they limited the students' and teachers' critical thinking ability and thoughtfulness. According to Matthews, the tenets of NOS should be given in much more detailed way by science teachers. In this regard, he emphasized that the terminology of NOS should be replaced with features of science (FOS) which has elaborated understanding of science. He added some items into NOS framework such as experimentation, idealization, models, values and socio-scientific issues, mathematization, technology, explanation, world views and religion, theory choice and rationality, feminism, realism and constructivism. In addition, he advocated that history of science, socio-scientific issues and techno-value debates should be practiced in classroom environments.

Finally, Romero-Maltrana et al. (2019) warned that consensus view had some relativistic explanations. Like Allchin (2011), they criticized consensus view of NOS because it did not include any philosophical attempt to realize science. They celebrated the authors such as Irzik and Nola, Matthews, Dagher and Erduran who created alternative approaches to consensus view in order to improve 'how philosophical and sociological dimensions of the scientific endeavour are treated in science education'. According to their understanding, science's features such as emphasizing human role and questioning the objectivity can also be seen in other human activities such as obtaining social consensus and religious occurrence.

2.2.2. School students' reasonings about nature of science and scientific knowledge. McComas (1996) proposed ten myths about NOS that are common among the school students using the consensus view. These myths are; (1) hypotheses become theories and theories become laws, (2) a hypothesis is educated guesses, (3) a general and universal scientific method exists, (4) evidence accumulated carefully will result in sure knowledge, (5) science and its methods provide absolute proof, (6) science is procedural more than creative, (7) science and its methods can answer everything, (8) scientists are particularly objective, (9) experiments are the principle route to scientific knowledge and (10) all work in science is reviewed to keep the process honest. He emphasized the importance of conducting corrections about such myths and that explicit NOS teaching should be performed in science classes

(McComas, 2017). In addition, he argued that although there were alternatives in order to enhance science education, general view of NOS should be adopted and focus should be on how to teach and asses of NOS aspects.

Yenice et al. (2018) uncovered 809 high school students' level of scientific epistemological beliefs. The data of the study was collected by scientific epistemological beliefs questionnaire and data was analyzed descriptively. Students' responses to scientific epistemological beliefs questionnaire were divided into following sub groups: 'authority and truth', 'knowledge generation process', 'knowledge source', 'reasoning and changeability of knowledge'. Students' levels of scientific epistemological beliefs were coded as traditional (underdeveloped), combined (intermediate) and contemporary (developed) from low grade to high grade respectively. They argued that students' responses were generally at contemporary level. This indicates that students are aware of changeable nature of scientific knowledge, empirical nature of scientific knowledge, subjectivity in science, creativity and imagination in science. Specifically, it has been determined that 12th grade students have much more developed beliefs towards the changeability of scientific knowledge than 11th grade students do.

Dogan and Ozcan (2010) investigated the effects of History of Science pedagogy on 56 seventh grade students' understanding of NOS. Views of Nature of Science Questionnaire (VNOS) was used before and after the intervention. Items in the test classified as 'accuracy and uncertainty of scientific knowledge', 'subjectivity', 'creativity and imagination', 'empirical nature of scientific knowledge', 'scientific models', and 'social and cultural influences'. Responses of participants were coded as 'uncategorised view', 'insufficient view' and 'more informed view'. In this classification, the "insufficient view" expressed (traditional) positivist perspective and the "informed view" represented (post-positivist) contemporary perspective. In the accuracy of scientific knowledge category, the student who thinks that *because buoyancy of water does not change, theory and law (about it) do not change* was classified in the insufficient view. On the other hand, the student who *explains that the example of atomic model changes in time* was classified in the more informed view. After the intervention, it was determined that there was a statistically significant difference between pre and post test results in understanding of accuracy and uncertainty of scientific knowledge category.

Cetinkaya (2019) examined the effects of nature of science activities based on explicit-reflective approach on 50 sixth grade students by using VNOSD+ questionnaire. They grouped their findings using following NOS aspects: ‘tentative nature of science’, ‘empirical nature of science’, ‘creative nature of science’, and ‘subjective nature of science’. In addition, participants’ responses were classified as following three groups: ‘insufficient’, ‘transitional stage’ and ‘informed’. In this study, the question ‘Scientists produce knowledge. Do you think scientific knowledge will change?’ was asked. Most of the experimental and control groups stated that scientific knowledge was tentative. It was observed that particularly the students in the experimental group got higher scores in the post-test compared to the pre-test answers in the ‘tentative nature of science’. For example, after the instruction, a student (in experimental group) who advocates tentativeness of science expressed that ‘*Yes it can change. For example, Galen presented a theory. Since there was no other theory at the time, he was accepted. Years later, Harvey presented a theory, showed evidence, so it might change.’*

In the Solomon et al. (1992) study, 94 middle school students’ (aged 11-14 years) preliminary perceptions and understanding about nature of science were investigated. Before the intervention, students were interviewed about their responses to the questionnaire. At this stage, students had some epistemological obstacles. Some of them were unfamiliar with scientists and the word of theory; also, they could not give any examples of scientific theory. Course materials were prepared by taking these results into consideration. The intervention included piece of history writing activities, making posters, performing experiments, taking part in a role play, and so on. Looking at the results, one of the questions in the interview was particularly related to present study: ‘Sometimes in the past groups of scientists have held different theories. Is this because: (a) they have done different experiments? (b) one group was wrong and the other group was right? (c) they looked at results of their experiments in different ways? (d) one group made a mistake in their experiments? 72 students selected the item c (looking at results of their experiments in different ways) both in pretest and post-test. 16 students selected item a (they have done different experiments). It was founded a negligible change about this question after the intervention though there were some positive developments in other NOS aspects such as considering a theory as an idea or explanation rather than a fact and seeing the experiments as trying out the explanations rather than making new discoveries.

Deve and Kucuk (2016) prepared a teaching material including historical approach of science and investigated the effects of this material on students’ understandings of nature of science. In this study, 20 seventh grade students’ NOS understandings were evaluated by using categories such as ‘weak’, ’changeable’ and ‘adequate’. NOS aspects were grouped as ‘tentativeness of science’, ‘empirical nature of science’, ‘creativity and imaginative nature of science’ and ‘inference based nature of science’. While students who thought that scientific knowledge changed in time was classified as ‘adequate view’, others who thought that scientific knowledge was certain and never changed and scientists obtained and proved this knowledge after long researches were evaluated as ‘weak view’. For example, a student who had weak insight expressed that *they have certain knowledge about the structure of the atom; because, scientists opened and examined the interior of the atom.* In the pretest findings, 15 % of the students had adequate insight, 30 % of the students had changeable view, and 55 % of them possessed weak insight. After the intervention, the “weak” opinions of the students decreased from 55% to 15%. One of the student in this group, for example, stated that *scientific knowledge was uncertain, it can change if new evidences were found and it has a falsifiable structure: Scientific knowledge is not certain, it can change. For example, Thomson compared the [atom] to a solid sphere. However, Bohr compared it to a cloud by doing different experiments.*

Rudge et al. (2014) investigated 130 preservice science teachers' beliefs about nature of science before and after a History of Science based NOS intervention. One of the question that was asked to students was: *Explain why do you think that scientific theories do (or do not) change. Defend your answer with the examples.* Responses of the students were analyzed under the categories of 'naïve' and 'sophisticated'. Students who have naïve conception thought that scientific knowledge never changes. For instance, *Scientific theories do change that is why they are theories and not laws,* the response of the student, was classified as naive NOS view. In contrast, students who have sophisticated understanding of NOS stated that theories could change over time due to new findings, falsifications or reinterpretation of existing data. *Yes, theories constantly change. A scientist will explain what they have found, then another scientist will prove that wrong or to be inaccurate*, one of the quotations of the participants, for example, was in the more sophisticated NOS view. In the pretest, most of the participants identified that the reason of changes in theories was finding new evidence. However, students who have more sophisticated understanding added reinterpretation of data as a reason for the changes. In the post-test, similar results were founded.

The study of Sutter et al. (2019) included 116 sixth grade students. Data obtained from students using the tasks and interviews about wind turbine module (a socioscientific issue). Results of the study analyzed by The Linguistic Category Model (LCM) in order to evaluate students' verbs, adjectives and nouns and how they abstract the problem. Their abstraction score were coded from lowest (highly concrete) to highest (highly abstract). In addition, the researchers investigated relationship between students' thinking style (level of abstraction) and their perceptions (positive, negative or neutral) about socio-scientific issue (SSI). It was founded that students who had negative perceptions of the wind energy added more concrete problem statements and more observable examples. Generally, students who problematised the issue more concretely added observable actions with little additional interpretation. In contrast, students who had abstract thinking provided more additional interpretation related to theoretical, spatial, social and temporal aspects.

Karpudewan and Roth (2018) studied with 68 12 year-old primary students in order to investigate informal reasoning skills about socio-scientific issues. The data obtained after completion of each SSI-based task using an open-ended questionnaire. The findings of the study were analyzed descriptively according to three dimensions of informal reasoning: decision making modes (intuitive and evidence-based decision), reasoning modes (social, ecological, economic and scientific arguments), and reasoning levels (supportive arguments, counterarguments, rebuttals). In decision making mode, before the instruction, most of students made intuitive decision (i.e., spontaneously respond or claims without concrete evidence); after the instruction, students increasingly made evidence-based decisions. For instance, before the instruction, a student stated that *I disagree with urban development because it causes many problems and* another student mentioned that *'water pollution is dangerous'* . When the interviewer asked them more information about the specific problems and how water pollution be dangerous, students responded the questions intuitively without specific and precise causes; for example, saying that '*Because water from tap sometimes is brown in colour and my mother says it is dangerous to use this water.'* Another response was that *'I know there will be many problems. I have read about it in the book and seen them on the television. But I don't know the exact answer.'* On the other hand, as the students moved through the curriculum, students' decision making modes developed through more evidence-based decisions. For instance, a student justified his decision by saying that *'Illegal logging destroys the animals' habitats and the plants go extinct and are endangered'.* This students' response was classified as 'evidence-based decision' because they have explicit and concrete evidences. In addition, after eight SSI-based tasks related to environment were applied, students increasingly used rational informal reasoning. Moreover, the frequency of using intuitive decision making modes and the number of students who were used them decreased.

Sadler et al. (2004), investigated students' conceptualizations of NOS and socio scientific decision making. The study included 84 high school students. The data of the study was collected by open ended questionnaires and interviews. When analyzing the question *how groups of scientists evaluating the same data could produce such divergent conclusions?,* the researchers produced four groups of responses: 'myth confusion', 'data concerns', 'beliefs and opinions', and 'different foci'. In 'myth confusion' group, one of the responses was *'The reason they have different conclusions is because one is based on facts and the other is based on myth.* 'Data concerns' group was divided into 'different data' and 'different data analysis' sub groups. In 'different data' group, one of the responses was *'Because even though they both talking about different material, one is on temperature changes and the other is about C. dioxide concentration.'* In 'different data analysis' group, one of the responses was '*Both groups have pretty much the same data from sensors and test, etc. But both are looking from different angles and processing the data in opposite ways.'* In 'beliefs and opinions' group, one of the responses was *'They have different conclusions because in science there is no one right answer. The scientist may also have different conclusions because of their beliefs or opinions on this subject.'* In 'different foci' group, one of the responses was *Articles have almost the same idea; the second is related that the icebergs will melt and flood many countries. The first article describes how the temperature change. The second is telling us about how to solve the problem.'* (Sadler et al., 2004, pp.399). The researchers concluded that

SSI contexts are good examples for contextualization of NOS aspects and teaching them effectively.

In Eastwood et al. (2012) study, the effects of socio-scientific issues (SSI) driven and content driven explicit-reflective NOS instruction on students' NOS conceptions were investigated. This study included four classes (each of them includes approximately 30 students) including 11th and 12th grade students. The VNOS-C questionnaire was applied prior to instruction and at the end of the academic year in both SSI and Content groups. They used ordinal categories of 'informed', 'transitional', and 'naive' in order to uncover the NOS perspectives. In the 'tentativeness' category, for example,*'Theories change because of new technological developments and influence of differing scientific opinions. However, it is still necessary to learn theories to gain current knowledge'* was an example of informed response. *'Science is always changing . . . Theories are constantly changing'* was classified as transitional statement. Finally, '*Scientific theories definitely do not change. A theory is something that's been proven time and time again by numerous people and when done the correct way, it always turns out with the same results'* was considered as na¨ive conception. The results showed that in both groups' pre test results there were no significant difference in the level of NOS understandings. The researchers only detected systematic differences in the examples on one particular item (social and cultural NOS). In addition, they did not find any significant differences between SSI and Content groups in terms of NOS aspects.

Chapter 3

Methodology

3.1. Sampling

In the present study, the data of the project ‘FESKOK: Educating science teachers on teaching socioscientific issues: A learning community study’ were used. The project covered four stages. In the first stage, the literature review about SSI, deep interviews with the scientists regarding specific SSI examples, a Delphi study with experienced science teachers and science educators were conducted and this knowledge was fused by an epistemic amalgam in order to develop a learning and teaching framework (a curriculum) for SSI. This framework covered an inquiry-based argumentation oriented teaching vision, the learning areas that are based on ‘searching for the data’, ‘thinking of the data’ and ‘believing or disbelieving’ and the learning goals such as ‘evaluating the justification processes of the evidence’ and ‘knowing the problems and misunderstandings in the development of evidence’. Therefore, the framework was particularly based on the epistemic development of the students by focusing on the data/evidence development processes. In the second stage, this framework informed four teaching modules that are developed based on specific SSI contexts and that target specific teaching units in the middle school science curricula from grades 5 through 8. In the third stage, an in-service science teacher education was planned for nine teachers in the same school so that these teachers apply the learning and teaching framework for SSI using the developed teaching modules. Within this education, the nature of knowledge, the relationships between knowledge and belief, the justification processes and the nature of SSI and SSI teaching were discussed. In the final stage, the efficiency of the Feskok Education (the project) was tested within real classrooms of these educated science teachers. In addition, these teachers came together in the learning community meetings in order to discuss their experience and get feedback from the project team in order to resolve the problems and improve their education. For testing the effectiveness of the education, four vignettes (one for each grade) covering SSI scenarios and the discussions among the experts and representatives of the public were developed. These vignettes were applied to the school students in both control (where traditional teaching methods and science textbooks were used) and experiment (where the developed learning and teaching framework for SSI and developed teaching modules were used) groups as pre and post-tests.

In the present study, we focused particularly on the data from these vignettes in the grades of 5 and 8 (two classes) in the experiment groups. Because the purpose of the present study was to uncover the school students' reasoning about multiple responses for the same scientific question, it was considered that these reasonings and their development could efficiently be pursued through an SSI-based education in the experiment groups particularly targeting epistemic development. In addition, considering the qualitative nature of the present study, we limit our coverage to two experiment groups out of nine. In addition, we selected grades 5 and 8 in order to uncover possible age-oriented patterns.

In the selected grade 5 experiment group, there were 33 students. All of these students completed the 5^{th} grade vignette as the pre-test; however, 28 out of them completed the same test as the post-test. In addition, taking a closer look at the written statements in the existing pre-post vignette couples, we decided to exclude 13 students' data because of limited writing or unresponded sections. In the end, we used the data of 15 grade 5 students in one of the experimental groups. In addition, 8 of them were males, 7 of them were females.

When it comes to grade 8 students, there were 33 students in the selected classroom. All of these students completed the 8^{th} grade vignette; however, 32 of them completed the same vignette as the post-test. In addition, we excluded the data of 8 students due to limited writing or unresponded sections. Therefore, we used the data of 24 grade 8 students in the selected experiment classroom in the present study. In addition, 12 of them were males, 12 of them were females.

3.2. Data Collection Tools

Two vignettes – one for grade 5 and the other for grade 8 – were used as the data collection tools in the present study. Both of the vignettes included one authentic SSI case covering one scientific question and follow-up multiple responses due to incomplete data. These vignettes were developed by the project team including two science education professors and five post-graduate students in science education.

5th grade Vignette: In the introduction section of the vignettes, a health-oriented problem in a village (an illness among the children) was presented. A detergent factory was established five years ago and there has been a problem for two months. A district governor, a headman, a countryman who works in factory, a biologist who searches about environmental problem, and one another biologist who is employed in Family Health Centre came together in order to find the reason for the problem. Their thoughts and discussions about the situation were given in the vignette.

8th grade Vignette: In the introduction section of the vignettes, a health-oriented problem in a village (mortality of heron eagles) was presented. The village was settled around a lake and there is a rich ecosystem in the lake. Villagers have recently observed that many heron eagles have died and expressed the situation to the district governor. The district governor brought together one resident of the village, headman and scientists (two Biology professors) working in the region. Their thoughts and discussions about the situation were given in the vignette.

3.3. Data Analysis

First, in order to better classify and compare the students’ responses, we transcripted students’ written statements on the vignettes and produced an Excel file. Two independent researchers, one of them was the author, have independently read all of the statements two times and they then initiated a constant comparative method in order to group the statements together. In these prolonged discussions, they pursued five stages that emerged during the data analysis. First, they brought the sentences representing ‘one reasoning about multiple responses for the same scientific question’ together. At this stage, some external sentences that are not related to building a conclusion (i.e., production of reasoning) are excluded. After selecting the sentence groups representing the reasonings, in the second stage, it was decided to group the reasonings under the themes such as ‘naïve reasoning’ and ‘sophisticated reasoning’ due to similar classifications in the literature (e.g., Abd el Khalick, 2012). However, we noticed that there were some reasonings that could be put into both of the reasoning themes. Therefore, at the third stage, we decided to change our classification themes and reread the existing philosophical considerations and NOS studies in order to find better themes. After this re-reading, we decided to use themes such as ‘fantasy-based reasoning’ and ‘data-based reasoning’. In the ‘fantasy-based reasoning’, consistent with the theological, metaphysical and positivist beliefs (science-based value) of Auguste Comte, the idols of Francis Bacon, the attempt of Feyerabend on equalizing scientific thinking with other social thinking types and the emphasize of Wittgenstein on importance of language games in building scientific thinking and the literature on school students’ positivist beliefs about science and value-oriented beliefs in socioscientific controversies, we considered that a fantasy-based reasoning effectively works in the minds of school students in the cases of controversial scientific claims. It is believed that this fast reasoning (Kahneman, 2013) immediately focuses on the words and stories within the vignette that have the nature of emotional arousal. Such arousal may make the emotion-loaded heuristics such as ‘science can answer every question’, ‘technologies destroy the nature’, ‘nuclear is harmful to human health’ and ‘factories need to be closed’ come to the mind and the students complete the incomplete data within the text with such heuristics and they then easily reach one single response. In the 'data-based reasoning', on the other hand, consistent with the Francis Bacon' belief that scientific approaches experience fundamental renewals due to new findings, Karl Popper's falsification process, Thomas Kuhn's multiple paradigms and two-staged historical scientific development and Lakatos's theoretical pluralism and the literature on students' relativistic beliefs about science and data-based reasonings in socioscientific controversies, we considered that data-based reasoning is the other reasoning type effectively working in the minds of students about multiple responses for the same question. In this slow reasoning (Kahneman, 2013), rather than a fast complementation of the incomplete data by the emotional heuristics, it is believed that the students stay with the data production process and analyze the missing pieces and alternatives in this process using their knowledge about scientific methodologies, validity and reliability process and the history of scientific developments. In addition, they do not easily apply to common emotion-loaded heuristics among the public; rather, they develop their own heuristic using the available (incomplete) data and necessary steps for sound scientific inquiry. At the fourth stage, after classifying the reasonings within pre and post vignette tests as 'fantasy-based' and 'data-based' and bringing the pre- and post-reasoning couples for each student together, we built the 'developmental themes'. This development represented the change, rather than the enhancement in our approach. At the final stage, we used descriptive statistics (i.e., frequencies and percentages) for numerically representing the developmental themes.

3.4. Validity and Reliability

For the validity and reliability of present research, the procedures of naturalistic inquiry (Lincoln & Guba, 1987) were used to some extent. The intervention in both of the experiment groups took about five weeks. The teaching modules and the vignettes were developed by a research team including seven researchers. In addition, the teachers in the selected experiment groups were exposed to the in-service teacher education regarding epistemology and epistemic development. It is considered that this ‘long-term’ planning and applications may contribute to the credibility of the knowledge produced. In addition, in the data analysis, ‘peer assessments’ were used and a ‘constant comparative analysis’ was adopted. In addition, the ‘negative case analysis’ was applied to the data in order to be sure of the classifications.

Chapter 4

Results

4.1.Developmental Themes

Table 1

The developmental themes for 5th grade

Developmental Themes	**Number of Students *(n=15)***	**Percentage *%***	**Total Percentage *%***
1.Phantasy based reasoning > Phantasy based reasoning	**7**	**46.6%**	**46.6%**
2.Data-based reasoning > Data based reasoning	**7**	**46.7%**	**46.7%**
2a. .Best argument epis. > Best argument epis.	2	13.3%	
2b. Multivariate epis. > Multivariate epis.	2	13.3%	
2c. Multiple methods epis. > Multiple methods epis.	1	6.7%	
2d Falsification > Multivariate epis	1	6.7%	
2e. .Multiple approaches epis. > Multiple approaches epis.	1	6.7%	
3. Data-based reasoning > Phantasy based reasoning	**1**	**6.7%**	**6.7%**

4.1.1. The developmental themes for 5th grade students

4.1.1.1. Phantasy-based reasoning > Phantasy-based reasoning. According to Table 1, seven students (46.6 %) did not change their **phantasy-based reasoning** through the treatment. 5S1, for example, did not change his phantasy-based reasoning through the treatment. He, in the pretest, said *I think that science gives us the only answer here: The disease that appears in children stems from environmental pollution. Thus, bacteria grow faster.* 5S1 used a similar expression with some extensions in the posttest by saying *Increasing minerals (heavy metals) in the body may cause the imbalance in the body. If all bacteria are thrown out (...are killed), the body cannot resist.* As shown in the statements, the available incomplete data seem to trigger his imageries and he built the relationships between pollution and bacteria growth or between heavy metals and bacteria reproduction even though these direct relationships were not available in the data/text. Similarly, 5S3 did not change his phantasy-based reasoning through treatment. In the pretest, he, for example, said *children may use water for fun. They do water battles with water filled with toxic waste but they do not realize it. For this reason, children may be sick, but the situation may have other explanations*. In the posttest, he said *yes, there is only one answer. There is no more. The detergent factory should be closed for a while, if the problems continue, it should be closed completely.* As can be seen, in the pretest, 5S3 used his phantasy regarding playing children with the polluted water perhaps because the incomplete data directly stimulated such a phantasy. In the post test, despite the lack of complete data, he built a direct relationship between the illness of the children and the detergent factory. As another case, 5S4, in the pretest, said *It is possible (there is only answer). Because the increase in the cells that are fighting microbes has been observed.* In the post-test, 5S4 said *there seems to be only one answer: Demolition of the detergent factory.* The student had phantasy-based reasoning in both pretest and posttests. In the pretest, she built a direct relationship between the increase in the cells fighting with microbes even though such relationship was not confirmed by the producer of it (second biologist). In the posttest, we noticed that she still believed that there was only one answer due to the availability of detergent factory despite the fact that such a sharp relationship was not available in the text. Similarly, 5S10, in the pretest, said *I think the* *answer to this question is chemical poisoning. Because there is a detergent factory in the village*. 5S10's posttest response was *I think the ideas are different, but their results are similar. Both of them are the causes of the disease.* Looking at the responses, in the pretest, 5S10 was sure that the response was the chemical poisoning because of the sharp reason/factor or evidence of the fact that there was a detergent factory in the village. Even if she seemed to slightly change her position in the post test, we can argue that she still based her position on the sharp cause/evidence-effect relationship by saying that two possibilities might be two reasons for the same disease despite the fact that such relationship was not available in the text. When it comes to the case of 5S11, in the pretest, he *said May be. Because there is an answer to diseases seen in children. If there is no answer to disease, it cannot heal. And if the disease does not recover its result may be death.* In the post test, 5S11 said *Children have become ill due to microbial contamination of water and various events have occured.* Looking at both of the responses, in the pretest he used the healing process of the children from his imagination, whereas in the post test he directly connected microbial contamination with the illness even though such direct relationship was not available in the text. Similarly, *5S12*, in the pretest, said *I think. I would agree with the biologist working in the Family Health Center. Because for me, it is true what the biologist says.* In the posttest, she said *I think the children are sick because of the odors. Polluted waters affect their health negatively.* As can be seen, in both of the tests, she used phantasy-based reasoning. In the pretest, he accepted biologist's argument even though the biologist identified some incomplete pieces in the data reasoning, whereas, in the post test, he mentioned the odors that were not available in the text. In one another case, 5S15, in the pretest, said *I think the filter may not be installed on the factory chimney.* On the other hand, in the post test, 5S15's response was *Reasons: 1. Factory owner attaching filters to the chimney 2. Throwing toxic water into the river 3. By mixing the poisonous air with natural air, the fountain can enter* *into there and poison it.* The student's statements in both of the tests represented phantasy-based reasoning because he directly based his response on the factory filters that were not a part of the text.

4.1.1.2. Data-based reasoning > ***Data-based reasoning.*** According to Table 1, seven students (53.4 %) did not change their **data-based reasoning** through the treatment. These students analyzed the available data in terms of its production processes rather than using their imageries in order to complete missing pieces for building the knowledge. Even if all of the sub-titles below represent data-based reasoning, we are keen to share them separately because there are clear nuance differences among them.

4.1.1.2.1. Best argument epistemology > Best argument epistemology. Two students did not change their **best argument** position that is one of the types of data-based reasoning. 5S6, for example, in the pretest, said *I don't think there is a single answer to a question in science. Because a lot of people say different ideas and some of them are likely to be true.* 5S6 gave similar response in the post test by saying *I don't think there is only one answer because more than one person interpret the question and some of them are possibly true.* Looking at the responses, we can argue that 5S6 considered that there were multiple explanations for one scientific question and one of them possibly was the best one. Similarly 5S7 did no change her best-argument epistemology. In the pretest, she said *because biologists cannot be sure, there can be a lot of reasons, there is no single answer.* In the post test, she said *I think there can be a lot of answers. According to the research of biologists and the symptoms, their diagnoses can be correct.* As can be seen, she was sure that biologists might have different results or opinions, but by further findings and research, they can be sure on one of the possibilities. Looking at the responses of both of the students, we can argue that they particularly dealt with the data and focused on knowledge production processes rather than producing incorrect connections stemming from phantasy-based reasoning.

4.1.1.2.2. Multivariate epistemology > Multivariate epistemology. One student (5S9) did not change her **multivariate epistemology** that is one of the types of data-based reasoning. 5S9, in the pretest, said *I don't think so. Because there can be multiple factors. These factors may have different effects. But sometimes there can be a single answer to a problem.* Similarly, in the post test, she said *It is a single one. Biologists conduct research and draw a single conclusion but sometimes they can reach more than one result.* Looking at both of the responses, 5S9 considered that multiple cause-effect relationships and follow up multiple interpretations were crucial in the development of valid and reliable knowledge. In one another case, 5S14, in the pretest, said *I think every child has a different structure, so a different disease may be seen in each child.* 5S14' posttest answer was *Each child's body structure may be different.* Looking at both of the responses, 5S14 focused on the available data and knowledge development process and identified one missing possible reason in addition to the available ones in the text.

4.1.1.2.3. Multiple methods epistemology > Multiple methods epistemology. One student (5S8) did not change his **multiple methods epistemology** that is one of the types of data-based reasoning. In the pretest, 5S8 said *I do not think there is a single answer to a problem in science. Because questions solved in science can be solved with different ways, different solutions, different techniques. For example, a scientist solves the question differently, another can solve differently and never use it again.* In the posttest, he did not change his position by saying *I don't think there is a single answer to a problem in science. Because a problem in science can be solved in different ways and by different techniques.Thus, there is no single answer to a problem in science.* Looking at the responses, we can argue that 5S8 was aware of the fact that different methodologies, research pathways and research tools/techniques might result in different data and conclusions in the development of clear knowledge.

4.1.1.2.4. Falsification > Multivariate Epistemology. One student (5S13) replaced his **falsification-based** position with **multivariate epistemology** through the treatment. We believe that both of the thinkings were the types of data-based reasoning. In the pretest, 5S13, for example, said *I think there is only one answer to everything in science, but it is hard to find the right answer, there is only one right answer within millions wrong.* In the post test, he said *There can be more than one toxic substance in chemicals coming from the factory and those substances may have caused different diseases.* Looking at his pretest response, despite the short response, we can argue that he was aware of the nature of the falsification. In the post test, he felt the multivariate nature of the disease development. Both of the responses were based on the available data.

4.1.1.2.5. Multiple approaches epistemology > Multiple approaches epistemology. One student (5S2) did not change his **multiple approaches epistemology** through the treatment. His pretest response was *I think that there is not only an answer, it commonly changes according to people's opinions. One person may have one opinion, others may have ten opinions.* He gave a similar response in the posttest by saying *there is no single answer, everyone's opinion is different.* Taken together, 5S2 considered that the answer changed according to **people's approaches** because different people had **different interpretations** on the same problem and he did not change his position after the treatment.

4.1.1.3. Data-based reasoning > Phantasy-based reasoning. According to Table 1, one student (5S5) (6.6 %) replaced her **data-based reasoning** with **phantasy-based one** after the treatment. 5S5's pretest response was *Some sciences may have one answer. Other sciences may not have one answer. Every science is different.* In the posttest, 5S5 said *I think that the cause of the disease is people's fault. People get sick, because they are polluting the environment. And many living things die.* Taken together, 5S5 first considered that some science disciplines may have answers that are more than one even though we believed that he might use the term ‘science’ instead of the terms ‘question’ or ‘problem’. Therefore, we can argue that she possessed a multivariate epistemology in the pretest. After the treatment, she replaced this multivariate epistemology with a phantasy-based reasoning in which she was sure of the fact/knowledge that the environmental pollution was the responsible factor despite the lack of clear data.

4.1.2. The developmental themes for 8th grade students

Table 2

The developmental themes for 8th grade students

Developmental Themes	**Number of Students *(n=24)***	**Percentage %**	**Total Percentage %**
1.Phantasy based reasoning > Phantasy based reasoning	**6**	**25%**	**25%**
2.Data-based reasoning > Data based reasoning	**10**	**41.5%**	**41.5%**
2a. Multivariate epis > Multivariate epis.	2	8.3%	
2b. Multiple approaches epis > Best argument epis.	2	8.3%	
2c. Multiple approaches epis. > Multiple approaches epis.	3	12.5%	
2d. Multivariate epis.> Multiple approaches epis.	2	8.3%	
2e. Multivariate epis. > Conditional relativity	1	4.1%	
3.Phantasy based reasoning > Data-based reasoning	**8**	**33.4%**	**33.4%**
3a. Phantasy based reasoning > Best argument epis.	5	21%	
3b. Phantasy based reasoning > Multiple approaches epis.	2	8.3%	
3c. Phantasy based reasoning> Multivariate epis.	1	4.1%	

4.1.2.1. Phantasy-based reasoning* > *Phantasy-based reasoning. According to Table 2, six students (25 %) did not change phantasy-based reasoning through the treatment. 8S1, for example, in the pretest, said *I think it might be. Agriculture is important for everyone.* 8S1 mentioned a similar expression in the post test *I think if I were the professor, I would allow agriculture. Because it is beneficial for me or for everyone, and everyone's thoughts are different.* As can be seen, despite the lack of clear data and the short responses, we can argue that 8S1, in both of the tests, seems to believe that agriculture was not responsible for the problems. In one another case, 8S14, in the pretest, said *In my opinion, Professor Arif integrated his own thought into the issue. Because; if the ground of the lake is too hard and If it was not getting water, algae due to soil hardness to grow. At the same time, if water is not received, water cannot be returned. There would be exuberation due to this reason. People do not perceive toxic originating from fishes due to taking vitamins and proteins.* When it comes to 8S14's posttest response was *I agree with the biologist Nergiz. Because the base of the lake is hard, it would be very difficult to grow algae. For this reason, the number of herbivorous carp would reduce. In addition, Ms. Nergiz's explanation can be provable logically and scientifically.* As can be seen, in the pretest, 8S14 benefitted from his phantasy-based reasoning. In order to rebut the Professor Arif's argument, he built many unclear relationships between algae production and the nature of lake ground. In the post test, 8S14 he built one another similar unclear relationship that would not be clearly confirmed by the text/available data between algae reproduction and the nature of lake ground.

In one another case, 8S16's pretest response was *It is true that chemicals used in agriculture kill eagles. This is why the eagles become extinct rapidly. For this, we have to stop the agriculture and get eagles to protect.* 8S16 gave a similar response in the post test by saying *Mrs. Nergiz proved to Mr. Arif that the causs of the eagles' death is chemical in their blood. There is chemical in the eagle according to the general solution. (The question is not a* *math question, there is only one way).* Looking at both of the responses, 8S16 was sure that the reason for the problem was the chemicals despite the lack of clear data. In addition, 8S19, in the pretest, stated *I think there is only one answer, this is what Mr. Arif says. Because no such thing happened in the past. The bowl should be made as Mr. Arif says.* In the posttest, 8S19 said *It could be. God created that and people spoil it. Mr. Arif says that the floor of lake is like a bowl and will never be passed, but Mr.Selim says that this farming has been around for a long time, so maybe that bowl can pass water getting thinner in time. Thus, he can say that eagles die by passing pesticides into the river.* As can be seen, 8S19 actively used his phantasy-based reasoning in both of the tests. In the pretest, even though Mr Arif identified bowl nature of lake ground, 8S19 accepted it as a solution and recommended making the ground bowl. In the post test, he further used a religious perspective by unclearly adding new approaches coming from one another actor in the text.

In one another case, in the pretest, 8S3 said *There may be no one answer to a problem in science because other assets may be affected if we do an activity.* In the post test, he argued *There may be a lot of solutions in a question. But a solution may cause other problems. I think that non-use of pesticides makes more sense.* Even if his responses seem to be considered under the multivariate epistemology, looking at closely, we can argue that 8S3 was sure of the fact that the agricultural activity was responsible for the problems despite the lack of clear data confirming such a result.

In the case of 8S25, in the pretest, she said *I think there is only one answer. Because no matter how many reasons a result of an event is the same. Let's look at the following example:- Ali took a minus for not doing his homework. - Ali took minus because he didn't bring his homework. Ali took a minus because he forgot his homework. There is only one result, even if there are three causes like the example. In other words, since a number of events have affected the other negatively, the two originate from the same situation.* In the post test, she said *I think there is only one answer because if there are more than one result, the results will come together and find logical solution.* Looking at both of the responses, it was clear that she was sure on the only answer by using her logic-oriented phantasy based reasoning.

4.1.2.2. Data-based reasoning* > *Data-based reasoning. 10 students (34 %) did not change their **data-based reasoning** through the treatment. These students analyzed the available data in terms of its production processes rather than using their imageries in order to complete missing pieces for building the knowledge. Even if all of the sub-titles below represent data-based reasoning, we are keen to share them separately because there are clear nuance differences among them.

4.1.2.2.1. Multivariate epistemology > Multivariate epistemology. Two students did not change their multivariate epistemology that is one of the types of data-based reasoning through the treatment. 8S5's pretest response, for example, was *I think there is no single answer to a question in science. Because, I think there may be more than one reason for eagle's dying.* 8S5 gave a similar response in the posttest *I think there cannot be a single answer to a question because it's an example there are many reasons the eagles' extinction.* As can be seen, 8S5 considered that there may be more than one reason/variable for the eagle's dying by thinking of the incomplete data in the text. In one another case, 8S24, in the pretest, said *Each factor can cause major problems. There are results that can vary according to surrounding factors.* In the post test, 8S24 stressed *An event can have multiple causes. This is similar to spider web, the spider establishes a web in a certain location for hunting. But when its environment is not suitable, it retracts its web. Briefly, there are multiple causes of the incident.* Looking at both of the responses, we can argue that 8S24 considered the available unclear data and suggested multivariate nature of resolving scientific questions.

4.1.2.2.2. Multiple approaches epistemology > Best argument epistemology. One student (8S21) replaced her multiple approach epistemology with best argument epistemology, both of which are the types of data-based reasoning. In the pretest, 8S21 said *There is only one answer to the question in science, but the problem is related with interpretation and perspective. Because biology professors have different perspectives, both of them had a different result from the event*. In the post test, 8S21 said *I think that the difference of Professors' comments may be dependent on a little research in the region. If biology professors conduct comprehensive research with a better team, their opinions can be changed. After this is done, if the biology professors' idea is different, other scientists who are interested in this discipline should be interviewed and their opinions should be gained. These views are evaluated and must be proven scientifically.* Although the student expressed the pretest methodological difference between scientists, s/he argued being only one answer in science. On the other hand, in posttest s/he mentioned that best argumentation should be done by gaining other scientists' opinion and evaluating, proving them. In addition, 8S9, in pretest, said *No, it cannot be. Because they talked about different issues.* In the post test, 8S9 said *It cannot be because a larger scale survey should be done and should be scientifically proven.* Looking at the responses, in the pretest, she had a multiple approaches epistemology whereas in the post test she argued the necessity of further research in order to justify one of the alternatives.

4.1.2.2.3 Multiple approaches epistemology > Multiple approaches epistemology. Three students did not change their multiple approaches epistemology that is one of the data-based reasoning through the treatment. For example, 8S2' s response in the pretest was *May be. Everyone is right in their opinion. There may be many reasons for this. But you need to come to a single conclusion.* 8S2, in the post test, argued that everyone has different opinions by saying *It is difficult to have a single answer. Because everyone speaks with the results that* *he finds. Everyone can find different results. Therefore, a common conclusion cannot be reached. We understand this from the dialogue: 'Should be done agriculture around the lake?'* Looking at both of the responses, 8S2 considered that different scientists might interprate the same data with different perspectives. In the pretest, even if he approached the case pragmatically by saying scientists need to come to single conclusion despite various approaches, we did not accept this comment as best argument epistemology because he did not mention evidence-based perspectives. Similarly, 8S8, in the pretest, said *People care about their own thoughts and think they are true, so there is no single answer in science. Every idea requires a different intelligence.* In the post test, 8S8 said *I think there should be a lot of thought in science; however, there should be one result and this result should be applied.* In the pretest, we can argue that 8S8 had a multiple approaches epistemology. Looking at post test, like 8S2, even if he argued that there should be one result, he did not consider that this conclusion need to be justified by the best evidence; therefore, we categorized the post-test response as the multiple approaches epistemology. In addition, 8S4 ,in the pretest, said *There is no single answer to a question in science. Because people have different thinking skills and can have different answers.* In the post test, 8S4 said *It cannot be, why would it? Ultimately, people's brains can work differently and give different answers from each other.* Both of the responses display that 8S4 had multiple approaches epistemology through the treatment.

4.1.2.2.3. Multivariate epistemology > Multiple approaches epistemology. Two students replaced their multivariate epistemology with multiple approaches epistemology through the treatment. 8S10, for example, in the pretest, said *I think there are multiple causes in science. Because nothing depends on one outcome. So there are multiple results and methods.* In the post test, she said *Everyone may have different ideas, of course we respect their decisions.* Looking at the responses, we can argue that she believed that multiple causes may be responsible for a single conclusion in the pretest, whereas she considered that scientists might have different approaches in the post test.

8S22, in pretest, said *No. Because different results can have different and many reasons. That's why, there is no single answer to a question in science.* In the post test, she said *There can be many answers to a question that are always valid, not just in science. Because the views of each person and the results they find through the methods applied are different.* In the pretest, 8S22 considered the multivariate nature of scientific problems. On the other hand, in the post test, she focused on the multiple approaches of the scientists and resulting multiple methods.

4.1.2.2.4. Multivariate epistemology > Conditional relativity. 8S18 said in the pretest *I think a question in science can have more than one answer. Because there are different factors that can affect the situation. The case is also an example, whereas a professor defends that chemicals can come from the river, other professors defend that they can only come from the rain. We find the answer that the lake polluted in both claims.* 8S18 changed his response in the posttest *I think there is no single answer to a question in science. There are possible questions only in a condition. If conditions change, results change.* While in pretest the student argued having more than one answer to a scientific question considering multiple reasoning in science, in posttest s/he attributed to change of conditions (paradigm) in science.

4.1.2.3. Phantasy based reasoning* > *Data-based reasoning. Eigth students (32 %) replaced their **phantasy-based reasoning** with **data-based reasoning** after the treatment. These students used their imageries in order to complete missing pieces for building the knowledge before the treatment. However, they exhibited a development through a data-based reasoning after the treatment because they analyzed only the available data and its production processes. Because we used sub-groups for representing the data-based reasoning, we uncovered following development types.

4.1.2.3.1. Phantasy-based reasoning > Best argument epistemology. 8S6's response in the pretest was *I think that they become extinct due to the chemicals used for agriculture.* 8S6 argued in the posttest *They may have different opinions. But the question has one answer in terms of science and we can find the answer. Which idea is more appropriate in terms of provability is the answer.* Looking at the responses, we can argue that 8S6 had a phantasy-based reasoning in the pretest because she seems to combine his personal beliefs with the unclear data in order to conclude that chemicals were the responsible for the extinction. In the post test, on the other hand, he emphasized the provability of the alternatives and exhibited best argument epistemology. In addition, 8S13's pretest response was *I think so, but my guess is that Mrs. Nergiz's statement is more attractive and the reason of that is; heron eagles feed with fishes in lake and eagle which feed with fishes may be poisoned by agriculture going to lake.* In the post test, 8S13 said *I think there is only one answer because everything is proven and investigated. But the accuracy of information can sometimes be low. For example, they may find it right that heron eagles die from squirrels they eat but they do not know that. It must be investigated too, but there is always only one answer.* Even if he emphasized that he had the estimation in the pretest, he seems to believe that one of the alternatives might be correct despite the lack of clear data. On the other hand, in the post test, he emphasized the accuracy of information and the necessity of further research, meaning that he had best argument epistemology. In the pretest, 8S15 said *Mr. Arif is right because local authority says that we have been doing this for years. I think that this is caused by acid rain and so on.* 8S15 said in the post test, *Yes, everything may have a single reason, but we cannot find it with a single experiment or observation. Maybe, we do tens of and hundreds of experiments to find it and there is freedom of thought of person. He can speak differently and everyone must respect this. But when it comes to science, everything has one answer. There may be different trials, but the result is always the same.* While in the pretest 8S15 was sure on the reason despite the lack of, in the posttest he changed his response by arguing that scientific progress need more experiments and observations to find single result. In one another case, in the pretest, 8S17 said *Mrs. Nergiz says that eagles contain chemicals and thinks they are poisoned by these chemicals. However, Mr. Arif thinks that it is not related to agriculture and rain pollutes lake water. I think the factories related to agriculture may pollute the air. Acids polluting the air, rain comes back to us as an acid rain. So I think both true. These are two events connected to each other.* In the post test, she argued *So it might be a question, but I think it's better to have more than one answer in science. Because scientists take into consideration everything. They have an opportunity to do research, experiment and so on. Thus, he can give definite answer to the result.* Looking at the responses, 8S17 connected two alternatives despite the lack of clear data in the pretest. However, in the post test, she argued that there is a necessity to have alternatives and justify one of them by research and experiment in order to reach the definite answer.

In the pretest, 8S23 said *Things what Mr.Arif says sounds wrong. What does it mean like the bowl? Mrs. Nergiz's answer is correct and logical, agriculture needs to be moved another place.* In the post test, he said *Depends on the situation. But I think if truth is found with one more than evidence, it is mean that there are more results and new knowledge. Thus, a better the result can be found.* Looking at the pretest, he used his phantasy-based reasoning in the evalution of the two approaches and he concluded that one of the approaches was correct considering its logical nature. On the other hand, in the post test, he argued that the result may vary according to situation and therefore much more research and evidence were necessary in order to reach better results.

4.1.2.3.2. Phantasy-based reasoning > Multiple approaches epistemology. 8S7, in the pretest, said *I want that fields are fertilized with natural fertilizers and they are located a few km away.* In the post-test, 8S7 changed his response by saying *I do not think , because all* *ideas are collected and then decided.* As can be seen, 8S7 was sure on the fact that chemical fertilizers were responsible for the problem despite the lack of clear data. However, in the post test, he argued that there would be multiple approaches even though there is necessity to select one of them. Even if he mentioned one single conclusion, as in the previous cases, we did not accept this response within best argument category because he did not mention the justification processes. In addition, 8S11 said *I think Mr. Arif is right because if it was about agriculture people and fish would be damaged. Because the ground of the lake is hard, the reason for chemicals is rain.* 8S11's posttest response was *Everyone can have different ideas, and we should respect that. If everybody's thoughts were the same life would be ridiculous.* Looking at the responses, 8S11 was sure on the reason for the problem in the pretest despite the lack of clear evidence. However, in the post test, she changed her position and possessed a multiple approach epistemology.

4.1.2.3.3. Phantasy based reasoning > Multivariate epistemology. In the pretest, 8S20 said *Sure. In fact, all except Selim Bey says they are sick and Mrs. Nergiz makes the explanation. So the only answer is to ban agriculture on the side of the lake.* On the other hand, in posttest she said *It cannot be. Because there can be a lot of problems or solutions that is related with it.* In pretest the student had absolutist conception about the case; whereas, in posttest s/he mentioned that there may be more than one answer to scientific question due to multiple reasoning.

Chapter 5

Discussion

The present study showed that school students used either fantasy-based or data-based reasonings about multiple responses for the same scientific question. In the fantasy-based reasoning, they easily reach a single conclusion due to three mechanisms. In the most used mechanism, they benefit from the value-oriented beliefs aroused within the text in order to complement the incomplete data. The terms within the scientists‘ responses in the Vignettes such as ‘pollution‘, ‘detergent factory‘, ‘contamination‘ and ‘chemical poisoning‘ seemed to attract the attention of some students perhaps because they used or were exposed to such emotion-loaded words in the arguments about (socio) scientific discussions in the daily life. After seeing these words/phrases, it seems that they lose their attention on the limitations in the data production process and perhaps the emotions aroused within their minds may block their knowledge about scientific methodologies and procedures of validity and reliability. In the second mechanism, it was noticed that some students may fuse two different scientific responses in the text and show them as if they are together one single conclusion. In the third mechanism, it was observed that one student used some language-oriented logic in order to complement the missing pieces in the data. Regarding data-based reasoning, it was found that the students used one of the following six mechanisms: 1) best argument epistemology, 2) falsification, 3) conditional relativity, 4) multivariate epistemology, 5) multi-methods epistemology, and 6) multiple approaches epistemology. In the best argument epistemology, students think that there are multiple responses for the same scientific question; however, the best response (argument) justified by sound evidence should be chosen. In falsification epistemology, students consider that there may be many wrong responses to the same scientific question and that it is important that these wrong explanations should be eliminated to leave the true response alone. In the conditional relativity epistemology, students think that the reason for multiple responses to the same scientific question is conditional changes (i.e., responses can change according to existing conditions). In multivariate epistemology, students think that the variety in responses to the same scientific question stems from multiple variables and multiple relationships among these variables within the situation. In multi-methods epistemology, students think the fact that researchers use different methodologies and research tools can cause multiple responses to the same scientific question. In multiple approaches epistemology, students think that people have different approaches and views about a scientific problem and this can cause different interpretations and multiple responses to the same problem.

In addition, we can argue that SSI-based education, one way of developing reasonings about NOS (Sadler et al., 2004), was influential in older school students. If we accept the development from phantasy-based reasoning through data-based reasoning as the positive and demanded reasoning development, for example, we can argue that such positive development did not occur in the 5th-grade students, whereas it was achieved almost one in third of the students in the 8th-grade students. Even if this result may stem from the differences in terms of the teaching units, modules and the teachers in the experimental classrooms, it was considered that such a result needed further discussion. Consistent with present findings, Doğan and Ozcan showed that 7th-grade students developed their understanding of accuracy and uncertainty of scientific knowledge after a history-based science education. Similarly Deve and Kucuk displayed that 7th-grade students could enhance their NOS understandings after a history-based science education. Similarly, Solomon (1992) found that students aged 11 through 14 (who are at the Grades 6 through 9 in the present study's context) could develop some of NOS aspects regarding the purpose of experiments and the nature of theory after a history-based science education.In addition, Karpudewan and Roth (2018), showed that 12-year old students (who are almost at Grade 7 according to present study's context)' decision-making modes changed from intuitive decision-making to evidence-based after SSI-based instruction. Intuitive decision-making responses in their study were similar to phantasy based reasoning in the present study, whereas evidence-based decision making responses were similar to data based reasoning in the present study. However, these consistent findings may cause a misinterpretation. The present study and supporting literature show that older students present an epistemic plasticity to the epistemic development attempts. However, this does not mean that most of the younger students possess some mental barriers to develop data-based reasonings. About a half of the Grade 5 students in the present study, for example, already used a data-based reasoning before the SSI-based intervention. The possible interpretation in this context may be the fact that those in younger ages with phantasy-based reasoning seem to be more resistant to epistemic development attempts to compare to their counterparts in older ages. At this point, Sutter‘s (2019) findings may explain why these young students experience such resistance. He displayed that 6th-grade students with limited abstracting abilities focused particularly on concrete negative examples with limited interpretations in SSI cases, whereas those with strong abstracting abilities benefit from sound interpretations. Therefore, we may argue that some younger students who are easily emotionally aroused perhaps because of limited abstracting abilities benefit from phantasy-based reasoning about multiple responses for the same science question and this reasoning is resistant to the epistemic development interventions because of age-related abstraction issues.

Chapter 6

Implications

The present study may produce two implications for different stakeholders in the science education community:

6.1. Science Education Researchers: Present findings showed that school students‘ reasoning about multiple responses for the same scientific question is more complex than an existing classification of reasonings (e.g., more naive-more sophisticated [Abd-El-Khalick, 2012], insufficient-transitional stage-informed [Çetinkaya, 2019], traditional-combined-contemporary [Yenice et al., 2018], intuitive -evidence-based, [Karpudewan & Roth, 2018]) about NOS in the literature. At this point, the science education researchers may benefit from the present study's classifications of reasonings about NOS/multiple responses for the same science question produced using a sound philosophical background and the findings thoroughly uncovered via naturalistic methodologies. These relatively clear classifications may have potential to resolve the confusions within the NOS literature and to ease reaching promising purposes of NOS-based science education reforms (Next Generation Science Standards [NGSS] Lead States, 2013; American Association for the Advancement of Science [AAAS], 1990; Council of Ministers of Education Canada [CMEC], 1997; NRC, 2012).

6.2. Science Teachers: For understanding whether to reach the learning outcomes regarding the nature of science, as science education researchers can do, science teachers can benefit from the present study's reasoning classifications as the rubrics. In addition, it seems that they need to be careful in designing epistemic development interventions (e.g, explicit NOS teaching, SSI-based education, history-based science education) for younger grades because the success of such interventions may be dependent on the abstraction abilities of school students.

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Appendices

Appendix 1: 5. Sınıf Vignet

DETERJAN FABRİKASI KAPATILSIN MI?

Yaklaşık beş yıl önce Bozkır köyünün 12 km kadar uzağında bir deterjan fabrikası kurulmuştur. Bu fabrikada 35 işçi çalışmaktadır. Bu işçilerden 25'i Bozkır köyünde yaşayan köylülerdir.

Yaklaşık iki aydır köyde bir sorun yaşanmaktadır. Çocuklarda ağır ishaller ve bağırsak problemleri görülmekte ve köylüler sürekli Aile Sağlığı Merkezi'ne gelmektedirler. Bu durumun nedeni ile ilgili olarak köyün bağlı bulunduğu ilçenin kaymakamı, köyün muhtarı, fabrikada çalışan köylülerden biri, bölgede çevre kirliliği ile ilgili çalışmalar yapan bir biyolog ve Aile Sağlığı Merkezi'nde görevli olan bir biyolog yan yana gelmişlerdir. Aşağıda aralarında geçen konuşmalar verilmiştir:

Kaymakam: Evet arkadaşlar. Önümüzde böyle bir sorun var. Göreve başladığım beş yıl öncesinden beri hiçbir sorun olmamasına rağmen iki aydır Aile Sağlığı Merkezi'ne başvuran hastalar var. Günde iki veya üç çocuk ağır ishale yakalanarak geliyor. Ne düşünüyorsunuz?

Köyün Muhtarı: Bence bunların hepsi fabrikadan oldu. Musluk sularımızı kokladığımızda garip kokular geliyor. Suyun rengi de eskisi gibi değil. Pınarlar da kuruduğu için mecburen bu suları içiyoruz. Fabrikadan çıkan kimyasal maddeler bir şekilde buraya kadar taşınmış olabilir.

Fabrikada çalışan köylülerden biri: Ben beş yıldır fabrikada çalışıyorum. Fabrikamız temizlik ve hijyen konusunda çok ciddi. Sürekli olarak ellerimizi yıkamamızı, plastik gözlük ve ağızlık takmamızı istiyorlar. Fabrikadaki müdürümüz de çok bilgili biri. Böyle bir fabrikanın çevreye zarar vereceğini zannetmem.

Çevre kirliliği üzerine çalışan bir biyolog: Ben yaklaşık on yıldır bu bölgede çalışmalar yapıyorum. On yıl öncesinde bölgedeki 130 ağaçtan örnek almıştım. Bu ağaçlarda kurşun ve civa gibi metallerin oranı yok denecek kadar azdı. Ancak bir ay önce aldığım örneklerde bütün ağaçlardaki kurşun ve civa oranları üç kat kadar artmıştı. Her ne kadar insanlarla böyle bir çalışma yapmamış olsam da bölgede kimyasal bir zehirlenmenin olduğunu düşünüyorum.

Aile Sağlığı Merkezi'nde çalışan bir biyolog: Merkezimize gelen çocukların kanlarıyla yaptığımız testlerde, mikroplarla savaşan hücrelerde artış olduğunu gözlemledik. Ayrıca hem kanlarında hem de dışkı örneklerinde yüksek oranda bakteri bulduk. Tüm bölgeyi etkileyen bir salgın enfeksiyondan şüpheleniyoruz. Ancak insan kanında kurşun ve civa gibi metalleri analiz edebileceğimiz testler maalesef elimizde yok. Onlara da bakmayı isterdik.

Sorular

1. Biyologların çocuklarda görülen hastalıkların nedeni ile ilgili olarak farklı görüşlere sahip olduğunu görüyoruz. Sizce bilimde bir sorunun tek bir cevabı olmaz mı? Cevabınızı aşağıdaki boşluğa yazar mısınız?

Appendix 2: 5^{th} Grade Vignette

SHOULD THE DETERGENT FACTORY BE CLOSED?

About five years ago, a detergent factory was established about 12 km from Bozkır village. 35 employees work in this factory . 25 of these workers are peasants living in the village of Bozkır.

There has been a problem in the village for about two months. Children experience severe diarrhea and intestinal problems, and peasants are constantly coming to the Family Health Center. Regarding the reason for this situation, the district governor of the village to which the village is connected, the village headman, one of the villagers working at the factory, a biologist working on environmental pollution in the region and a biologist working at the Family Health Center came together. Talks between them are given below:

District Governor: Yes, friends. We have such a problem. There have been patients who have applied to the Family Health Center for two months, although there has been no problem since I started working five years ago. Two or three children a day come with severe diarrhea. What do you think?

Headman: I think all of these came from the factory. Strange odors come when we smell our tap water. The color of the water is not the same as before. We are obliged to drink these waters because the fountains are also dry. Chemicals from the factory may have somehow been transported here.

The peasants working at the factory: I have been working at the factory for five years. Our factory is very serious about cleaning and hygiene. They want us to constantly wash our hands, wear plastic glasses and mouthpieces. Our manager at the factory is also very knowledgeable. I do not think that such a factory will harm the environment.

A biologist working on environmental pollution: I have been working in this region for about ten years. Ten years ago, I took samples from 130 trees in the region. The proportion of metals such as lead and mercury was negligible in these trees. However, in the samples I took a month ago, the lead and mercury rates in all the trees increased three times. Although I did not do such a study with people, I think there is a chemical poisoning in the area.

A biologist working at the Family Health Center: In our tests with the blood of children coming to our center, we observed an increase in cells that fight microbes. We also found high levels of bacteria in both blood and stool samples. We suspect an epidemic that affects the entire region. However, unfortunately, we do not have tests to analyze metals such as lead and mercury in human blood. We would like to look at them too.

Questions

1. We see that biologists have different views on the cause of diseases in children. In your opinion, wouldn't a question have a single answer in science? Can you write your answer in the blank below?

Appendix 3: 8. Sınıf Vignet

GÖLÜN ETRAFINDA TARIM YAPILMALI MI?

Mahmutlar Köyü bir gölün etrafına kurulmuştur. Bu köyde yaşayan insanlar hem buğday tarımı hem de balıkçılık ile yaşamlarını sürdürmektedirler. Gölde ise canlı bir ekosistem mevcuttur. Göl dibinde yosunlar, göl içerisinde ise otçul Sazanlar ve etçil Turna balıkları yer almaktadır. Ayrıca soyu tükenmek üzere olan Balıkçıl Kartallar da bölgede yuva yapmaktadır. Bu kartalların zaman zaman cevizle beslenen sincapları da avladığı görülmektedir.

Köylüler son dönemde birçok Balıkçıl Kartal'ın öldüğünü gözlemlemiş ve bu durumu köyün bağlı olduğu kaymakamlığa bildirmiştir. Kaymakamlık ise köyün sakinleri ve bölgede çalışmalar yapan bilim insanlarını bir araya getirmiştir.

Kaymakam Mehmet Bey: Evet arkadaşlar. Mahmutlar Köyü'nde çok sayıda Balıkçıl Kartal'ın öldüğü haberleri geliyor. Bu durumun nedeni ile ilgili olarak ne düşünüyorsunuz?

Köylülerden Ayşe Hanım: Ben bir hastalığın bunları öldürdüğünü düşünüyorum. Bu kartallara baktığımızda hepsinin çok zayıf olduklarını gördük. Muhtemelen hastalandılar ve bir şey avlayamadıkları için öldüler.

Biyoloji Profesörü Nergiz Hanım: Ölmek üzere olan kartalların kanlarına baktık. Kanlarında normal değerin iki katı miktarda kimyasal maddeler bulduk. Bu maddeler köylülerin kullandıkları tarla ilaçlarında da var. Muhtemelen tarla ilaçları yer altı sularına karıştı ve bu sular da dereler aracılığıyla göle geldiler. Bir şekilde besin zinciri ile Balıkçıl Kartallar'a kadar bu kimyasal maddeler taşındı.

Biyoloji Profesörü Arif Bey: Ben tarım ile ilişkili olduğunu düşünmüyorum. Bu gölün zemini dışarıdan su alınmasını engelleyecek bir sertlikte. Bir çanak gibi düşünün. Dolayısıyla bu gölün ana su kaynağı sadece yağmurlar.

Mahmutlar Köyü'nün muhtarı Selim Bey: Bizler gölün kenarında yıllardır tarım yapıyoruz. Ana geçim kaynağımız. Çocuklarımıza bu tarlalarda ürettiklerimizi yediriyoruz. Yıllardır kimseye bir şey olmadı. Bence tarımla alakalı bir sorun değil.

Sorular

1.Biyoloji profesörlerinin gölün etrafında tarım yapılmasının etkileri ile ilgili olarak farklı görüşlere sahip olduğunu görüyoruz. Sizce bilimde bir sorunun tek bir cevabı olmaz mı? Cevabınızı açıklayarak anlatınız.

Appendix 4: 8th Grade Vignette

SHOULD AGRICULTURE BE DONE AROUND THE LAKE?

Mahmutlar Village was established around a lake. People living in this village lead their lives with both wheat farming and fishing. There is a living ecosystem in the lake. There are mosses at the bottom of the lake and herbivorous Carps and carnivorous Crane fishes in the lake. In addition, the heron, which is about to become extinct, also nest in the region. It is seen that these eagles sometimes hunt squirrels that feed on walnuts.

The villagers have recently observed that many Heron Eagle has died and reported this to the district governor's office. The District Governorate brought together residents of the village and scientists working in the region.

Governor Mehmet: Yes, friends. There are reports that a large number of Heron Eagle died in Mahmutlar Village. What do you think about the reason for this situation?

Mrs.Ayşe (villagers): I think a disease has killed them. When we look at these eagles, we saw that they were all very weak. They probably got sick and died because they couldn't hunt anything.

Biology Professor Nergiz: We looked at the blood of eagles that are about to die. We found twice as many chemicals in their blood as normal. These substances are also found in pesticides used by peasants. Probably field pesticides mixed with groundwater and these waters came to the lake through streams. Somehow these chemicals were transported to the Heron Eagles with the food chain.

Biology Professor Arif : I do not think it is related to agriculture. The ground of this lake is tough enough to prevent water from getting outside. Think like a dish. So the main water source of this lake is just raining.

The headman Selim : We have been farming for years on the edge of the lake. Our main source of livelihood. We feed our children what we produce in these fields. Nothing happened to anyone for years. I don't think it's a problem with agriculture.

Questions

1. We see that biology professors have different views on the effects of farming around the lake. In your opinion, wouldn't a question have a single answer in science? Explain and explain your answer.

Appendix 5: Etik Kurul Onayı

SOSYAL VE BEŞERİ BİLİMLER ARAŞTIRMALARI ETİK KURULU

Toplantı Sayısı: : 7

Toplantı Tarihi : 27.02.2015

Toplantı Yeri Saat : C Salon 14^{00}

Karar 3 : Eğitim Fakültesi öğretim üyelerinden Doç. Dr. Ahmet KILIÇ tarafından hazırlanan 'Fen Bilimleri Öğretmenlerinin Sosyo Bilimsel Konuların Öğretimi Konusunda Yetiştirilmesi: Bir Profesyonel Öğrenme Topluluğu Çalışması' hakkında görüşme, gözlem ve Vignet soru formunun uygulamasında etik bakımından sakınca olup olmadığına ilişkin Prof.Dr. Muhlis ÖZKAN tarafından hazırlanmış olan raporun görüşülmesine geçildi.

Yapılan görüşmeler sonucunda söz konusu görüşme, gözlem ve Vignet soru formunun uygulamasında etik açıdan herhangi bir sakınca bulunmadığına oy birliği ile karar verildi.

27.02.2015

Prof. Dr. Muhlis ÖZKAN
Sosyal ve Beşeri Bilimler Araştırma Etik Kurulu Başkanı

ULUDAĞ ÜNİVERİTESİ REKTÖRLÜĞÜNE,

U. Ü. Eğitim Fakültesi Dekanlığının 25.02.2015 tarih ve 274 sayılı yazılarıyla Doç. Dr. Ahmet KILIÇ'ın 'Fen Bilimleri Öğretmenlerinin Sosyo Bilimsel Konuların Öğretimi Konusunda Yetiştirilmesi: Bir Profesyonel Öğrenme Topluluğu Çalışması' hakkında görüşme, gözlem ve Vignet soru formunun, Sosyal ve Beşeri Bilimler Araştırma Etik Kurulu'nun 27.02.2015 gün ve 7 sayılı toplantısında raportör olarak tayin edilen uzman görüşü de dikkate alınarak değerlendirilmiş, uygulanmasında herhangi bir sakınca bulunmadığına karar verilmiştir.

Durumu gereği için bilgilerinize arz ederim.

27.02.2015

Prof. Dr. Muhlis ÖZKAN
Sosyal ve Beşeri Bilimler Araştırma Etik Kurulu Başkanı

EKİ: Kurul Kararı

Appendix 6: MEB İzin Formu

BURSA VALİLİĞİ

BURSA

T.C.
BURSA VALİLİĞİ
İl Milli Eğitim Müdürlüğü

Sayı : 11742200/604/2575571
Konu: Uygulama İzni

09/03/2015

VALİLİK MAKAMINA

İlgi: a) 1739 Sayılı Milli Eğitim Temel Kanunu.
b) 26/07/2014 tarih ve 29072 sayılı Milli Eğitim Bakanlığı Okul Öncesi Eğitim ve İlköğretim Kurumları Yönetmeliği.
c) Uludağ Üniversitesi Rektörlüğü Genel Sekreterliğinin 06/03/2015 tarih ve 7624 sayılı yazısı.

Uludağ Üniversitesi Eğitim Fakültesi İlköğretim Bölümü öğretim üyesi Doç. Dr. Ahmet KILINÇ'ın "Fen Bilimleri Öğretmenlerinin Sosyo-Bilimsel Konuların Öğretimi Konusunda Yetiştirilmesi: Bir Profesyonel Öğrenme Topluluğu Çalışması" adlı proje kapsamında Müdürlüğümüze bağlı ortaokullarda görevli fen bilgisi öğretmenleri ve onların derslerine girmiş öğrencilerine uygulama yapmak istediklerine ilişkin Uludağ Üniversitesi Rektörlüğü'nün ilgi (c) yazısı ilişikte sunulmuştur.

Uludağ Üniversitesi Eğitim Fakültesi İlköğretim Bölümü öğretim üyesi Doç. Dr. Ahmet KILINÇ'ın "Fen Bilimleri Öğretmenlerinin Sosyo-Bilimsel Konuların Öğretimi Konusunda Yetiştirilmesi: Bir Profesyonel Öğrenme Topluluğu Çalışması" adlı proje kapsamında İlimiz Osmangazi İlçesi Bisaş Ortaokulu'nda fen bilgisi öğretmenleri ve onların dersine girmiş öğrencilerle uygulama yapması Müdürlüğümüzce uygun görülmüştür.

Makamlarınızca da uygun görüldüğü takdirde Olur'larınıza arz ederim.

Veli SARIKAYA
Milli Eğitim Müdürü

OLUR
09/03/2015

Mehmet Vedat MÜFTÜOĞLU
Vali a.
Vali Yardımcısı

Rıdvan ÖZKOCA
Bölüm Şefi

Güvenli Elektronik İmzalı
Aslı İle Aynıdır.
09/Mart/2015..

Yeni Valilik Binası A/Blok 16050 Osmangazi/BURSA
Elektronik Ağ: www.bursameb.gov.tr
e-posta:temelegitim16@meb.gov.tr

Ayrıntılı bilgi için: Md.Yrd. Arzu AYYILDIZ
Tel: (0 224) 256 70 00 /141
Faks: (0 224) 256 66 80

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Öz Geçmiş

Doğum Yeri ve Yılı : İstanbul-1992

Öğr. Gördüğü Kurumlar	**: Başlama Yılı**	**Bitirme Yılı**	**Kurum Adı**
Lise	2006	2010	Özel Başarılı Akşam Lisesi
Lisans	2010	2017	Boğaziçi Üniversitesi
Yüksek Lisans	2017	2020	Uludağ Üniversitesi

Bildiği Yabancı Diller ve Düzeyi : İngilizce-İleri, Almanca-Başlangıç

Katıldığı Yurt içi ve Yurt Dışı Bilimsel Toplantılar:

Keskin, A. & Saribas, D., (2017). Investigating Undergraduate Students' Conceptual Understanding and Models of Climate Change, IHPST,4-7 Temmuz 2017, Hacettepe Üniversitesi, Ankara.

Koroglu, M., Sahin, H., Keskin, A.(2017). Undergraduate Students' Undrstanding About Environmental Problems Related to Global Warming, TİKDEK, 5-7 Temmuz, İstanbul.