UNIVERSITY STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENCE

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DECLARATION OF ORIGINALITY

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ABSTRACT

University Students' Understanding of the Nature of Science

This study is formed by Reconceptualized Family Resemblance Approach to Nature of Science (RFN) as reconceptualized notion of nature of science (NOS) from a "Family Resemblance Approach" (Erduran & Dagher, 2014; Kaya & Erduran, 2016b). This study aims to investigate undergraduate university students', who are from faculty of education, arts and sciences and engineering, understandings of NOS within the scope RFN framework, determine the differences in students' understanding of five different RFN categories by taking their faculties and majors into consideration and suggest effective curricular strategies to improve university students' understanding of NOS. A total of 637 third and fourth grade university students from 3 different faculties and 12 different majors participated in the study. A 70-item "NOS Questionnaire'' which is reflected five different categories of RFN and interview questions which are supported by two science related texts were used as data sources of the study. Quantitative data analysis results indicate that there is a statistically significant difference between university students' understanding of NOS in terms of their majors, which are science and non-science. Qualitative data analysis results also show that while the university students from non-science majors have a broader and comprehensive perception of epistemic, cognitive and social-institutional categories of NOS; science major students have a lower level and superficial perception of different categories of NOS.

ÖZET

Üniversite Öğrencilerinin Bilimin Doğasına Dair Anlayışları

Bu çalışmanın teorik altyapısını ‘‘Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımı’na Dayalı Bilimin Doğası’’ (RFN) yaklaşımı oluşturmaktadır (Erduran & Dagher, 2014; Kaya & Erduran, 2016a). Çalışma, bir devlet üniversitesinin 3 farklı fakültesinde ve bu fakültelerin 12 farklı bölümünde öğrenim görmekte olan lisans öğrencilerinin, ‘‘Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımı’na Dayalı Bilimin Doğası’’ (RFN) doğrultusunda bilimin doğası anlayışlarının belirlenmesini ve karşılaştırılmasını amaçlamaktadır. Çalışmanın diğer bir amacı da, üniversite öğrencilerinin bilimin doğasına dair anlayışlarını geliştirebilmek için pedagojik stratejilerin önerilmesidir. Bu çalışma, üniversitenin farklı fakülte ve bölümlerinde 3. ve 4. sınıf düzeyinde öğrenim görmekte olan 637 öğrencinin katılımı ile gerçekleştirilmiştir. Katılımcılara 5 farklı RFN kategorisini yansıtan ve 70 maddeden oluşan “Bilimin Doğası Anketi” uygulanmıştır. Anket uygulaması sonrasında belirlenen öğrencilerle RFN kategorileriyle ilgili görüşmeler yapılmıştır. Nicel araştırma sonuçlarına göre farklı fakültelerde öğrenim görmekte olan üniversite öğrencilerinin bilimin doğasına dair anlayışlarında anlamlı bir fark görülmezken; farklı bölümlerde öğrenim görmekte olan öğrencilerin bilimin doğası anlayışlarında anlamlı bir fark görüldüğü belirlenmiştir. Nitel araştırma sonuçları ise bilimsel olmayan bölümlerde öğrenim görmekte olan öğrencilerin bilimin doğası anlayışlarının daha yüksek olduğunu desteklemektedir.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION……1

1.1 Purpose of the study…….....3

1.2 Significance of the study……...3

1.3 Relevance of working with university students……....5

1.4 Research questions……....7

1.5 Definition of key terms……...10

CHAPTER 2: REVIEW OF THE LITERATURE……12

2.1 Nature of science perspectives by philosophers of science….....12

2.2 Major Perspectives on NOS in Science Education……..……..…….18

2.3 Reconceptualized family resemblance approach to NOS……..…….26

2.4 Academic programs of the Council of Higher Education (YÖK) and course descriptions of the faculties and majors of the university……...37

2.5 Research on university students' understanding of NOS…….....43

2.6 Summary of the review of the literature……..….....48

CHAPTER 3: METHODOLOGY ……..…..51

3.1 Research design……..51

3.2 Participants…….……53

3.3 Instrumentation……..…….……55

3.4 Data collection……..……..61

3.5 Data analysis…..……..62

3.6 Research permission and ethical consideration…..……..…..……64

CHAPTER 4: RESULTS …….……..……...66

4.1 Quantitative data analysis…...…….…….……..66

4.2 Qualitative data analysis…...……..……....78

4.3 Summary of the results…..……..…….123

CHAPTER 5: DISCUSSION……...127

5.1 Summary of the study…...…….…….....127

5.2 Discussion of the results…...…….……129

5.3 Implications of the results…….……. ……..….139

5.4 Limitations of the study …….…..140

5.5 Recommendations …….…...141

APPENDIX A: NATURE OF SCIENCE (NOS) QUESTIONNAIRE 145

APPENDIX B: INTERVIEW QUESTIONS.....150

APPENDIX C: TEXT 1 ….....……152

APPENDIX D: TEXT 2 …….……..……..154

APPENDIX E: INTERVIEW QUOTES (TURKISH) ……...…156

APPENDIX F: INFORMED CONSENT …….……161

REFERENCES .…….……..163

LIST OF TABLES

Table 1. Frequency Distributions for the Selected Faculties, Departments and Majors.…….....54

Table 2. Categories of ‘‘NOS Questionnaire’’, Number of Items, Item Numbers of the Categories…..……...57

Table 3. Descriptive Statistics Analysis for Total and Category Based Nature of Science (NOS) Questionnaire…..……..67

Table 4. Students’ NOS Understanding in Terms of NOS Questionnaire Scores….68

Table 5. ANOVA Summary Table for the NOS Questionnaire.……...70

Table 6. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants’ Faculties in Terms of Their Total NOS Scores…..……...71

Table 7. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants’ Faculties in Terms of Their Category Based NOS Scores …….……...72

Table 8. Comparison of the Understanding of Social-Institutional Systems of Science Among Faculties…..…….74

Table 9. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants’ Majors in Terms of Their Total NOS Scores…..……..74

Table 10. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants’ Majors in Terms of Their Category Based NOS Scores …….……...76

Table 11. Abbreviations for students’ majors, faculties and NOS understanding….79

Table 12. The Codes for Students’ Perceptions of Aims and Values of

Science Without Text 1……..……82

Table 13. The Codes for Students' Perceptions of Aims and Values of Science Through Text 1….……86

Table 14. The Codes for Students' Perceptions of Scientific Practices Without Text 1…….…..…91

Table 15. The Codes for Students' Perceptions of Scientific Practices Through Text 1…….…….....95

Table 16. The Codes for Students' Perceptions of Methods and Methodological Rules of Science Without Text 1…..…….……..99

Table 17. The Codes for Students' Perceptions of Methods and Methodological Rules of Science Through Text 1…..……..…103

Table 18. The Codes for Students' Perceptions of Scientific Knowledge Without Text 1…….……107

Table 19. The Codes for Students' Perceptions of Scientific Knowledge Through Text 1…..……110

Table 20. The Codes for Students' Perceptions of Social-Institutional Systems of Science Without Text 1 and Text 2 …….……114

Table 21. The Codes for Students' Perceptions of Social-Institutional Systems of Science Through Text 1 and Text 2…….…….119

LIST OF FIGURES

Figure 1. Description of the FRA categories of science.....17

Figure 2. The Scope of FRA, represented in the largest circles, relative to other alternative views of NOS…...……24

Figure 3. FRA wheel: Science as a cognitive-epistemic and social-institutional system…….……....27

Figure 4. Aims and values in science.……....28

Figure 5. ‘‘Benzene Ring’’ heuristic of scientific practices.…….30

Figure 6. The ‘gears’ image illustrating how evidence from a variety of methods work synergistically ……..32

Figure 7. TLM, growth of scientific knowledge and scientific understanding…..…33

Figure 8. Science as a social-institutional system.……...…. 35

LIST OF ABBREVIATIONS

AV	Aims and Values of Science
CET	Computer Education and Educational Technology
CHE	Chemical Engineering
CHEM	Chemistry
CMPE	Computer Engineering
FAS	Faculty of Arts and Sciences
FED	Faculty of Education
FEN	Faculty of Engineering
FLED	Foreign Language Education
H	High Level Understanding of NOS
IE	Industrial Engineering
L	Low Level Understanding of NOS
M	Moderate Level Understanding of NOS
M	Methods and Methodological Rules of Science
NOS	Nature of Science
NSCI	Non-science Majors
PHIL	Philosophy
PHYS	Physics
PRED	Primary Education
PSY	Psychology
RFN	Reconceptualized Family Resemblance Approach to NOS
SCED	Science Education
SCI	Science Majors

SI	Social-Institutional Systems of Science
SK	Scientific Knowledge
SOC	Sociology
SP	Scientific Practices

CHAPTER 1

INTRODUCTION

Nature of science (NOS) is one of the most debated and fundamental research topics in science education context (Abd-El-Khalick & Lederman, 2000; Allchin, 2013; Duschl & Grandy, 2012; McComas, Clough & Almazroa, 1998). There are plenty of different perspectives and norms to explain the concept of nature of science in terms of philosophy and history of science and science education contexts (e.g., Irzik & Nola, 2014; Kuhn, 1970; Popper, 1959; Wittgenstein, 1958). At present, science education researchers underline that science education has an important objective that learning of not only the content knowledge of science, but also the nature of science (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003).

The rationale of the learning NOS and teaching the concept in school science is the requirement for understanding of the nature of science to be a scientific literacy citizen (Allchin, 2011; Irzik & Nola, 2014). Driver, Leach, Millar, and Scott (1996) emphasized potential advantages and benefits of learning NOS for students. They claimed that learning and understanding NOS can help students to raise awareness about socio-scientific issues, understand the process of science, be aware of the norms about scientific society, appreciate science as one of the main elements of society and culture, and learn science related content more profoundly. It also orientates students to search for explanations about the events in real world, interact with a wider culture, and understand the nature of scientific knowledge (Driver et al., 1996). In that sense, understanding of nature of science is an essential and integral component of the public understanding of science.

In literature, there are major philosophical perspectives on NOS, which originated the NOS debate. From Aristotle to Wittgenstein, philosophers of science have tried to define the concept of science by focusing on epistemic features of science. They dominantly discussed the nature of scientific method and scientific knowledge (e.g., Kuhn, 1962; Popper, 1959). All these perspectives made an enormous impact on understanding the nature of scientific processes, activities, and epistemic components of science for science educators and science education researchers. In that sense, the contexts of philosophy of science and science education are interrelated with each other.

In addition to the philosophical perspectives, there are several different theoretical frameworks and empirical studies in relation to define NOS and the possible educational applications of NOS in science education context. Especially, the notions of ‘‘consensus view’’ (Abd-El Khalick & Lederman, 2000), ‘‘whole science’’ (Allchin, 2011), ‘‘features of science’’ (Matthews, 2012), and ‘‘reconceptualized family resemblance approach to NOS (RFN)’’ (Erduran & Dagher, 2014) are the most influential approaches that advocate the importance of teaching and learning of the nature of science in science education.

Within this scope, the study was triggered by the questions of how learners understand the concept of the nature of science; and which aspects or categories of science they are familiar with.

In that sense, RFN is a fresh new perspective that explain how science can be conceptualized in a general sense and how such conceptualization can be used to learn and teach epistemic, cognitive, and social-institutional categories of science in a coordinated fashion (Erduran & Dagher, 2014). Although, other researchers provided similar arguments in terms of presenting various aspects of science, RFN

provides a holistic and collective treatment of science (Erduran & Dagher, 2014). Hence, Erduran and Dagher's (2014) ''Reconceptualized Family Resemblance Approach to Nature of Science (RFN)'' perspective was used to determine university students' understanding of different categories of science. Using RFN framework for this study was also beneficial in terms of gathering empirical data and transforming such comprehensive theoretical framework into practice.

1.1 Purpose of the study

The study aims to (a) investigate university students', who are from faculty of education, arts and sciences and engineering, understandings of NOS within the scope of Erduran and Dagher's (2014) Reconceptualized Family Resemblance Approach to Nature of Science (RFN), (b) determine the differences in students' understandings of five different RFN categories by considering their faculties and majors, (c) present students' understandings and perceptions of NOS in terms of their ''NOS Questionnaire'' scores and in-depth interview results (d) and suggest effective curricular strategies to improve university students' understanding of NOS.

1.2 Significance of the study

Nature of science is the notion that helps students to develop an understanding of how science works (Allchin, 2011). It is also significant for students to understand the different categories of science and raise awareness about the scientific concepts (Erduran & Dagher, 2014; Smith & Scharmann, 1999). Hence, the study aims to understand university students' ability to embrace nature of science concepts through focusing on the categories of nature of science within the scope of RFN.

Although, there are plenty of empirical studies in elementary, secondary and university students' understanding of NOS in terms of different perspectives of NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Murcia & Schibeci, 1999; Schwartz, Lederman & Crawford, 2004; Ryder & Leach, 1999); there are no empirical studies in relation to determine university students' understanding of NOS within the framework of Erduran and Dagher's (2014) RFN.

RFN is a new holistic perspective that promotes understanding of science as the conceptions of dynamic cognitive, epistemic and social-institutional systems. In that way, the framework presents a meta-level perspective and categories for science. Classification of the categories of science provides a whole system that is inclusive and includes variety of different categories about science. In other words, the framework and categories are not closed to addition. Since it is an inclusive system, each reasonable and relevant new idea about epistemic, cognitive and social-institutional systems of science can be added into the existing categories. Additionally, all the categories of RFN are meaningful individually, but the whole system is also meaningful in a holistic way. The categories of RFN also present the concept of domain-specificity, which means each category focuses on the similarities and differences of different branches of science instead of considering science as one general concept. Overall, RFN framework articulates perspectives from philosophy of science by appealing coherent theoretical explanations on NOS and developing and extending the theoretical rationale in science learning, teaching and curriculum context (Erduran & Dagher, 2014). This conceptualization can be considered as an account that potentially motivate students and provide visual teaching tools to teachers in a coordinated fashion (Erduran & Dagher, 2014). With all these aspects

of RFN, using RFN framework for this study was the modest choice in terms of contributing to literature by providing a new set of data.

RFN framework has been studied empirically in terms of teacher education, elementary science education, and textbook analysis (BaouJoude & Dagher, 2017; McDonald, 2017). There are also plenty of conference papers and published articles about theoretical and practical aspects of RFN and its categories in the literature (Akgun, Kaya, Erduran & Aksoz, 2017; Aksoz, Erduran, Kaya & Akgun, 2018; Karabaş, 2017; Kaya, Erduran, Akgun & Aksoz, 2017; Saribas & Ceyhan, 2015; Tas, Cetin, Kaya, Erduran, Akgun & Aksoz, 2016). Additionally, RFN framework was used for curriculum analysis context as an alternative NOS characterization (Kaya & Erduran, 2016a; Kaya & Erduran, 2016b). As can be seen, although there are some empirical studies within the usage of RFN in different contexts, there is still limited number of research which discusses university students' understanding of NOS within the base of RFN.

1.3 Relevance of working with university students

Additionally, working with university students from different faculties and majors are important and relevant for investigating university students' images of science. There are possible reasons for this, as Ryder, Leach and Driver (1999) pointed out that students' approaches and actions during science learning process are influenced by their perceptions of nature of science and scientific knowledge. Another reason is that science and non-science graduates become potential teachers, physicist, politicians, economists, journalists, CEO's, philosophers, engineers and professional scientists. All these individuals with variety of professions may require to perform tasks which need an understanding of NOS, such as teachers describe the nature of

scientific knowledge and different kinds of methods of science to their students, health officials give an information to public about vaccine use or food safety by using scientific evidences, and environmental scientists or biologists mention about the dynamics of global warming to draw public's attention about the causes and effects of the climate change. Depending on the task, knowledge of the conceptions of science is in fact necessary and crucial for all members of the society. For instance, a teacher who does not know about the experimentation process of science, an engineer who does not know about the aim of the developing new technologies or a philosopher who does not care about the concept of epistemology cannot provide a competent profile in the social and professional life settings. In other words, understanding of NOS for university students can allow them to make more comprehensive and higher-level decisions on science-related issues in their daily and professional lives. As Linus Pauling (1951), who is the winner of a Nobel Prize in the field of chemistry made an outstanding explanation about the necessity of learning science for university students from science and especially non-science majors:

> It is impossible to deny that science has played a major part in determining the nature of the modern world. The food that we eat, the clothes that we wear, the means of transportation that we use in going from place to place, the medicines that keep us well, the weapons that we use in killing each other have all been changed in recent years through scientific discovery. It may well be contended that the world is now in a dangerous situation because science and its application has developed faster than the understanding of the average citizen. It is evidently of great importance to attempt to improve this situation through a program of education of the citizen in science ...The citizen must have knowledge enough of the world to make the right decisions; and in the modern world this means that the citizen must have a significant understanding of science. (p. 10)

Pauling's explanations about the importance of learning science remain still valid today. In that sense, reforming undergraduate courses to provide a holistic insight for university students' NOS understanding and perceptions can help instructors and

researchers to share their impressions of science with undergraduate students (Miller et al., 2010). Hence, it is crucial to work with university students for researchers in terms of helping science educators by improving and implementing effective instructional strategies to provide better understanding of NOS and develop scientifically literate future college graduates and scientists (Liu & Tsai, 2008).

Overall, this study can contribute to literature by providing an empirical data and new points of view in terms of investigating university students' understanding of NOS by taking their faculties and majors into consideration. In other words, the study addresses the question of what nature of science and the categories of science mean for university students with the lenses of RFN. The study also tries to answer the questions of how university students' science learning process can be promoted and enhanced. The study may also provide an insight for future researchers and teachers in many ways. It may help science educators to understand the importance of teaching and learning different categories of NOS in relation to students' achievement in science. Finally, the study may provide some effective suggestions for science curricula modifications that might be considered by primary, secondary, and university educators.

1.4 Research questions

In the direction of the purposes of the study, the following main and sub research questions were addressed:

Main research question 1. How do university students from different faculties in a university differ in terms of understanding of nature of science?

Main research question 2. How do university students from different faculties in a university differ in terms of understanding of aims and values, scientific practices, methods, scientific knowledge and social-institutional systems of science?

The sub-questions:

2.1 Are there any significant differences among university students from different faculties in terms of their understanding of aims and values of science?

2. 2 Are there any significant differences among university students from different faculties in terms of their understanding of scientific practices?

2.3 Are there any significant differences among university students from different faculties in terms of their understanding of methods and methodological rules of science?

2.4 Are there any significant differences among university students from different faculties in terms of their understanding of scientific knowledge?

2.5 Are there any significant differences among university students from different faculties in terms of their understanding of social-institutional systems of science?

Main research question 3. How do university students from science and non-science majors in a university differ in terms of understanding of nature of science?

Main research question 4. How do university students from science and non-science majors in a university differ in terms of understanding of aims and values, scientific practices, methods, scientific knowledge and social-institutional systems of science?

The sub-questions:

4.1 Are there any significant differences between students from science and non-science majors in terms of their understanding of aims and values of science?

4.2 Are there any significant differences between students from science and non-science majors in terms of their understanding of scientific practices?

4.3 Are there any significant differences between students from science and non-science majors in terms of their understanding of methods and methodological rules of science?

4.4 Are there any significant differences between students from science and non-science majors in terms of their understanding of scientific knowledge?

4.5 Are there any significant differences between students from science and non- science majors in terms of their understanding of social-institutional systems of science?

Main research question 5. How do university students from science and non-science majors in a university perceive nature of science in terms of aims and values, scientific practices, methods, scientific knowledge and social-institutional systems of science?

1.5 Definition of the key terms

- Nature of science (NOS): The nature of science is a concept that includes historical, sociological, and philosophical aspects of science. It has been defined in terms of epistemological, cognitive and social sense in the literature (Erduran & Dagher, 2014; Irzik & Nola, 2014).
- Reconceptualized family resemblance approach to NOS (RFN): Erduran and Dagher (2014) developed a holistic perspective on NOS that represents all cognitive, epistemic and social-institutional categories of science. According to the RFN framework, aims and values, scientific practices, methods and methodological rules, and scientific knowledge reflect the epistemic-cognitive categories of science. Scientific ethos, social certification and dissemination, social values, professional activities, political power structures, social organization and interactions, and financial systems reflect the social-institutional categories of science.
- Aims and values of science (AV): Epistemic, cognitive and social aims and values of science were defined by the concepts of objectivity, novelty, accuracy, empirical adequacy, honesty, equality of intellectual authority and decentralizing power (Erduran & Dagher, 2014).
- Scientific practices (SP): Erduran and Dagher (2014) formed a ‘‘Benzene Ring Heuristic’’ to reflect the key aspects of scientific practices with the six main compounds of real world, explanation, model, prediction, activities and data.
- Methods and methodological rules of science (M): Observational and experimental types of methods and methodological rules of science were defined by Erduran and Dagher (2014). Manipulative, non-manipulative,

hypothesis testing and non- hypothesis testing methods are reflected as the different types of methods to provide explanatory consilience about specific phenomena.

- Scientific knowledge (SK): Scientific knowledge is explained by focusing on the three various forms of the scientific knowledge. Theories, laws and models (TLM) work together to generate and validate new knowledge and provide coherent explanations about specific phenomena (Erduran & Dagher, 2014).
- Social-Institutional systems of science (SI): Erduran and Dagher (2014) explained the social-institutional systems of science in terms of professional activities, social certification and dissemination, scientific ethos, social organizations and interactions, political power structures, and financial systems of science.
- Science majors: The departments of science education, computer education and educational technology, chemistry, physics, computer engineering, industrial engineering and chemical engineering were determined as science majors of the study. The students from these departments take several natural science courses including biology, chemistry and physics which cover theory-based instruction and laboratory sessions.
- Non-science majors: The departments of foreign language education, primary education, philosophy, sociology and psychology were determined as non-science majors of the study. The students from these departments take several courses in relation to sociology, psychology, philosophy and pedagogy. More specifically, epistemology, ethics and philosophy of science related courses are covered in these majors.

CHAPTER 2

REVIEW OF THE LITERATURE

There are some main questions raised by philosophers of science and science education researchers to understand the definition of nature of science and possible educational strategies that can be used in science teaching context. In that sense, the first section of this chapter focuses on nature of science perspectives by philosophers of science from different points of views. The second section provides the major ideas and perspectives of NOS with the lenses of science education researchers. The third section gives a detailed information about the theoretical framework of the study which is ‘‘Reconceptualized Family Resemblance Approach (FRA) to Nature of Science (NOS)’’ (RFN). The fourth section covers the academic programs of **“**The Council of Higher Education (YÖK)”, and course descriptions of the faculties and majors of the universities to provide information about the context of the higher education in Turkey. The fifth section mentions about the previous empirical studies on the university students’ understanding of NOS. The final section covers the first five sections as a summary. In that sense, this chapter focuses on the several theoretical perspectives, the context of the higher-level education in Turkey and empirical research which are conducted by science education researchers.

2.1 Nature of science perspectives by philosophers of science

Reviewing the major strands of philosophical views about the nature of science is beneficial and crucial to identify the roots of the NOS debate and understand the interconnectedness of the contexts of philosophy of science and science education context while exploring university students’ images of NOS.

Philosophers of science made an endeavor to answer the question of what is known as science since the time of Aristotle. When the literature is examined, philosophers of science raised major questions and mount arguments about nature of scientific knowledge and scientific method to understand the nature of science (Duschl, 1994). Hence, it is important to touch upon these perspectives to make sense of today's philosophical and educational approaches on scientific method and scientific knowledge. More specifically, the field of philosophy of science mainly explains the rationale of doing science, the processes of science and the concept of epistemology of science (Duschl, 1994).

Later on the section, inductive view, Popper's (1959) falsificationism, Kuhn's (1962) scientific revolution, Wittgenstein's (1958) the idea of family resemblance and Irzik and Nola's (2014) family resemblance approach were mentioned to discover the earliest as well as current philosophical perspectives about the nature of science to understand the roots of science education researchers' perspectives on NOS as well.

2.1.1 Inductive view, falsificationism and scientific revolution

Since one of the central aims of science is to provide explanations about particular phenomena; philosophers of science considered the concept of science as a form of knowledge (Chalmers, 1982). According the inductive view which dates to Aristotle, the process of generalizing and deriving scientific knowledge provided by a series of observations and facts. In other words, scientific knowledge generated by using set of facts and used for building a theory which fits the facts. According to inductive view, making logical observations help to infer conclusions about a concept (Chalmers, 1982).

However, philosophers also identified some fundamental problems about the concept of induction. The main problem was about the uncertainty of the number of observations to provide explanations. It is not possible to know that the enough number of observation to explain phenomena. Another problem was that making observations are not always suitable to explain an event and make inferences about phenomena for some domains. Hume also brought the argument that how the beliefs itself can be justified by induction. For Hume, the claim can be justified by direct logical inferences or experiences (Okasha, 2011).

Although these problematic characteristics, inductive view is one of the milestone perspectives for the philosophy of science in terms of explaining the methods of science and the process of forming scientific knowledge. The view also triggered the philosophers to present alternative perspectives on nature of scientific methods, such as empiricism and deductive view (Chalmers, 1982).

Karl Popper (1959) produced an alternative approach to inductive view which is known as falsificationism. According to Popper, induction cannot be used as a tool to make accurate generalizations. Popper (1962) supported the hypothetic-deductive approach which is formed by using refutations and proposing testable hypothesis. Theories or hypothesis are falsified or disproved, rather than using verification. Popper also indicated that scientific progression occurs through the replacement of scientific hypothesis which are falsifiable and testable with the refuted ones. In other words, scientific process includes of trial and error process of hypothesis with the use of refutations and tentative conjectures.

However, falsificationism also holds some fundamental question marks and problematic points. For instance, according to Popperian criteria, the concept of falsifiability was the solution of the demarcation problem (Schilpp, 1974). In other

words, the testable and refutable structure of the hypothesis was used to discriminate the concepts of science and non-science. However, the method of testing and the falsifying the hypothesis are not convenient for each domain of science. The bottom line is that the view of falsificationism had a big contribution to the literature in terms of representing the alternative methods of science, besides making observations and using experiences.

Another phenomenal and remarkable perspective about nature of scientific knowledge is presented by Thomas Kuhn's (1962) publication of "Structure of Scientific Revolutions". According to Kuhn, scientific process includes some key concepts as normal science, paradigm shift and scientific revolution. Kuhn (1962) pointed out that scientific revolutions are generated through some stages. For the first stage, Kuhn used the term of normal science. Normal science refers to apply regular scientific procedures, such as working with existing theories or frameworks or articulating implications as puzzle-solving activities (Kuhn, 1970). The concept of paradigm refers to the terms of facts, practices, theories and laws which are the components of the natural world and scientific knowledge. Paradigm provides road maps and guides scientists in the practical field. According to Kuhn's notion, when the scientists determine the anomaly situation in existing theory or hypothesis which is problematic and cannot be solved; they are possibly offered a new theories or perspectives as a replacement mechanism. When a hypothesis or theory cannot fit the relevant concept and existing puzzles cannot be solved any longer, the change is unavoidable (Kuhn, 1970). This revolutionary and changing process is also called as ''paradigm shift'' (Kuhn, 1970; McNamara, 1979). In other words, scientific revolutions reflect the process of puzzle solving activities and paradigm shifts.

Additionally, Kuhn (1977) identified the characteristics of a good scientific theory with the concepts of accuracy, consistency, simplicity and fruitfulness of the theory.

2.1.2 The idea of family resemblance and family resemblance approach

Irzik and Nola (2014) provided a comprehensive perspective to answer the question of what nature of science is about. They provided the description of major aspects of science through proposing eight main categories on NOS. The authors are utilized the idea of family resemblance which was developed by the philosopher Ludwig Wittgenstein. In that sense, it can be useful to mention about the idea of family resemblance as a background rationale of family resemblance approach.

The German philosopher Wittgenstein (1958) claimed that the complicated concepts cannot be defined in terms of traditional sense. The author claimed that the complex networks of overlapping features should be used to explain the any specific concept. As his well-known example of 'game' explains that all kinds of games include different tools or structures, such as people use different parts of their bodies or follow different kind of rules while playing different kind of games. For instance, volleyball and basketball have certain rules to follow, but there are some distinguishing rules in these games when a player just throws ball in the air. In that sense, Wittgenstein argues that the terms about some complex concepts cannot be defined without specifying the natures or the essences of the concept (Wittgenstein, 1958). The analogy of family resemblance also reflects the same ideology with the 'games' concept because the term of 'family' reflects the physical or mental similarities between the members of the family (Kenny, 1975; Murphy, 1991). In other words, the similar and common features among the concepts can be used to categorize and describe the main concept itself.

After touching upon the roots of the family resemblance approach, it can be meaningful that illustrating Irzik and Nola (2014)'s description of the eight categories of science through the Figure 1. As can be seen in the figure, Irzik and Nola (2014) identified the components of science in terms of cognitive-epistemic, and social systems. The authors explained the cognitive-epistemic systems of science by focusing on process of inquiry, aims and values, methods and methodological rules of science and scientific knowledge.

<table>
<tr><td colspan="8">Science</td></tr>
<tr><td colspan="4">Science as a Cognitive-Epistemic System</td><td colspan="4">Science as a Social System</td></tr>
<tr><td>1
Process of inquiry</td><td>2
Aims & Values</td><td>3
Methods & Methodological Rules</td><td>4
Scientific knowledge</td><td>5
Professional Activities</td><td>6
Scientific Ethos</td><td>7
Social Certification & Dissemination of Scientific Knowledge</td><td>8
Social Values</td></tr>
</table>

Fig. 1 Description of the FRA categories of science

Source: [Irzik & Nola, 2014, p. 17]

Process of inquiry refers to activities, such as posing questions about particular problems, making observations, collecting data, forming hypothesis, constructing models and theories. Aims and values of science explained by the terms of consistency, simplicity, prediction, explanation, fruitfulness and viability. Methods and methodological rules indicated as systematic approaches and rules that scientists follow to gather reliable scientific knowledge, such as constructing hypothesis, theories and models, rejecting inconsistent theories, using controlled experiments in scientific process etc. Scientific knowledge is called as a 'product'. When process of inquiry come up with certain results through using scientific aims and methods, scientific knowledge is labelled as an ''end- product''.

As the second main component of science; Irzik and Nola (2014) focused on the social systems of science by using the notions of professional activities, scientific

ethos, social certification and dissemination of scientific knowledge, and social values. Professional activities include the activities that attending academic meetings, presenting the studies in conferences, publishing proposals, writing research projects, doing consulting work, and informing public about particular matters. Scientific ethos considered as ethical norms that scientists follow in their works and interactions. Social certification and dissemination of scientific knowledge refers to the process of peer reviewing and publishing. Finally, social values of science reflected by the actions that improving people's health and quality of life, respecting to the environment, and providing economic development for people.

By these eight categories of science, Irzik and Nola (2014) suggested a new way to describe the term of NOS as a philosophical enterprise.

Overall, it can be concluded that philosophers of science proposed various major perspectives to understand the meaning of nature of science over the years. Several arguments were formed about the nature of scientific method and scientific knowledge by referring inductive and deductive methods of science by Aristotle, Hume, Wittgenstein, Popper, Kuhn and many other philosophers and scientists. In the latest decade, Irzik and Nola (2014) constructed a compact and integrated approach to explain all these components of science as an updated version by covering previous philosophical views of science. In the next section, the views of science education theorists and researchers of NOS provided in details as a relevant and complementary component of the literature.

2.2 Major perspectives on NOS in science education

This section reflects the different perspectives of NOS which are proposed by science educators and researchers. In literature, there is no certain consensus among

the science educators in terms of define the concept of NOS. In order to understand the loose definition of NOS, it is crucial to cover the previous perspectives of NOS in science education context.

In the following sections, consensus view (Abd-El-Khalick & Lederman, 2000), features of science (Matthews, 2012), whole science (Allchin, 2011), reconceptualized family resemblance approach to NOS (RFN) (Erduran & Dagher, 2014) and some additional perspectives presented to discover science education researchers' perspectives on NOS.

2.2.1 Consensus view

One of the most influential perspectives on the definition of NOS in science education context was proposed by Abd-El-Khalick and Lederman (2000). The authors (2000) formed the "consensus view" and discussed the major tenets of NOS by benefiting from the views of history and the philosophy of science.

Lederman (1992) proposed some arguments about epistemology of science, development of scientific knowledge and the notion of science as a way of knowing. These arguments provided a base for the ''consensus view''. The seven key components of the view as following (Abd-el Khalick & Lederman, 2000):

1. Scientific knowledge is tentative: Scientific knowledge is never certain or absolute. The facts, theories and laws can be reliable, but they have a dynamic structure and they are subject to change.
2. Scientific knowledge is theory-laden: Scientists' personal beliefs, experiences, backgrounds and expectations can affect their work.

3. Scientific knowledge is produced by creative and imaginative processes: The construction process of scientific knowledge consists of human creativity and imagination.
4. Scientific knowledge is affected by society and culture: Science is a human based enterprise that reflects the context of a larger society and culture.
5. Scientific theories and laws are different kind of entities: Scientific theories are well established and coherent systems of explanations. Scientific laws are descriptive statements that reflect the relationship among specific and observable phenomena. Theories and laws supply different kind of roles in the formation process of the scientific knowledge.
6. Science has an empirical-based nature based upon observations about natural world: Observation is a kind of tool to explain specific phenomena which is constructed by prior knowledge, theories and beliefs.
7. The diversity of scientific methods: There is not only one scientific method in scientific process. There are different kinds of scientific methods while doing science, such as hypothetic-deductive method, observations etc.

The tenets of consensus view are adopted and used as a body of empirical studies in science education (Abd-El-Khalick & Lederman, 2000). Many other science educators also supported the view and explained the NOS concept through these tenets. For instance, McComas, Clough and Almazroa (1998), and Osborne (2003) verified the consensus view by adding some points, such as roles of the

theories and laws and the social and historical embeddedness of scientific ideas. In a similar sense, Smith and Scharmann (1999) defined a set of descriptors to identify more scientific and less scientific concepts by using the notions of tentativeness and fallible nature of scientific knowledge, and predictive power of scientific values etc.

On the contrary, several opponent arguments also proposed to underline the lacking parts of the consensus view. For instance, involving the process of inquiry, such as asking questions, designing experiments and collecting data, in NOS tenets became a matter of debate (Irzik & Nola, 2014). While Lederman (2007) advocated leaving the concept of inquiry out, Duschl and Grandy (2011) argued that inquiry is the inseparable part of NOS.

Additionally, Allchin (2011), Matthews (2012), and Erduran and Dagher (2014) criticized the consensus view. According to Matthews (2012), consensus view dominantly focused on the epistemological aspects of science under the NOS umbrella. The view does not cover the sociological aspects of science in a comprehensive way. In other words, the issues of politics, aims and values, professional structures, advertising, commerce and education are not covered in the consensus view. Allchin (2011) and Matthews (2012) also added that the tenets of the consensus view do not refer to empirical basis of science and the role of inference in scientific process. For these authors, these points should be elaborated to provide much more sophisticated insights and holistic understanding of science instead of piece by piece science conception. Similarly, Erduran and Dagher (2014) also criticized the consensus view. They claimed that the view lacks clarity in terms of combining NOS related concepts in an inclusive and comprehensive way.

Overall, consensus view provided an influential viewpoint about NOS in terms of explaining the concept in an epistemological sense (Abd-el Khalick &

Lederman, 2000). However, the inadequacies of the view and the well-defined alternative perspectives of NOS provided a new glance in NOS research. In that sense, the following section presents the most influential opponent and alternative perspectives to consensus view.

2.2.2 Whole science, features of science (FOS) and reconceptualized family resemblance approach to NOS (RFN)

Allchin (2011) provided an additional perspective about epistemic and cultural values of science by using the general term of whole science. The author (2011) argued that the concepts of scientific enterprise, motivation, funding, peer review, validation of scientific methods and cognitive bias are the lacking parts of the consensus view. The author also noted that epistemic values of science are important to guide the pursuit and methods of science. Allchin (2011) also emphasized that cultural values mainly shape the works of scientists.

Allchin (2011) also claimed that the concepts of science and values are interrelated with each other in terms of three ways. First, there are epistemic values that help researchers to maintain their research. For example, testability, accuracy, and novelty are crucial concepts for scientists to conduct their experiments effectively and maintain their judgmental sides while they are working. Second, science is doing in a particular cultural and social context. For instance, the issues of gender and race can be a subject matter in some contexts when considering the values of relevant society and the characteristics of the community. Finally, science itself advocates the value of contributing to society, and takes ethics as a base.

Matthews (2012) widened the scope of nature of science. The author changed the notion of ‘nature’ of science (NOS) to ‘features’ of science (FOS). Matthews

(2012) underlined the features of science by adding the categories of experimentation, idealization, models, mathematization, socio-scientific issues, technology, worldviews and religion, explanation, theory choice and rationality, feminism, realism and constructivism. By adding these characteristics to science definition, the author reflected epistemological, psychological, technological, historical, social, and economic perspectives of science.

Duschl and Grandy (2011) also outlined the three phases of the scientific enterprise which are theory-driven enterprise, experiment-driven enterprise, and model-driven enterprise. This characterization provided a different conceptualization for the scientific method (Erduran & Dagher, 2014). For instance, the experiment-driven enterprise reflected the hypothetic-deductive method of science. Unlike the traditional view of scientific method. Duschl and Grandy (2011) used epistemic practices of science to conceptualize the scientific method in a different sense. For instance, building models and evaluation of these models can be proceeded by using theory-building and model-building epistemic practices. In that sense, the authors also criticized the consensus view in terms of not addressing the developmental process of scientific knowledge. In other words, the consensus view did not cover the dialectical processes of science, such as the role of theory, explanation, evidence, and models in the process of the growth of scientific knowledge (Erduran & Dagher, 2014).

"Reconceptualized Family Resemblance Approach to NOS" (RFN) is the latest inclusive perspective that promote students' understanding of science through the conceptions of cognitive, epistemic and social-institutional systems of science (Erduran & Dagher, 2014). The authors used the concepts of aims and values, scientific practices, methods and methodological rules, and scientific knowledge to

cover the cognitive-epistemic categories of science. The concepts of scientific ethos, social certification and dissemination, social values, professional activities, political power structures, social organization and interactions, and financial systems were used to cover social-institutional systems of science (Erduran & Dagher, 2014). This approach benefits from the philosophical approaches of science. It provides a sound rationale in terms of understanding what science is about and what kind of implications can be taught in various ways in science lessons. Additionally, the approach provides a pedagogical and curricular tool for teacher education context (Erduran & Dagher, 2014). Therefore, RFN perspective presented a unique approach in terms of providing a collective and holistic treatment of science.

On the other hand, RFN relates to existing NOS frameworks which are mentioned above. Dagher and Erduran (2017) represented the relationship (Fig. 2) between RFN and other NOS approaches through using a series of circles as each circle presents the listed components of NOS.

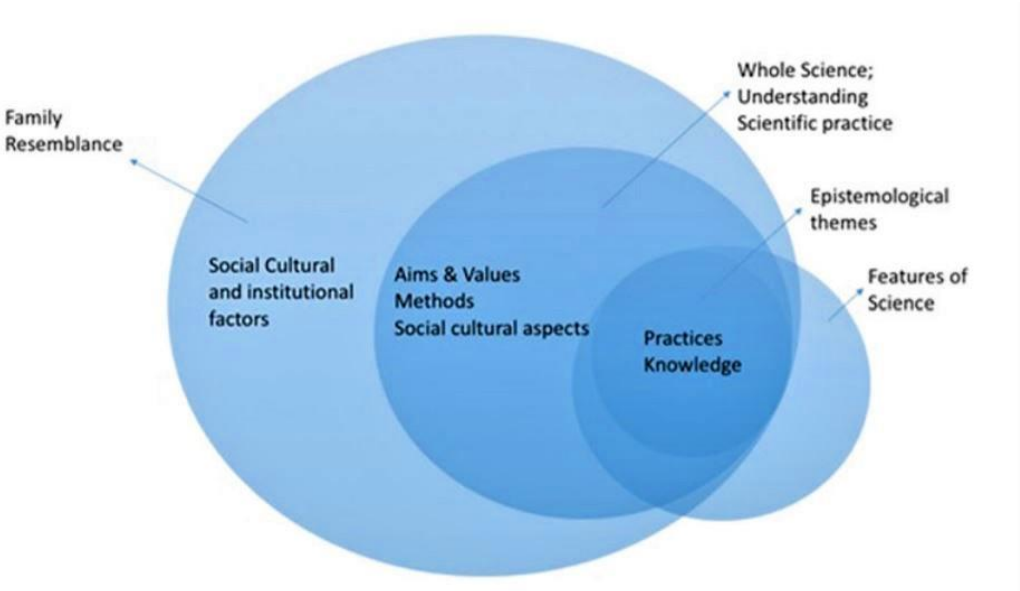


Fig. 2 The scope of FRA, represented in the largest circles, relative to other alternative views of NOS

Source: [Dagher & Erduran, 2017, p. 49]

Almost all alternative NOS frameworks focus on scientific practices and methods. Allchin's (2011) perspective addresses the component of aims and values, sociocultural and socio-scientific aspects and methods. RFN includes all aspects which are proposed by other authors, except the Matthews' (2012) perspectives about philosophical points such as feminism, realism etc. Sandoval's (2005) epistemological themes also emphasize on the scientific practices and knowledge, although the author did not explicitly used the terms about NOS in characterizing those concepts. In brief, RFN provides a holistic and inclusive perspective in terms of covering all the previous frameworks and adding some additional standpoints to explain the meta-level perspective of NOS.

Overall, the most influential approaches and alternative perspectives on consensus view were mentioned throughout the section. Features of science (FOS) brought a sociological sense while explaining the concept of NOS, besides the epistemological characteristics. Whole science raised an awareness in terms of social and cultural values of science. Duschl and Grandy (2011) contributed to NOS literature by expanding the notion of scientific method through focusing on the formation process of scientific knowledge. Finally, RFN framework (Erduran & Dagher, 2014) provided a comprehensive and holistic view point by underlining epistemic, cognitive and social-institutional categories of science. Overall, all these different perspectives gave a new impulse to the characterization of NOS.

The next section provides a detailed information about the latest and most comprehensive version for the characterization of NOS. In that sense, reconceptualized family resemblance approach to nature of science (RFN) was used to determine university students' understanding of different categories of NOS as a theoretical framework of the study.

2.3 Reconceptualized family resemblance approach to nature of science (RFN)

Erduran and Dagher (2014) reconceptualized Irzik and Nola's (2014) depiction of family resemblance approach (FRA) which focuses on the components of science in terms of epistemic, cognitive and social systems. Erduran and Dagher (2014) applied the FRA to science education context for instructional and educational purposes. Then, Kaya and Erduran (2016b) formed the notion of ''Reconceptualized FRA-to-NOS'' (RFN) by synthesizing educational and curricular applications. RFN framework provides an additional and extended insights in relation to pedagogical, curricular and instructional issues for science education research (Kaya & Erduran, 2016b). Since RFN is the most inclusive and diverse conceptualization of NOS in the science education context, this perspective was used as a theoretical body of the study.

Erduran and Dagher (2014) developed a holistic model called "FRA Wheel" (Fig. 3). This wheel represents all cognitive, epistemic and social-institutional categories of science. While the inner circle of the model represents the cognitive-epistemic categories of science; second and third circles represent the social-institutional categories of science. The cognitive and epistemic categories of the wheel, as well as RFN are the aims and values of science, scientific practices, methods and methodological rules of science, and scientific knowledge. The social-institutional categories of the RFN are scientific ethos, social certification and dissemination, social values, professional activities, political power structures, social organization and interactions, and financial systems (Erduran & Dagher, 2014).



Fig. 3 FRA wheel: Science as a cognitive-epistemic and social-institutional system

Source: [Erduran & Dagher, 2014, p. 28]

The wheel provides an extensive contribution in terms of representing interactive, visual and holistic account of reconceptualized FRA-to-NOS (RFN).

The rest of the section presents a detailed information about each category in terms of cognitive, epistemic and social-institutional systems of science.

2.3.1 Aims and values of science

Erduran and Dagher (2014) considered aims and values of science in relation to epistemic, cognitive, social, cultural, political, ethical and moral perspectives. They differentiated these perspectives to promote science learning and teaching process. Epistemic and cognitive aims and values of science are covered by the concepts of critical examination, accuracy, objectivity, novelty and empirical adequacy. The epistemic values of accuracy, explanatory power and empirical adequacy also can be varied with social and cultural values (Allchin, 1999; Longino, 1995). The values also play an important role in the process of the growth of scientific knowledge (Erduran & Dagher, 2014). Social aims and values indicated through the terms of

human needs, honesty, equality of intellectual authority and decentralizing power. Additionally, political and cultural values highlighted as social values of science to indicate the sake of simplicity in communication (Olson, 1998).

The authors (2014) provided a conceptualization of aims and values of science by using a range of epistemic and cognitive aspects. They used a triangular visual representation to show the range of values (Fig. 4). The corners of the triangle symbolize the epistemic, cognitive and social values of science. They are not separable entities, but the boundaries between the aims and values are represented as a continuous and blurry structure in the visual. Additionally, the triangle representation intentionally eliminates the moral and ethical values. As Irzik and Nola (2011) suggested that aims and values of science do not include the concepts of ethics and morality. In other words, science is not an enterprise that building moral values or ethical issues.

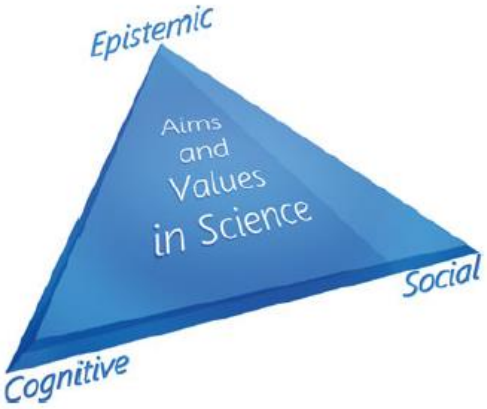


Fig. 4 Aims and values of science

Source: [Erduran & Dagher, 2014, p. 49]

Erduran and Dagher (2014) also proposed that teaching epistemic, cognitive and social aims and values in school science may promote students' understanding of the

scientific aims and values, and process of the growth of scientific knowledge. It may also increase students' cognitive ability levels (Allchin, 1999).

2.3.2 Scientific practices

Erduran and Dagher (2014) explained scientific practices by focusing on three main concepts (i.e. observation, classification, and experimentation) of science as the components of the process of growth of scientific knowledge (Kuhn, 1977; Matthews, 1994; Sandoval & Millwood, 2005). Scientific practices do not only include epistemic practices but also consist of the social-institutional and cultural practices of science (Erduran & Dagher, 2014). The authors used the notion of "scientific practices'' to promote science learning and teaching of NOS by providing a heuristic as a pedagogical tool.

Erduran and Dagher's (2014) heuristic used the epistemic, cognitive and social-institutional categories of science to provide a holistic and nuanced interpretation of scientific practices. The heuristic (Fig. 5) also provides the key aspects of the scientific practices within the analogy of benzene ring structure.

In the context of chemistry, the benzene ring is defined as an organic compound that includes six hydrogen atoms and six carbon atoms with one hydrogen atom which are bounded to each other. According to the analogy, epistemic and cognitive categories of science represented with the carbon atoms. The chemical bonds also represent the social context and practices of science. For instance, epistemic and cognitive categories of scientific practices symbolized with the carbon atoms which are reflected by real world, explanation, model, prediction, activities and data. Social dimensions of science also illustrated by the concepts of

representation, discourse, reasoning, and social certification as the electron cloud around the carbons.

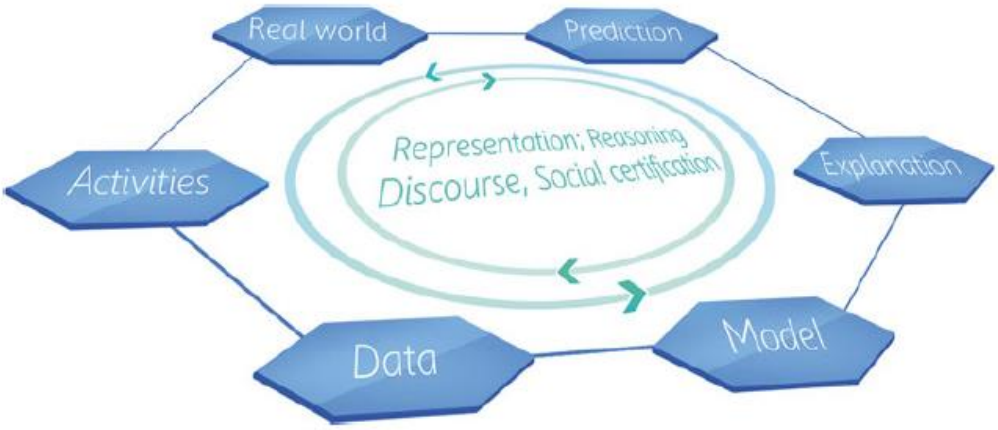


Fig. 5 ‘‘Benzene Ring’’ heuristic of scientific practices

Source: [Erduran & Dagher, 2014, p. 82]

Benzene ring heuristic represents the interrelatedness of cognitive and epistemic aspects of science and the impact of the social dimensions of science in scientific processes.

The authors (2014) also suggested that the heuristic can be considered as a pedagogical tool for teaching and learning about scientific practices (Erduran & Jimenez-Aleixandre, 2008; Jimenez-Aleixandre, Bugallo-Rodriguez, & Duschl, 2000). In other words, the heuristic can be considered as a holistic, visual and iconic representation as a noteworthy teaching tool for science teachers to create a more dynamic connection between scientific practices and the different categories of scientific activities.

2.3.3 Methods and methodological rules of science

Erduran and Dagher (2014) explained the concept of methods and methodological rules of science by emphasizing various scientific methods and focusing on the significance of using evidences to provide explanatory consilience (Wilson, 1998). The authors (2014) also proposed possible educational strategies to teach scientific methods in school science.

Erduran and Dagher (2014) firstly clarified the deficiencies of the popular and stereotypical depiction of the scientific method. The depiction includes the scientific steps that asking questions, doing background research, constructing and testing hypothesis by doing experiments, analyzing the data and drawing conclusions about the problem. Such kind of characterization is a deeply problematic and unadaptable in some contexts and scientific domains where it is impossible to conduct experiments (Dagher & BouJaude, 2005; Driver, Leach, Millar, & Scott, 1996). For instance, experimentation cannot be used as a scientific method while working on distant objects and stars in the field of astronomy. In such cases, scientists dominantly make observations, present evidences through observational data, and test hypothesis without doing any experiment (Brandon, 1994).

In that sense, alternative explanations provided for the questions like how different types of methods and evidences are possible and can be used in literature (Duschl; 1994; Windschitl, Thompson, & Braaten, 2008; Wivagg & Allchin, 2002).

Erduran and Dagher (2014) defined observational and experimental types of scientific methods through manipulative, non-manipulative, hypothesis testing and non- hypothesis testing methods. The authors (2014) illustrated these methods by using the gears image (Fig. 6).



Fig. 6 The ‘gears’ image illustrating how evidence from a variety of methods work synergistically contribute to explanatory consilience

Source: [Erduran & Dagher, 2014, p. 101]

By these four forms of scientific methods and methodological rules, it is indicated that how different kind of methods work synergistically together to gain variety of evidences and provide explanatory consilience (Erduran & Dagher, 2014; Brandon, 1994). As an educational standpoint, they recommended to focus on the significance of orientating students to develop questions, designing different kind of investigations, and drawing students’ attention to the different kinds of methods in science lessons. In this way, students can start to appreciate the nuances in the way that different domains of sciences operate with different methods.

2.3.4 Scientific knowledge

Scientific knowledge is a concept that grows by the development and extension of theories, laws and models to explain a phenomenon about the universe (Erduran & Dagher, 2014; Kuhn, 1970). Theories, laws and models (TLM) are three various forms of scientific knowledge (e.g., Kuhn, 1962; McComas, 1998). They are the products of scientific enterprise (Giere, 1991). In TLM mechanism, theories, laws

and models work together to generate and validate new knowledge and provide coherent explanations about specific phenomena. However, as Kuhn (1962/1970) noted that when the anomaly situation occurs in existing theory, model or law, the new theories, laws and explanations can be provided as a replacement mechanism or a notion of paradigm shift. When particular theory, law or model cannot fit the relevant concept or existing puzzles, the conceptual change is inevitable in the flow of theory, law and model.

For instance, the concept of the ‘atom’ explained by the atomic theory, atomic models and periodic law. These entities work together to explain the nature and the structure of matter. In that sense, theories, laws and models do not work individually. On the contrary, each component work together to explain a specific phenomenon. Explanations also act as a glue to form relationships among the TLM components (Sandoval & Reiser, 2004). As illustrated that TLM mechanism (Fig. 7) work together to explain phenomena at a point in time.

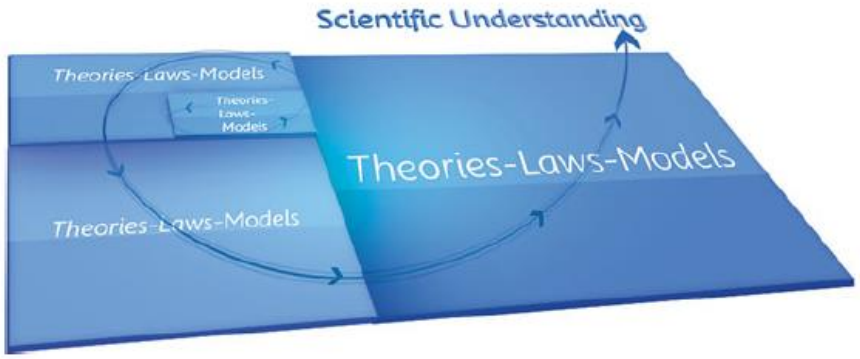


Fig. 7 TLM, growth of scientific knowledge and scientific understanding

Source: [Erduran & Dagher, 2014, p. 115]

TLM framework also reflects the certain structures of the different disciplines. In other words, although all branches of science use theories, laws and models as the three forms of knowledge, TLM identified as domain-specific concept (Duschl, 1990; Erduran & Dagher, 2014; Lakatos, 1978). The domain-specificity stands for an understanding of what exactly a law or theory means and functions in different branches of science, such as in biology, chemistry, or physics (Christie & Christie; 2000; Scerri, 2000).

The framework also sufficient to provide effective educational strategies for science education. The visual representation of the growth of scientific knowledge can provide a coherent and dynamic system for teachers as a pedagogical tool. Erduran and Dagher (2014) indicated that with the usage of TLM framework, students can appreciate the interrelatedness of the individual components of TLM as a coherent and dynamic system. The framework also provides an understanding of the epistemic dimensions of TLM and promotes students' understanding of why and how we know that what we know in science (Duschl & Erduran, 1996).

2.3.5 Social-institutional systems of science

Social and institutional categories of science are crucial to learn about the social norms, social structures and scientific enterprise, and understanding the impact of social context on science (e.g. NRC, 2012; Zeidler, Sadler, Simmons & Howes, 2005). Erduran and Dagher (2014) worked on Irzik and Nola's (2014) four components (i.e., scientific ethos, professional activities, social values, social certification and dissemination) of social categories of science. They defined additional categories in relation to economic, political and institutional components of science.

The authors (2014) proposed a visual representation to summarize the main characteristics of social-institutional systems of science (Fig. 8). The visual includes professional activities, social certification and dissemination, scientific ethos, and social values as an inner part of the circle. The outer circle represents the elaborated components of the social-institutional systems that are social organizations and interactions, political power structures, and financial systems of science.

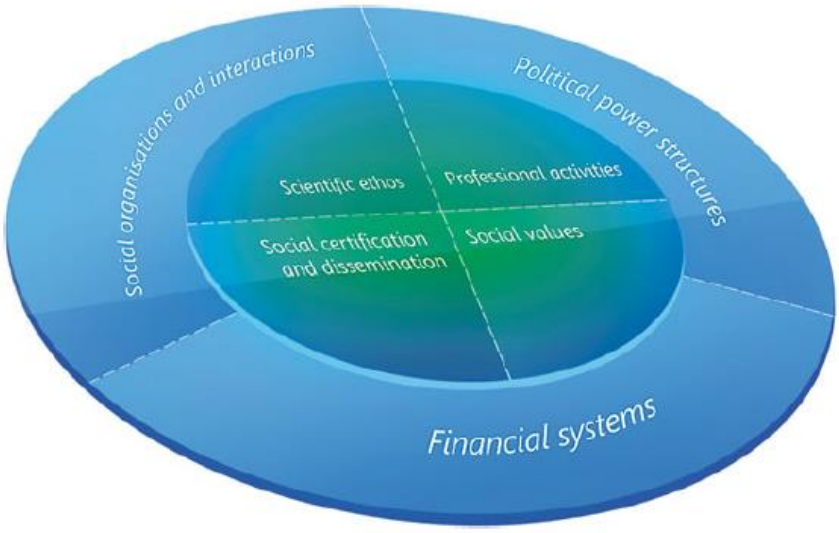


Fig. 8 Science as a social-institutional system of science

Source: [Erduran & Dagher, 2014, p. 143]

Professional activities refer to attending conferences, publishing articles, presenting findings, writing proposals, searching for funding, grant application process as well as reviewing papers (Irzik & Nola, 2014). Social certification and dissemination process includes presenting a work at events and conferences, producing manuscripts, and publishing articles in reviewed journals (Irzik & Nola, 2014; Kitcher, 2011). Scientific ethos involves a set of institutional attitudes that scientists expected to exhibit in their communications with other scientists while doing their

scientific activities (Irzik & Nola, 2014). Resnik's norms (Resnik, 2007) also provide insights in terms of ethical considerations of science, such as respect for intellectual property and research subjects, openness, animal care, integrity, social responsibility, competence etc. Social values cover the concepts of social utility, respect for environment and freedom (Erduran & Dagher, 2014; Jacob, 1997).

Besides these four components, Erduran and Dagher (2014) added three additional aspects to reflect cultural, economic, sociological and anthropological perspectives of science. Social organizations and interactions reflect the institutions that scientists work, such as research centers, universities or industrial sites which are socially organized (e.g., Knorr-Cetina, 1999). Within these institutions, such as CERN and NASA, scientists have a chance to work on projects. In short, this category provides a perspective to think scientists as an employee or an employer, and what is the role of the institutional dynamics and structures for scientists. Political power structures refer to the impact of the politics of governments, and race and gender issues on science (Harding & Hintikka, 1983). For instance, most of the feminist philosophers of science pointed out the role of gender in the characterization process of science. Therefore, this category is crucial to internalize that how science relates to politics and how history of science involves political ends to construct explanatory synthesis about the real world (Prakash, 1999). As a final component, financial systems cover the actions of scientists to get financial resources in scientific process which are mediated by economic authorities (e.g., Wibble, 1998). Governments and states are governing bodies and funding sources of universities and research institutions (e.g., National Science Foundation in the USA). These economical dynamics directly affect the investigation process of scientific research (Erduran & Mugaloglu, 2013).

Overall, teaching the social-institutional systems of science can raise awareness of students about various aspects of science, and promote their ethical awareness towards controversial issues of science (Erduran & Dagher, 2014).

2.4 Academic programs of "The council of higher education (YÖK)" and the course descriptions of the faculties and majors of the university

This section provides information about the context of higher education in Turkey. The following section gives an information about "The Council of Higher Education (YÖK)" to illustrate the academic, administrative and institutional context of higher education in Turkey. The second section focuses on the detailed academic programs, and the general course objectives and structures of the faculties of arts and sciences, education and engineering. Additionally, the last section covers the course structures and the detailed descriptions of the courses for the non-science and science majors.

2.4.1 The council of higher education (YÖK) in Turkey

The council of higher education (YÖK) has a responsibility that constructing the process of academic, administrative and institutional aspects of higher education in Turkey (YÖK, 2014). All higher education institutions in Turkey have combined under the roof of YÖK. All academies, universities and educational institutions follow the program and course structures that are determined by YÖK (YÖK, 1998). In that sense, the course programs of the faculties of arts and sciences, education and engineering are determined by the directions of YÖK and the council of the university itself.

As it is declared in the websites of the faculties and instructions of YÖK, each faculty offers students some must and elective courses during their undergraduate

education. The must courses are mostly mass courses and majority of the students from each majors of the related faculty must enroll these courses. Elective courses are selectional courses for students. Students are free to choose an elective course which are listed in their academic program. These courses are generally related to humanities and social sciences (HSS) or natural sciences (YÖK, 2014).

2.4.2 Academic programs of the faculties of arts and sciences, education and engineering

The faculty of arts and sciences suggests programs leading to the degree in chemistry, physics, philosophy, sociology and psychology. These majors offer students to opportunity to understand the fundamental laws and theories of the nature ("Faculty of Arts and Sciences", 2018). For instance, the majors of chemistry and physics provide students courses which cover the concepts of the structure, composition, properties, electronics, astrophysics, computational physics, or medicine (YÖK, 2014). The major of sociology combines a social scientific approach with the concept of humanities and sustains strong connections with political science, economics, history, philosophy and psychology. The major of psychology provides an instruction of the study of the brain and abnormal behavior, counseling, and basic research in university laboratories. The major of philosophy combines analytic and continental way of thinking as well as historically and scientifically-minded approaches. It provides a chance to learn about a variety of philosophical issues, approaches, methods, positions in sufficient depth and breadth for students ("Faculty of Arts and Sciences", 2018).

The faculty of education offers degrees in foreign language education; science education, preschool education and computer education and educational

technology. The major of foreign language education provides a program about English language development, linguistics, and various cultural and professional subjects (“Faculty of Education”, 2018). The major of science education has a strong focus on educational research, pedagogical courses, and curriculum related courses to introduce students with different aspects of education, psychology, guidance, and classroom management. The major of preschool education aims to educate skilled professionals who will be working with the families of young children, with the social institutions related to health, community development and education (YÖK, 1998; YÖK, 2014).

The faculty of engineering programs consist of the degrees on industrial engineering, computer engineering and chemical engineering for this study. These majors provide their students an opportunity to apply knowledge of mathematics, science, and engineering. They also allow students to design and conduct experiments, as well as analyze and interpret data meet desired needs within realistic restraints such as economic, environmental, social, political, ethical, health and safety and sustainability. The majors of engineering also aim to provide understanding of professional and ethical responsibility, using several scientific techniques, and modern engineering tools which are necessary for engineering practice, and learning about probability and statistics. Analyzing and designing electrical and electronic devices are also some other objectives for those majors (“Faculty of Engineering”, 2018).

2.4.3 Course descriptions of the non-science and science majors

Each faculty prepared specific course programs for their majors with the directions of YÖK. These courses are identified as musts and electives.

For the non-science majors which are philosophy, sociology, philosophy, foreign language education and preschool education, students do not have to enroll any theoretical and laboratory based must courses in the field of natural sciences, such as physics, biology or chemistry (YÖK, 2014). On the contrary, they have to enroll courses, such as history, psychology, humanities, language, philosophy, and research and academic orientation-based courses for social sciences ("Faculty of Arts and Sciences", 2018). Additionally, these majors have a variety of elective courses which cover the fields of humanities and social sciences. For instance, the majors of primary education and foreign language education provide courses that entitled as "Research Methods" and "Research Methods in Applied Linguistics". These courses cover the basic methods of quantitative and qualitative research and basic concepts and techniques in the research in education and linguistics. These courses potentially offer students a perspective about the variety of scientific methods. The major of sociology presents students a bunch of humanities and research methods related courses. Some of these courses are "Economic Anthropology", "Social Anthropology" and "Political Anthropology". These courses provide an examination of thinking about the functions and meanings of economic, political and social dynamics and activities in society, focus on the economies of pre-modern and pre-capitalist societies, discover the forms of power, authority and control in different social and cultural settings. Besides these courses, the courses of "Sociology of organizations", "Politics, religion and social change" and "Sociology of gender" cover the social structure of the organizations, impact of the large organizations on the structure of modern societies and the role of religion in the process of social change. These courses also emphasize the nature of religious belief and its impacts on social and political dynamics. The relation between gender and social structure in

terms of the position of woman in society and their place in the economic and political spheres are also one of the subject matters. Additionally, the major of philosophy offers students the comprehensive and sophisticated courses in terms of understanding the nature of scientific knowledge, ethics and nature of science. For instance, “Philosophy of Science”, “Scientific Reasoning”, “Applied Ethics”, and ‘Epistemology’ some course contents in the major of philosophy. In these courses, students able to examine the goals of science, the nature of scientific explanation, theory construction, the use of models and confirmation process of hypotheses within the different context. Students also have an opportunity to talk about contemporary moral issues, such as abortion, affirmative action, the ethics, moral justification of war and animal rights, and they can consider some philosophical problems through the concept of knowledge with respect to the origins, limits and validity of the knowledge. As can be seen that, the courses that are given in these non-science majors provide students perspective to understand nature of scientific knowledge and scientific methods, social and cultural values of science, existence of social organizations, and political and economical aspects of science. In that sense, working with these majors are meaningful and significant to observe students’ understanding of NOS to see the effect of having courses which related to NOS content (YÖK, 2014).

For the science majors which are chemistry, physics, science education, computer education and educational technology, and engineering majors, students do not have to enroll humanity and social science-based courses as much as non-science students do. On the contrary, they have to enroll some natural science-based mass courses which are theory and laboratory-based courses and cover the concepts of physics, biology or chemistry. Nevertheless, science majors still can enroll

humanities and social sciences related elective courses if they prefer. For instance, the majors of chemistry and physics offer students some courses with the titles of “Quantum Physics”, “Classical Mechanics”, “Basic Concepts in Modern Physics”, “Fundamentals of Chemistry” and “Organic Chemistry Laboratory” (“Faculty of Arts and Sciences", 2018). All those theoretical and laboratory-based courses provide students an understanding of the concept of simultaneity in special relativity and applications, identification and purification of organic compounds, atomic and molecular structures, and mechanisms of reactions through the hours of laboratory per week. Additionally, the major of science education suggests variety of scientific and pedagogical courses such as “Academic Orientation for Math and Science Teachers”, “Science, Technology and Society” and “Nature of Science in Science Education” (“Faculty of Education”, 2018). These courses may help students to understand the process of collecting and analyzing educational data through observation and experimentation, making inferences about results, reviewing relevant science education literature, writing academic reports, and documenting sources using suitable citation formats and discussing results. These courses also provide an information about advancement of technology, economics of knowledge and educational reflections by the consideration of popular science topics. Through these courses, students hopefully learn more about history, philosophy and sociology of science, and pedagogical approaches and strategies to apply and assess the understanding of the nature of science. At last, the majors of engineering cover some applicational courses such as “Data Structures and Algorithms”, “Principles of Programming Languages”, “Development in Software Engineering”, “Modeling and Optimization” and “Chemical Engineering and Biotechnology Laboratory” (“Faculty of Engineering”, 2018). These courses provide students an insight about basic

optimization theories and algorithms with the use of applications for engineering problems (YÖK, 2014). In brief, the courses in science majors generally cover the cognitive and epistemic points of view of science. However, there are some additional elective courses for science majors to improve their conceptions about the history of science and technology, such as “Science and Technology as Contemporary Issues”, “History of Modern and Classical Physics” and “History of Science: up to the 18th century” (“Faculty of Arts and Sciences”, 2018). In those courses, the subjects of scientific exploration, technical alterations, the role of mathematics in the context of technology and science, the evolution of science from the ancient Near Eastern civilizations, and the basic principles of classical and modern physics are discussed.

2.5 Research on university students’ understanding of NOS

The research on university students’ understanding of NOS is important to visualize the understanding and perceptions of university students and provide some implications for the higher-level education. As Ryder, Leach and Driver (1999) pointed out that students’ approaches and actions during science learning process are influenced by their perceptions of nature of science. Additionally, knowing about the conceptions of science is really necessary and crucial for all university students who are the potential future of the society. In other words, understanding of NOS for university students can allow them to make more comprehensive and higher-level decisions on science-related issues in their daily and professional lives. Therefore, providing an empirical research about their existing perceptions of NOS can help science educators to improve and implement effective instructional strategies to

provide better understanding of NOS, and develop scientifically literate future college graduates and scientists (Liu & Tsai, 2008).

In this manner, the following section covers the previous studies about university students' understandings of the nature of science and the variety of assessment tools which are used to measure university students' perceptions of NOS.

There are many empirical researches about to the nature of science in relation to assessment of the students and teachers' understanding of NOS, evaluation of the textbooks about NOS and intervention studies to develop students' conceptions of the nature of science. In this regard, this section provides an information about the previous research on the university students' understanding of NOS, the variety of early assessment tools on NOS understanding (e.g., Abell & Smith, 1994; Griffiths & Barry, 1993; Kimball, 1967; Parker, Krockover, Eichinger & Lasher-Trapp, 2008; Pomeroy, 1992; Scharmann, 1990; Welch & Walberg, 1972), and empirical studies that benefited from RFN (e.g., Aksoz et al., 2016; Saribas & Ceyhan, 2015) introduced in the following section.

Kimball (1967) conducted a study to assess undergraduate students' understanding of the nature of science by focusing on the concepts of subjectiveness, tentativeness, and products and processes of nature of science. Welch and Walberg (1972) also analyzed undergraduate students' understanding of NOS in relation to processes and tentativeness of nature of science. The authors used the ''Test on Understanding Science'' (TOUS) to measure students' understanding of NOS in the study.

Scharmann (1990) assessed the freshman students' understandings of the nature of scientific theories by focusing on their understanding levels. The author used traditional lecture strategies and diversified instructional strategies to

investigate the effect of using different pedagogical strategies in students' understanding of the scientific theories. The results suggested that the usage of diversified instructional strategy provided a better understanding of the nature of scientific theories for freshman, because this strategy includes formal presentations, discussions and interactive questioning and answering sections.

Abell and Smith (1994) analyzed the pre-service elementary teachers' written responses about the nature of science by using the notions of evidence-based investigations, scientific ideas and scientific thinking. The results showed that pre-service teachers have a realist and positivist views on the concept of the nature of science.

Pomeroy (1992) considered the secondary science teachers', scientists', and elementary educators' beliefs of the nature of science and investigated the differences in their beliefs. The author found that elementary educators had a better understanding of NOS in comparison to secondary science teachers.

Griffiths and Barry (1993) investigated university students' views of NOS. The concepts of the nature of scientific facts, theories, and laws were used throughout the interview sessions. The authors found that students perceive science as a concept that a part of school science, rather than a practical notion that is formed by scientists. The results also showed that students perceive the concept of science as a mechanism that answering all the scientific questions. The students also pointed out the hierarchical relationship among facts, theories, and laws in scientific process.

More recently, Parker, et al. (2008) conducted a study at a university in the Midwest to analyze students' understanding of the nature of science. The authors explored atmospheric science students' views about NOS through some questions, such as what science is about and how it works, and what are the aims, products, and

methods of science. According to the results of the study, the authors claimed that most of the university students who are majoring in science retain the misunderstanding that science establishes facts and proves immutable truths.

TOUS, NKSK, NOSS and VNOS are the instruments that dominantly used to analyze students' understanding of the nature of science in literature (Aikenhead, 1973; Lederman & O'Malley, 1990; Mackay, 1971; Rubba & Anderson, 1978). "Test on Understanding Science" (TOUS) was developed by Cooley and Klopfer in 1961. The test consists of three subscales that reflect understanding of scientific enterprise, scientist, and methods and aims of science. "The Nature of Scientific Knowledge Scale" (NSKS) test was developed by Peter Rubba in 1977. This test includes six factors that amoral, developmental, testable, creative, parsimonious, and unified characteristics of the scientific knowledge. Finally, "Views of the Nature of Science Questionnaire" (VNOS) was developed by Lederman and O'Malley in 1990. The test consists of 7 items open-ended questionnaire which was used by the follow up interviews. TOUS and NSKS tests made an important contribution to literature in terms of providing an instrument to analyze NOS understanding. However, there are main limitations of these instruments in terms of assessing and gaining an in-depth information about university students understanding of aims and values, scientific practices, methods and methodological rules, scientific knowledge and social-institutional categories of science. Wade, Lederman and Bell (1999) also claimed that these tests appear inappropriate as a sole assessment instrument for the study of an individual's understanding of the nature of science.

Each of these early studies and assessment tools focused on to determine students' understanding of NOS and improve their existing NOS understanding. However, since there is a paucity of research addressing the university students'

understanding of the NOS in terms of using the RFN framework and working with the population of faculty of education, arts and sciences and engineering in literature; the intention is to determine these students' understanding of NOS within the perspective of RFN for this study.

RFN is a fresh new perspective that how science can be conceptualized in a sense of epistemic, cognitive and social-institutional categories of science in a coordinated fashion (Erduran and Dagher, 2014). RFN framework have been studied in terms of pre-service teacher education and elementary level science education context. 70-items ''NOS Questionnaire'' within the 5 categories of RFN and in-depth interviews were used as new and relevant instruments in these studies. There are published articles, conference papers and thesis in literature with the use of the categories and educational applications of RFN (Akgun et al., 2017; Aksoz et al., 2016; Karabaş, 2017; Saribas & Ceyhan, 2015; Tas et al., 2016). Additionally, RFN framework was used for curriculum analysis context as an alternative NOS characterization (Kaya & Erduran, 2016a; Kaya & Erduran, 2016b). Although, there are plenty of empirical studies to analyze pre-service science teachers and elementary school students' understanding of NOS within the framework RFN; it is clear that there is still a need for an empirical research regarding university students' understanding of the five categories of RFN, as well as NOS.

Overall, the current study focused on the population of university students from different faculties and RFN framework was used as the base of the research. The ''NOS Questionnaire'' was used as a new, beneficial and supported instrument in terms of reflecting five categories of RFN.

2.6 Summary of the review of the literature

This chapter includes the philosophical and educational perspectives on NOS by covering the context of higher education in Turkey and empirical research on NOS in science education context.

In the first section, the major philosophical views on NOS are reviewed to identify the roots of the NOS debate and show the interrelatedness of the contexts of philosophy of science and science education. From Aristotle to Kuhn, philosophers have tried to identify science by focusing on the epistemic features of science. Especially the nature of scientific knowledge and scientific methods were discussed by the important philosophers of science through focusing on such approaches that inductive view, falsificationism (Popper, 1959), the notion of scientific revolution (Kuhn, 1962) and family resemblance approach (Irzik & Nola, 2014). All these perspectives made a huge contribution to understand the dynamics of science, nature of scientific processes and activities, and epistemic, cognitive and social components of science. More importantly, all these views provided a baseline for science education researchers and science educators in terms of understanding the nature of scientific knowledge and methods, and forming more comprehensive pedagogical perspectives on epistemic, cognitive and social aspects of science. In that sense, philosophy of science and science education contexts are tightly connected and supported each other.

The second section represents the most influential perspectives in science education context. The rationale of the appearance of consensus view (Abd-El-Khalick & Lederman, 2000), its major tenets and criticized points mentioned throughout the section. Additionally, the main opponent and alternative approaches to consensus view which are features of science (Matthews, 2012), whole science

(Allchin, 2011), and reconceptualized family resemblance approach to NOS (RFN) (Erduran & Dagher, 2014) was scrutinized in the section.

In the following section; RFN framework (Erduran & Dagher, 2014) was described as a theoretical body of this study. The inclusive, holistic, comprehensive and diverse nature of RFN was explained. The cognitive, epistemic and social institutional categories of science, the explanatory images of these categories and possible educational strategies about these categories were also mentioned in details.

The fourth section provides information about the context of higher education in Turkey. As an academic, administrative and institutional structure of the higher education, the council of higher education (YÖK) and its impact on the academic programs in universities were mentioned. Additionally, the detailed academic programs and the course descriptions, and the objectives of the faculties of arts and sciences, education and engineering were introduced to provide a context of universities in Turkey. Finally, course programs and detailed explanations of the courses of non-science and science majors were mentioned. This section hopefully reflects the higher education context for non-science and science majors in terms of reflecting their course backgrounds in their majors. This information might be possibly used to explain the potential reasons of the similarities and differences in university students' understanding of NOS due to the consideration of the majors' NOS related course structures and backgrounds.

The last section introduces the previous empirical researches on university students' understanding of NOS by explaining the variety of early assessment tools on NOS understanding and previous studies on RFN. The several studies (e.g., Abell & Smith, 1994; Aksoz et al., 2016; Griffiths & Barry, 1993; Kaya & Erduran, 2016a; Parker, Krockover, Eichinger & Lasher-Trapp, 2008; Pomeroy, 1992; Scharmann,

1990) on university students' understanding of NOS and the usage of RFN in literature were discussed throughout the section. The necessity of the conducting more empirical studies in the field was also pointed out through the section.

All these different perspectives, studies and arguments from the literature show that there are many illuminative expressions made about the concept of NOS, the importance of understanding of NOS, how students are aware of the concept; and how the concept affects students' future career decisions, and their interactions with society. However, there is still a little dialogue on understanding of the different categories of NOS in terms of epistemic, cognitive and social-institutional sense (Erduran & Dagher, 2014). In this manner, learning and understanding of science as a holistic and inclusive system is really important to embrace science as a social and human endeavor, appreciate science as a core element of contemporary life, and learn about science content and scientific norms deeply.

CHAPTER 3

METHODOLOGY

This chapter provides an information about the methodological details of the study. The following sections cover the design of the research, participants, instruments, the process of data collection, procedures that used during data analysis process, and ethical considerations of the study. The design of the study and the potential reasons to use of explanatory mixed methods design are discussed. The numeric information and description of the participants in terms of their faculties, departments, science and non-science majors, and their sampling process are introduced in the chapter. The data sources which are "NOS Questionnaire" and interview questions are addressed to identify the quantitative and qualitative instruments of the study. Finally, the steps of data collection and analysis procedures of the data are displayed at the end of the chapter.

3.1 Research design

The purpose of this explanatory mixed methods design is to investigate university students' understandings and perceptions of nature of science. In this design, the strengths of quantitative and qualitative methods of inquiry were combined while compensating the weakness of each approach. In that sense, quantitative data provided a general profile about university students' understanding of NOS. Qualitative data also was used to build or explain the initial quantitative results (Creswell & Plano Clark, 2007). While gathering data, an emphasis was given to both quantitative and qualitative data sets. ''Nature of Science (NOS) Questionnaire'' (see Appendix A) was used to investigate the university students'

understanding of different categories of nature of science. At the same time, students' perceptions of NOS were investigated through interviews (see Appendix B). The reason for collecting both qualitative and quantitative data sets was to incorporate elements of both quantitative and qualitative approaches to provide in-depth and complete understanding of a research questions than either approach alone (Creswell, 2014).

3.1.1 Quantitative design of the study

A survey was used as an initiative quantitative data source for this explanatory design study. The rationale of using a survey was to provide a quantitative or numeric description of opinions and determine the NOS understanding of the sample (Creswell, 2014). Quantitative data collection process was carried out through the application of "Nature of Science Questionnaire". The identification of the students' questionnaire scores helped to determine university students' understanding of NOS and five different categories of NOS. After the analysis of the survey data, quantitative results were explained and justified through the follow-up interviews in a detailed way (Creswell, 2014).

3.1.2 Qualitative design of the study

The second phase of the study was actualized by using the follow-up as well as in depth interviews. In order to elaborate initial quantitative results, qualitative data collected through semi-structured interview questions. The qualitative data results were used to determine university students' understanding of the different categories of science in a deeper sense. As Benbasat, Goldstein, and Mead (1987) proposed that, qualitative case study design is best suited for analyzing participants´ deeper

understanding of particular phenomenon in its natural settings. Thus, more compelling interpretations about students' perception of nature of science and the categories of RFN became possible.

3.2 Participants

This study was conducted at a highly ranked public university that provides an education in the language of English in Turkey. The sample of the study is third and fourth year university students who were registered in 12 different majors of the faculty of education, arts and sciences and engineering. Students from faculty of education, faculty of arts and sciences and faculty of engineering participated the study in the fall semester of the 2017-2018 academic year.

Table 1 represents the faculties, departments and majors that participated in study. The table also illustrates the number and percentage of students who participated to quantitative part of the study.

Table 1. Frequency Distributions for the Selected Faculties, Departments and Majors (*N*=637)

Variable	Category	Abbreviation	*n*	%
Faculty				
	Arts and Science	FAS	185	29.0
	Education	FED	232	36.4
	Engineering	FEN	220	34.5
Department				
	Psychology	PSY	26	4.1
	Philosophy	PHIL	28	4.4
	Physics	PHYS	31	4.9
	Chemistry	CHEM	50	7.8
	Sociology	SOC	50	7.8
	Computer Education and Educational Technology	CET	72	11.3
	Primary Education	PRED	48	7.5
	Foreign Language Education	FLED	70	11.0
	Science Education	SCED	42	6.6
	Chemical Engineering	CHE	66	10.4
	Industrial Engineering	IE	93	14.6
Major	Computer Engineering	CMPE	61	9.6
	Non-Science	NSCI	222	34.9
	Science	SCI	415	65.1

The sample of the study was composed of 637 university students from different faculties and majors. There were 185 students from the faculty of arts and science, 232 students from the faculty of education and 220 students from the faculty of engineering. There were also 222 students from the non-science majors which are psychology (PSY), sociology (SOC), philosophy (PHIL), foreign language education (FLED) and primary education (PRED). Besides non-science majors, there were 415 students from science majors which are physics (PHYS), chemistry (CHEM), computer education and educational technology (CET), science education (SCED), and industrial (IE), chemical (CHE) and computer (CMPE) engineering.

Since most of the third and fourth year university students, especially science majors must enroll science mass courses (e.g., physics, biology, and chemistry) in

their first two years, it was meaningful to work with them. This is because their competence level in relation to understand the items of the "NOS Questionnaire'' was expected to be higher. Additionally, the reason for working with university students from different faculties and different majors that analyzing the effect of their course programs in their understanding and perceptions of different categories of NOS. While non-science majors dominantly have courses, which are related to humanities, politics, economics, history, philosophy, and psychology; science majors generally have courses based on theory and laboratory based natural science courses. For instance, students from science majors take several natural science courses including biology, chemistry, and physics. Hence, it is interesting to analyze the students' perceptions towards NOS, when it is considered that students in non-science majors take epistemology, ethics, and philosophy of science courses.

Within the convenience sampling procedures (Fink, 1995), a number of 637 participants were recruited from each of the faculties and majors. According to the results of ''NOS Questionnaire'' scores, purposive sampling procedures were drawn for the qualitative part of the study (Walliman, 2011). University students' ''NOS Questionnaire'' scores were estimated as low, moderate, and high-level understanding of NOS. Five students from each level were selected from 3 different faculty. It was mapped to interview with 15 students in total.

3.3 Instrumentation

Several data sources were used to gather qualitative and quantitative data to address the interest of explanatory mixed methods study.

3.3.1 Quantitative data source

"NOS Questionnaire'' is a 70-items questionnaire that designed to measure university students' understanding of NOS by covering five different categories of RFN (Kaya, Erduran, Akgun & Aksoz, 2017). The questionnaire items were developed based on Erduran and Dagher's (2014) framework of ''Reconceptualized Family Resemblance Approach to Nature of Science". The items of the questionnaire were developed in a project called ''Nature of science in science teacher education: A comparative research and development project'' which is funded by Bogazici University Research Fund. Three researchers of the project were developed the items of the questionnaire. The items are also analyzed by the two experts who have expertise in the fields of science education and philosophy of science. After the examination of the items by the experts, some repetitive and unnecessary items were eliminated to finalize the items of the questionnaire. By that way, the content validity of the questionnaire was provided.

The questionnaire includes six demographic items related to participants' department, faculty, age, term or grade, gender and e-mail address. Table 2 includes the five categories of ''NOS Questionnaire'' that aims and values of science, scientific practices, methods and methodological rules of science, scientific knowledge and social-institutional systems of science. It also includes the abbreviations of the categories, the number of items for each category and the item numbers for the categories.

Table 2. Categories of ‘‘NOS Questionnaire’’, Number of Items, Item Numbers of the Categories

# of Items	Categories of the ‘‘NOS Questionnaire’’	Item numbers of the categories
9	Aims and Values (AV)	2, 20, 27, 34, 40, 46, 51, 56, 62
15	Scientific Practices (SP)	5, 6, 15, 19, 23, 26, 33, 35, 38, 44, 50, 52, 55, 57, 64
12	Methods and Methodological Rules (M)	8, 12, 22, 24, 25, 28, 37, 42, 49, 59, 60, 69
14	Scientific Knowledge (SK)	3, 10, 11, 16, 17, 21, 30, 31, 43, 47, 54, 63, 66, 68
20	Social-Institutional Systems (SI)	1, 4, 7, 9, 13, 14, 18, 29, 32, 36, 39, 41, 45, 48, 53, 58, 61, 65, 67, 70

In the questionnaire, there are 9 items that represent the category of aims and values (AV), 15 items that reflect scientific practices (SP), 12 items that reflect methods and methodological rules of science (M), 14 items that stand for scientific knowledge (SK) and 20 items that cover the category of social-institutional systems of science (SI). The items are interspersed randomly in the questionnaire.

The questionnaire is composed of both pedagogical and scientific items. For instance, for the categories of aims and values and scientific knowledge, the items of “Educating students about scientific aims and values improves scientific literacy.’’ and “Students should understand that theories are a collection of models.’’ are the pedagogical items. On the other hand, for the categories of methods and methodological rules and scientific knowledge the items of “There is no step by step order in doing science.” and “Theories and laws are forms of scientific knowledge, but models are not” are the scientific items. Since the students from arts and sciences and engineering faculties do not have any pedagogical base courses, it may be perceived as using these pedagogical items in the questionnaire can be challenging or meaningless for these students. On the contrary, using these pedagogical items can

be beneficial to understand their perceptions about how effective science instruction and teaching should be for their higher education. For instance, when an industrial engineering student considers the item of “Students should understand that scientists have social values such as honesty.”, she can possibly evaluate the idea of whether science teaching should focus on the social values and honesty or not, and whether scientists have social values as honesty or not. In both arguments, the student can reflect her own perspective about the existence of social values in science and necessity of learning these points as a university student. Therefore, including both pedagogical and scientific items in “NOS Questionnaire” is potentially beneficial to make inferences about university students’ expectations about their science learning process and their understanding of different categories of science.

“NOS Questionnaire’’ is a 5-point Likert-type scale. The options for each item are “totally disagree”, ‘disagree’, “neither agree nor disagree”, ‘agree’ and “totally agree”. The total “NOS Questionnaire’’ score was equal to the sum of all five categories of RFN. While a score of 5 represents the numeric description of the option of “totally agree”, a score of 1 represents the numeric description of the option of “totally disagree”. Total “NOS Questionnaire’’ score ranged from 70 to 350. The score of 350 is the highest score and the highest level of NOS understanding. The score of 70 is the lowest score and lowest level of NOS understanding.

The questionnaire also includes 16 negative items in total. After gathering the raw data, firstly, recoding procedure was actualized, and negative items were recoded (Pallant, 2007). Since the questionnaire is a 5-point Likert-type scale, the negative items were recoded from 1 to 5, 2 to 4, 4 to 2, and 5 to 1. After the application of recoding procedure on the raw data, the total NOS scores and category-based NOS scores were calculated.

The internal consistency reliability of "NOS Questionnaire'' was determined as Cronbach proposed in 1951. Cronbach's α value symbolizes the internal consistency reliability of the questionnaire, and it indicates how the items of the questionnaire are related to each other (Gay, Mills, & Airasian, 2012). The value is measured by Pearson r and varies between 0 and 1. Cronbach's $\alpha > 0.7$ is considered as an acceptable value for a questionnaire's internal consistency reliability (Gay, Mills, & Airasian, 2012). The reliability coefficient of the total ''NOS Questionnaire'' score was determined as 0.77. Therefore, it can be said that the questionnaire's items are consistent among themselves and within the questionnaire as a whole.

3.3.2 Qualitative data source

Semi-structured interview questions were used as a qualitative instrument of the study (see Appendix B). It was expected to explain the results of ''NOS Questionnaire'' in a deeper sense. According to Benbasat, Goldstein and Mead (1987), using semi-structured interviews help to analyze the effects of participants' personal experiences and inner thoughts while exploring a phenomenon. Fifteen participants from three different faculties were selected according to participants' total ''NOS Questionnaire'' scores for the interview session. Interview questions were designed to reveal students' understanding of aims and values, scientific practices, methods and methodological rules, scientific practices and social-institutional systems of science. Two contextually relevant texts (see Appendix C and Appendix D) were used to help students in terms of expressing their ideas more easily and specifically. Thus, students' understanding of the five categories of NOS

were investigated within the consideration of their educational backgrounds, science related experiences, science content knowledge and interpretations.

Two science related texts were used during the interview sessions. The texts reflect the scientists' work on bacteria (Jones, 2014) and operational dynamics of NASA as one of the biggest scientific organizations (Moseman, 2015). Content of the articles include different RFN categories and the concept of nature of science in a general sense. Some of the interview questions were ''In your opinion, what are the aims and values of science? Can you give any examples?'', and ''When you read to the text, which key terms and concepts were raised in your mind in terms of the social-institutional categories of science?''.

Through the first 5 questions of the interview, participants' current perceptions about the five categories of NOS were observed. Then, the first and second texts (Jones, 2014; Moseman, 2015) were presented to participants. The follow-up text related sixth and seventh questions were asked to students to understand their perceptions about the epistemic, cognitive and social-institutional categories of science with the consideration of the texts. The last two interview questions were asked to students to illustrate their perceptions about the interconnectedness of the different categories of NOS and the efficiency of the RFN framework in terms of explaining the holistic structure of NOS.

The first text (see Appendix C) generally covers epistemic, cognitive and social-institutional categories of RFN by focusing on the activities, such as attending conferences, presenting new evidences, working as a researcher at the university and using observations and experimentation in the scientific process. The second text (see Appendix D) mainly focuses on the social-institutional categories of science by using the concepts of scientific organizations, research funding, financial systems of

science and political power structures. Overall, all categories of the RFN are covered in these texts.

Using these texts can be useful to provide a relative context for participants. It helped them to reflect and share their opinions easily, give more various and specific examples about the categories of NOS, and concretize the concepts through the real-world examples from the texts. In other words, benefiting from the articles can be useful to observe whether participants perceive the key terms of the different categories of science in the real contexts and make a connection between their experiences and the actions of the scientists in the given texts.

Content validity of the interview questions was provided through conducting pilot studies. Before started to work with the selected sample, interview questions were asked to two students from science and non-science majors. Thus, inappropriate and repetitive questions were eliminated.

3.4 Data collection

3.4.1 Quantitative data collection

‘‘NOS Questionnaire’’ which includes 70 items and demographic information about the participants was applied to participants from the faculty of education, arts and sciences and engineering. Quantitative data collection process was completed in the fall semester of the 2017-2018 academic year. Before conducting the questionnaire, permissions of the instructors were obtained to apply the questionnaire in their lecture hours.

All participants were informed that the questionnaire measures their understanding of the nature of science within the RFN perspective. The participants

were also informed clearly about their rights and gains during the study. The consent form which includes information about the general purpose of the study and expectations from the participants was given to students. Each participant was assigned with a numeric code to provide confidentiality.

3.4.2 Qualitative data collection

After the collection of the quantitative data, participants' total "NOS Questionnaire'' scores were analyzed and classified in terms of high, moderate, and low levels. These three levels of NOS understanding were used as a selection criterion for the participants who participated interview process. In that sense, five students from each faculty and each NOS understanding level were selected purposively. In other words, there were 15 students who participated to the qualitative part of the study. E-mail addresses of the students were used as a contact information for the selected participants. This information was not shared with anybody, and it was only used for communicating with students about their participations to the qualitative part of the study.

The interviews were audio-taped with the permission of the participants. The transcriptions were made immediately after each interview session. Each interview lasted approximately 30-35 minutes. All participants were told that their responses kept anonymous and confidential.

3.5 Data analysis

In this section, the analysis procedures of quantitative and qualitative data are explained. The data analysis procedure for "NOS Questionnaire" and interview questions are expressed in detail throughout the section.

3.5.1 Quantitative data analysis

The total scores of the “NOS Questionnaire” which is the sum of each five categories refer to university students’ understanding of nature of science. In that sense, university students’ understanding of the nature of science is served as a dependent variable of the study. Additionally, the initial independent variable of the study is the faculties of the university students.

In relation to the initial independent variable, main and sub-research questions of 1 and 2 were analyzed in terms of comparing total and categorical scores of ‘‘NOS Questionnaire’’ for the faculty of education, arts and sciences and engineering. In other words, the total and categorical ‘‘NOS Questionnaire’’ scores of the three groups (faculty of education, arts and sciences and engineering) were analyzed and compared for the first and second research questions.

The second independent variable of the study was the majors of the students which are science and non-science. In relation the second independent variable, main and sub-research questions of 3 and 4 were analyzed. The total and categorical ‘‘NOS Questionnaire’’ scores of the students in science and non-science majors were compared. In other words, the total and categorical ‘‘NOS Questionnaire’’ scores of the two main groups (science departments and non-science majors) were analyzed and compared for the third and fourth research questions.

One-way Analysis of Variance (ANOVA) test was used for analyzing the first 4 research questions. The comparison of the total scores and categorical NOS Questionnaire scores were achieved within each department and each faculty of the study. The significance level set at $\alpha = 0.05$. Data were initially tabulated using standard descriptive statistics (e.g., means, standard deviations and frequencies). The five assumptions of ANOVA, such as assumptions of normality and homogeneity of

variances were checked before conducting the analysis procedures (Keselman, Huberty, Lix, Olejnik, Cribbie & Donahue, 1998; Pallant, 2007).

3.5.2 Qualitative data analysis

The analysis of the questionnaire findings became more meaningful through the analysis of in depth interviews. The research question 5 was answered by using qualitative analysis procedures. Coding and categorization techniques were used to produce themes about the participants' understandings of NOS in relation to RFN. As Bogdan and Biklen (2007) suggested that using coding and categorizing system helps researcher to reveal clear patterns of the data.

As a first step, the audio-taped interviews were transcribed immediately after each interview sessions. Then, the coding and categorization of the data were assigned within the scope of Erduran and Dagher's (2014) "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) framework. Literature also were used as an additional coding source for providing wider code pool to increase reliability of the study.

3.6 Research permission and ethical consideration

Ethical guidelines were followed throughout this study. Permission from the "Bogazici University Research Ethics Sub-Committee" was requested and received in March 2017. An information about the researcher and coordinator of the study and the general content of the research were provided for the committee as an existing protocol. Confidentiality and anonymity were the crucial ethical considerations for the study. The names of the participants were not asked, and the participants were symbolized with numeric codes (e.g., 1, 2, 3). The exact location of the study was not

revealed. Participants informed that their individual responses would remain anonymous.

CHAPTER 4

RESULTS

This chapter includes the results of quantitative and qualitative data analyses. For the quantitative data results, descriptive and inferential statistics results were provided to show university students' understanding of NOS by using their questionnaire scores in the following section. For the qualitative data results, students' responses for semi-structured interview questions are examined. The section covers the students' perceptions of NOS through focusing on the main themes and codes that are related to five categories of RFN. Students' majors and NOS understanding levels are also considered to show their NOS perceptions and make comparisons among them.

4.1 Quantitative analysis results

In this section the descriptive and inferential statistics results of the total and category based "NOS Questionnaire" are introduced. University students' maximum, minimum, standard deviation and mean values are given in details as a part of descriptive statistics results. Additionally, the first four research questions are answered through the inferential statistics results during the section.

4.1.1 Descriptive statistics results

Descriptive statistics results which are related to students' total "NOS Questionnaire" scores and their scores for 5 different categories of RFN were determined. Descriptive statistics results, such as minimum (min.), maximum (max.), mean, standard deviation (SD), skewness and kurtosis were presented in Table 3. It shows the total "NOS Questionnaire" scores which are ranged from 210 to 302 with the

mean value of 258.44. Additionally, the scores for the category of ‘‘Aims and Values’’ are ranged from 21 to 53 with the mean value of 33.96. The scores for the category of ‘‘Scientific Practices’’ are ranged from 40 to 72 with the mean value of 56.81. The scores of ‘‘Methods and Methodological Rules’’ are ranged from 28 to 50 with the mean value of 40.34. As the last two categories, while the scores for ‘‘Scientific Knowledge’’ are ranged from 35 to 64 with the mean value of 50.88; the scores for ‘‘Social- Institutional Systems’’ are ranged from 57 to 95 with the mean value of 76.44. It can also be seen that the total NOS score and the scores of five different categories of RFN were approximately normally distributed, as total NOS score with a skewness value of .190 and a kurtosis value of .668 (Tabachnick & Fidell, 2013).

Table 3. Descriptive Statistics Analysis for Total and Category Based Nature of Science (NOS) Questionnaire (*N*=636)

Category	Number of Items	Min	Max	Mean	SD	Skewness	Kurtosis
Total NOS Score	70	201	302	258.44	14.522	.190	.686
Aims and Values (AV)	9	21	53	33.96	3.529	.155	1.435
Scientific Practices (SP)	15	40	72	56.81	4.571	.170	.735
Methods and Methodological Rules (M)	12	28	50	40.34	3.311	-.206	.696
Scientific Knowledge(SK)	14	35	64	50.88	3.965	-.020	.940
Social- Institutional Systems (SI)	20	57	95	76.44	5.824	-.059	.325

On the other hand, according to the participants’ minimum and maximum scores of the ‘‘NOS Questionnaire’’, the score intervals were determined to identify participants’ level of NOS understanding. Making this classification was significant in terms of selecting participants for follow-up interviews. In other words, students were selected for the interviewing process according to their level of NOS

understanding to provide representativeness in terms of working with students from each level and learn their perceptions about NOS in a deeper sense. In that sense, students NOS understanding intervals were provided (see Table 4).

Table 4. Students' NOS Understanding in Terms of NOS Questionnaire Scores (*N*=637)

NOS Understanding	Score Interval	*n*	%
Low	200-235 points	30	4.7
Moderate	236-270 points	489	76.8
High	271-305 points	118	18.5

Table 4 reflects the number and the percentage of the participants from each NOS understanding level. The students with low level understanding had a total NOS score between 200 and 235. The students with moderate level NOS understanding had a score between 236 and 270. Finally, students with a high level of NOS understanding had a score between 271 and 305.

4.1.2 Inferential statistics results

In this section, the analyses of four research questions of the research are presented. These research questions were tested by using one-way ANOVA with a significance level of .05. "The Statistical Program for Social Science" (SPSS) was used to carry out the analyses.

Before inferential statistics analyses were done, the assumptions of the ANOVA were checked in terms of level of measurement, random sampling, independence of the observations, normal distribution, and homogeneity of variances (Pallant, 2007). The assumptions of the one way between groups ANOVA are:

1. Independent variable should have three or more levels or groups and dependent variable should be measured as a continuous variable,
2. The scores should be obtained using a random sample from the population,
3. There should be independence of observation or measurement within each sample,
4. Dependent variable should be normally distributed for the samples of the population.
5. The variances of the populations should be equal (Gravetter & Wallnau, 2004).

The first assumption was provided since the independent variable stands for the students' faculties and majors, and dependent variable is a continuous variable which is "NOS Questionnaire" score. The second assumption was satisfied by working faculties and majors based independent groups which were randomly selected and assigned. For the third assumption, each participant took the questionnaire under standard and optimum conditions, and it was assumed that there was no interaction between or within the groups during the "NOS Questionnaire" administration. The fourth assumption of the ANOVA was satisfied through the normal distribution of the "NOS Questionnaire" scores which are based on the skewness and kurtosis values of the total and category-based scores (see Table 3). For the final assumption of the one-way ANOVA, Levene's Test was conducted by using the SPSS to check homogeneity of variances (see Table 5).

Table 5. ANOVA Summary Table for the NOS Questionnaire

Category	Source	SS	*df*	MS	F
TOTAL	Between Groups	1014,795	2	507,397	2,417
	Within Groups	133114,128	634	209,959	
	Total	134128,923	636		
AV	Between Groups	50,402	2	25,201	2,031
	Within Groups	7868,536	634	12,411	
	Total	7918,939	636		
SP	Between Groups	23,434	2	11,717	,560
	Within Groups	13266,707	634	20,925	
	Total	13290,141	636		
M	Between Groups	10,281	2	5,140	,468
	Within Groups	6963,427	634	10,983	
	Total	6973,708	636		
SK	Between Groups	26,872	2	13,436	,854
	Within Groups	9970,821	634	15,727	
	Total	9997,692	636		
SI	Between Groups	513,983	2	256,992	7,737
	Within Groups	21059,175	634	33,216	
	Total	21573,159	636		

The variances of the total "NOS Questionnaire" scores and the scores of five different categories were equal based on the results of Levene's Test of Equality ($F(2, 634) = 2.417$, $p>.05$).

4.1.2.1 Main research question 1

The first main question that "How do university students from different faculties in a university differ in terms of understanding of nature of science?" was tested by using one-way ANOVA test. In that way, it is aimed to determine the differences in students understanding of NOS in terms of focusing on the diversity of their faculties.

The one-way ANOVA was conducted after testing all five assumptions of ANOVA. Then, the results for the research question were provided (see Table 6).

Table 6. One Way ANOVA Test for the Nature of Science (NOS) Questionnaire Based on Participants' Faculties in Terms of Their Total NOS Scores (*N*=637)

Category	Faculty	*M*	*SP*	*F*	*p*
Total NOS Score	Arts and Sciences	260.41	14.209	2.417	.09
	Education	257.57	14.190		
	Engineering	257.70	15.027		

The results indicated that there was no significant difference among the students from faculty of arts and sciences, faculty of education, and faculty of engineering in terms of their total scores of "NOS Questionnaire" ($F(2, 634) = 2.417$, $p>.05$). In other words, having an education in the faculty of education, arts and sciences or engineering did not directly affect students' understanding of the nature of science.

4.1.2.2 Main research question 2 and sub-questions

The second main question of "How do university students from different faculties in a university differ in terms of understanding of aims and values, scientific practices, methods, scientific knowledge and social-institutional systems of science?" and five sub-questions about students' understanding of each category of NOS in terms of their faculties were tested through one-way ANOVA. The intention was investigating the differences in students' understanding of five different categories of NOS by focusing on their faculties. In that sense, the statistical results for each category of RFN within the consideration of students' faculties were illustrated (see Table 7).

Table 7. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants' Faculties in Terms of Their Category Based NOS Scores (*N*=637)

Category	Faculty	*M*	*SD*	*F*	*p*
AV	Arts and Science	34.30	3.672	2.031	.132
	Education	34.02	3.339		
	Engineering	33.60	3.584		
SP	Arts and Science	56.76	4.495	.560	.572
	Education	57.06	4.469		
	Engineering	56.61	4.747		
M	Arts and Science	40.49	3.259	.468	.626
	Education	40.19	3.285		
	Engineering	40.39	3.390		
SK	Arts and Science	51.03	3.859	.854	.426
	Education	50.61	3.719		
	Engineering	51.04	4.293		
SI	Arts and Science	77.83	5.677	7.737	.00
	Education	75.70	5.532		
	Engineering	76.06	6.067		

For the first sub-question of "Are there any significant differences among university students from different faculties in terms of their understanding of aims and values of science?", the result showed that there was no significant difference in terms of students' understanding of the of aims and values of science within the consideration of their faculties ($F(2, 634) = 2.031$, $p>.05$).

The results for the sub-question of "Are there any significant differences among university students from different faculties in terms of their understanding of scientific practices?" showed that there was no significant difference in terms of students' understanding of scientific practices with respect to students' faculties ($F(2, 634) = .560$, $p>.05$).

For the sub-question of "Are there any significant differences among university students from different faculties in terms of their understanding of methods and methodological rules of science?" the result illustrated that there was no significant difference in terms of students' understanding of the methods and methodological rules of science in terms of their faculty-based differences ($F(2, 634) = .468$, $p>.05$).

Additionally, the result of the sub-question of "Are there any significant differences among university students from different faculties in terms of their understanding of scientific knowledge?" showed that there was no significant difference in terms of students' understanding of the scientific knowledge in terms of university students' faculties ($F(2, 634) = .854$, $p>.05$).

As a last category, the sub-question of "Are there any significant differences among university students from different faculties in terms of their understanding of social-institutional systems of science?" was answered. It can be indicated that there was a statistically significant difference among the students from faculty of arts and sciences, faculty of education and faculty of engineering for the scores of social-institutional systems of science ($F(2, 634) = 7.737$, $p<.05$).

According to the results, it can be said that faculty-based differences did not affect university students' understandings of aims and values, scientific practices, methods and methodological rules of science and scientific knowledge. However, having an education in different faculties may affect students' understanding of the social-institutional systems of science.

At this point, Tukey's post hoc analyses were conducted to determine which faculty held the better understanding of the social-institutional systems of science (see Table 8). It is a common procedure in statistics that indicates exactly where

(between which groups) there are differences when the means are compared between three or more group (Pallant, 2007).

Table 8. Comparison of the Understanding of Social-Institutional Systems of Science Among Faculties

Category	Faculty I	Faculty	*MD*	*SE*	*p*
SI	Arts and Science	Education	2.124*	.568	.001
		Engineering	1.768*	.575	.006
	Education	Arts and Science	-2.124*	.568	.001
		Engineering	-.357	.542	.788
	Engineering	Arts and Science	-1.768*	.575	.006
		Education	.357	.542	.788

*. The mean difference is significant at the 0.05 level.

Table 8 shows that students from the faculty of arts and sciences have a higher-level understanding of social-institutional systems of science (m = 77.85, sd = 5.67) than faculties of education and engineering.

4.1.2.3 Main research question 3

The third main question of "How do university students from science and non-science majors in a university differ in terms of understanding of nature of science?" was tested by using one-way ANOVA procedures. It is aimed to see whether there is a difference between science and non-science majors' understandings of NOS or not.

Table 9. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants' Majors in Terms of Their Total NOS Scores (N=637)

Category	Major	*M*	*SD*	*F*	*p*
Total NOS Score	Non-Science	261.22	12.938	12.686	.00
	Science	256.95	15.109		

Table 9 indicated that a significant difference was found between the students' majors which are non-science majors and science majors ($F(1,635) = 12.686$, $p < .05$) in terms of their understanding of NOS. This analysis revealed that students who were educated in non-science majors scored higher ($m = 261.22$, $sd = 12.938$) than students who were educated in science majors ($m = 256.95$, $sd = 15.109$). In other words, students from non-science majors had a higher understanding level of NOS in comparison to students from science majors.

4.1.2.4 Main research question 4 and sub-questions

The fourth main question of "How do university students from science and non-science majors in a university differ in terms of understanding of aims and values, scientific practices, methods and methodological rules of science, scientific knowledge and social-institutional systems of science?" and five sub-questions about students' understanding of each category of NOS in terms of their majors were tested through one-way ANOVA. The aim is to investigate the differences in students understanding of five different categories of NOS in terms of their majors. In that sense, the statistical analyses for each category of RFN in terms of students' majors were provided (see Table 10).

Table 10. One Way ANOVA Tests for the Nature of Science (NOS) Questionnaire Based on Participants' Majors in Terms of Their Category Based NOS Scores (*N*=637)

Category	Major	*M*	*SD*	*F*	*p*
AV	Non-Science	34.54	3.298	9.371	.002
	Science	33.65	3.612		
SP	Non-science	56.87	4.175	.057	.812
	Science	56.78	4.774		
M	Non-science	40.93	2.979	10.786	.001
	Science	40.03	3.439		
SK	Non-science	51.50	3.598	8.454	.004
	Science	50.55	4.113		
SI	Non-science	77.37	5.320	8.818	.003
	Science	75.94	6.024		

Table 10 shows that for the first sub-question of "Are there any significant differences between students from science and non-science majors in terms of their understanding of aims and values of science?", it can be said that there was a statistically significant difference between science majors and non-science majors in terms of their understanding of the category of aims and values ($F(1,635) = 9.371$, $p<.05$).

The result of the sub-question of "Are there any significant differences among university students from different faculties in terms of their understanding of scientific practices?" showed that there was no significant difference in terms of students' understanding of scientific practices with respect to their majors ($F(1, 635) = .057$, $p>.05$).

For the sub-question of "Are there any significant differences between students from science and non-science majors in terms of their understanding of methods and methodological rules of science?" the results illustrated that there was a

statistically significant difference in terms of students' understanding of the methods and methodological rules of science in terms of students' majors ($F(1,635) = 10.786$, $p<.05$).

Additionally, the result of the sub-question of "Are there any significant differences between students from science and non-science majors in terms of their understanding of scientific knowledge?" showed that there was a statistically significant difference in terms of students' understanding of the scientific knowledge within the consideration of university students' majors ($F(1,635) = 8.454$, $p<.05$).

As a last category, the sub-question of "Are there any significant differences between students from science and non-science majors in terms of their understanding of social-institutional systems of science?" was answered. There was a statistically significant difference among students from science a non-science majors for the understanding of social-institutional systems of science ($F(1,635) = 8.818$, $p<.05$).

In general, non-science majors scored higher for most of the categories of RFN than students who were educated in science majors. According to the results, non-science majors have a better understanding about aims and values, methods and methodological rules, scientific knowledge and social-institutional systems of science. Exceptionally, no significant difference was found between the majors in terms of their understanding of scientific practices. However, it can be said that the students from non-science majors scored higher ($m = 56.87$, $sd = 4.175$) than students who were educated in science majors ($m = 56.78$, $sd = 4.774$) for this category. In other words, students from non-science majors have a better understanding level of NOS compare to the students from science majors.

4.2 Qualitative analysis results

Qualitative data analyses reflect the semi-structured interview results which cover the main themes and codes in terms of the five categories of RFN, and participants' perceptions of NOS in details. In the following sections, participants' perceptions about aims and values, scientific practices, methods and methodological rules, scientific knowledge, social-institutional systems of science and holistic structure of RFN are presented to answer the last research question of "How do university students from science and non-science majors in a university perceive nature of science in terms of aims and values, scientific practices, methods, scientific knowledge and social-institutional systems of science?".

In each section, students' perceptions about each category are examined through students' responses about RFN based interview questions and Text 1 and Text 2 based interview questions. Since there is no statistically significant difference was found in students' understanding of NOS in terms of their faculties; the major based similarities and differences are analyzed in university students' NOS perceptions with the use of their level of NOS understandings. Some related quotes are also given to display students' perceptions about the RFN categories and given texts. The information about abbreviations that are used in the end of each quotes to describe the characteristics of the responder are also provided in Table 11. At the end of the chapter, the summary of the results section is provided to summarize the main points and trends in terms of participants' perceptions of RFN categories.

Table 11. Abbreviations for students' majors, faculties and NOS understanding

Abbreviation	Explanation
CET	Computer Education and Educational Technology
CHE	Chemical Engineering
CHEM	Chemistry
CMPE	Computer Engineering
FAS	Faculty of Arts and Science
FED	Faculty of Education
FEN	Faculty of Engineering
FLED	Foreign Language Education
H	High Level Understanding of NOS
IE	Industrial Engineering
L	Low Level Understanding of NOS
M	Moderate Level Understanding of NOS
N-SCI	Non-Science Majors
PHIL	Philosophy
PRED	Primary Education
PSY	Psychology
SCED	Science Education
SCI	Science Majors
SOC	Sociology

For instance, the owner of the following quote is from faculty of arts and sciences (FAS) and this student is studying in the department of primary education (PRED) which is defined as a non-science (NSCI) major for this study. The participant also has a moderate level understanding (M) of NOS in terms of her "NOS Questionnaire" score.

> I think scientific practices are applicational steps of science. For instance, making experiments and observations [as scientific practices]. These are the practices of science, not theoretical aspects. [FAS- NSCI- PRED- M] (Appendix E, 1)

The following sections reflect participants' perceptions of five different categories of RFN in term of their responses to the RFN based and Text 1 and 2 based questions. Their majors and NOS understanding levels are conceived to analyze and compare their perceptions about the concepts.

4.2.1. University students' perceptions of aims and values of science

The qualitative research analysis was carried out to illustrate students' perceptions of aims and values of science. In order to determine students' perceptions about aims and values of science, two separate questions that "What comes to your mind when I say aims and values of science, could you give some examples?'' and "When you consider the Text 1, which key terms and concepts raise in your mind in terms of the aims and values of science?" were asked to students. While the first question reflects their general perception about the concept of aims and values of science, the second question intends to show their perception of aims and values in terms of the context of Text 1 which includes a study from a real world. Students' responses to these questions were assessed separately below.

4.2.1.1 Perceptions for aims and values (without using Text 1)

Table 12 represents students' most frequent answers for the first question and general trends about the aims and values of science. It includes the common codes for the category of aims and values of science. The explanations of the codes which reflect and define students' answers were also provided in the table. In other words, the definitions of the codes were written according to the students' responses for the related code. The table also reflects the response rates for each code in terms of students' majors which are science and non-science and their level of NOS understandings which are high, moderate, and low. Thus, the table hopefully provides a clear vision to see the similarities and differences between science and non-science majors, and it allows us to make comparisons about them. Another important point is that stating students' response rates for high, moderate, and low-level understanding of NOS allows the reader to see whether there is a coherence

between quantitative and qualitative results by comparing the response rates for each level. In other words, the table is formed to assist audience to see whether a student with high level understanding of NOS according to "NOS Questionnaire" score gives a better, comprehensive and nuanced answers or not in comparison to moderate and low-level students.

As can be seen in the Table 12, science and non-science majors held similar ideas about the aims of science. For instance, 75% of the science majors and 57% of the non-science major held common views that science has an aim that serving to humanity and making easier the people's daily life. They meant that science should meet the demands of mankind and provide a better future for humanity through making progressions in different fields of life, such as in medicine, technology etc. It was also observed that while 80% of the students with high and moderate level understanding of NOS expressed their ideas about aims of science by focusing on these two points; only 40% of the students with low level understanding of NOS focused on the concept of serving to humanity when explaining the aims of science. Another common code about the aim of science was understanding the universe which is appointed by 75% of the science and 85% of the non-science students. Through the code of understanding the universe, they meant to discover the dynamics of the universe, life and nature and make sense of the nature of humanity.

Another prevalent view which mostly adopted by science majors, especially the majors of engineering, was about the practical and applicational aims of science. About 62% of the science majors claimed that science has an aim of providing a progression in technology. This view implies that science has a practical and applicational side, besides the theoretical frameworks, norms and explanations

Table 12. The Codes for Students' Perceptions of Aims and Values of Science Without Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}:		Low N_{l}:	
		#	%	#	%	#	%	#	%	#	%
Serving to humanity (aim)	Progression in different fields of life as medicine and technology; meeting the demands of mankind	6	75	4	57	4	80	4	80	2	40
Understanding the universe (aim)	Understanding the dynamics of the universe and nature; making sense of the nature of humanity	6	75	6	85	5	100	4	80	3	60
Making easier the daily life (aim)	Providing a better future for humanity and produce solutions to people's problems	6	75	6	85	5	100	4	80	3	60
Providing progress in technology (aim)	Practical and application-based aims of science, production of devices; research and developmental processes of science and improvements in technology	5	62	1	14	4	80	2	40	0	0
Searching for truth (aim)	Explaining the specific phenomenon; providing evidences to clarify the concepts without pragmatist concerns	1	12	4	57	3	60	2	40	0	0
Ethics (values)	A set of moral issues or values that include concerns about human and animal rights, convenience level of the human behavior in terms of the related context	7	87	6	85	5	100	5	100	3	60
Dependence of scientific knowledge and scientific methods (values)	The value and the power of science in terms of depending on falsifiable, uncertain and non-dogmatic scientific knowledge and effective scientific methods	4	50	1	14	4	80	1	20	0	0
Objectivity (values)	The characteristic of scientific claims which are independent from cultural and religious values	2	25	2	28	2	40	1	20	1	20

about the subjects. For instance, research and developmental processes about a specific phenomenon, production of new devices and improvements in technology represent the progressional steps in technology for science majors. The response rates for this code also showed that while students with high level understanding of NOS tend to explain the aim of science with its practical and applicational use; students with low level understanding of NOS show no tendency to consider such point.

Table 12 also shows that while more than half of the non-science majors held the view that science has an aim of searching for the truth without any pragmatist concern, only 12% of the science majors advocated that view. According to these participants, science can be done to satisfy one's curiosity about any subject matter without the concern of serving to humanity. In other words, science should aim to explain specific subject matter and provide evidences about this subject as suggested:

> I think aims and values of science are simply explaining a phenomenon and understanding the basic components and characteristics of this phenomenon. I think that science does not have necessarily a pragmatic approach. My perspective possibly related to my discipline. I mean that the aim of science is explaining a phenomenon. For instance, explaining the concept of separation of the visual [or the image] from the retina [as an aim]. When we consider that, we cannot see a pragmatist approach here. There is an aim of explanation. [FAS-NSCI-PSY-H] (Appendix E, 2)

This student seems aware of the epistemic and cognitive aims of science. Since the participant considered the main aims of science as discovering and explaining a phenomenon; it can be said that the student gave an importance to explanatory power and empirical adequacy of science to provide the growth of scientific knowledge.

Besides aims of science, participants offered a bunch of ideas about the values of science. For instance, almost all students from both science and non-

science majors claimed that ethics is one of the important themes to explain values of science. The students generally had the view that ethics is one of the key concepts in terms of expressing the values of science, because it reflects the rights of the animals and humans in scientific processes and experiments, and it stands for the value of no harm to nature and living creatures when doing science.

Table 12 also illustrated that while half of the science majors asserted that science has a value because of its dependence on scientific knowledge which has a falsifiable, uncertain and non-dogmatic nature, and use of effective and objective scientific methods in scientific processes; only 14% of the non-science majors gave credit to this specific point. It is also observed that this view is adopted only by the majority of students with high and moderate level understanding of NOS. The following excerpt from an engineering major describes the participant's understanding about values of science:

> I think one of the important things about the science is its falsifiable nature. Science never talks in a certain way. So, this is the difference between science and religion for me. Science also respects for other ideas and views and it does not have a dogmatic nature. I mean people can always criticize [the arguments and views] science. [FEN-SCI-IE-M] (Appendix E, 3)

As can be seen that, the student implicitly found a connection between epistemic and cognitive aspects of science with the values of science. Hence, it can be said that students from science majors focused more on the methodology of science and gave more value and importance to use scientific knowledge in scientific process.

4.2.1.2 Perceptions for aims and values through Text 1

The second question aimed to exhibit participants' perceptions about aims and values of science in a deeper sense by using the real world related Text 1. Text 1 includes some anecdotes about potential aims and values of science.

The text covers a study which is about the working mechanism of the brain and its relationship with gut bacteria. In the text, scientists pointed out that working with gut bacteria is tricky, because of the discovering the function of the brain and the causes of the autism. In other words, the aim and value of understanding a neuroscientific phenomenon, presenting evidences about the autism and human health, and the importance of contributing different research fields are explicitly mentioned in the text.

Table 13 shows the most frequent aims and values related codes in relation to responses of Text 1 based interview questions. The codes and their explanations were formed according to students' responses. Response rates for each code in terms of students' majors and their level of NOS understandings were also provided in the table to make clear comparisons.

The table shows that there are some common conceptions in terms of students' explanations about aims and values of science. For instance, more than 85% of science and non-science majors focused on the points of serving to humanity and providing solutions for people's problems when they were explaining the aim of the given study in Text 1. For majority of each levels of understanding of NOS, participants precisely expressed that the study has some significant contributions for people with autism and directly helps people to enhance their life standards and solve their health problems.

Additionally, responses of the students with high level understanding of NOS were markedly different from those of moderate and low-level students in terms of expressing the concept of values of science. About 60 % of the high-level students declared that science has a pragmatist nature and 40% of them proposed that science has a practical value. They meant that the process of making

Table 13. The Codes for Students' Perceptions of Aims and Values of Science Through Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Serving to humanity (aim)	Progression in different fields of life as medicine and technology; meeting the demands of mankind	7	87	6	85	5	100	5	100	3	60
Providing solutions for problems (aim)	Developing some solutions to people's health problems to provide them a better and quality future	8	100	6	85	5	100	5	100	4	80
Pragmatist values	The benefit or profit based nature of science; the practical focus of science	2	25	1	14	3	60	0	0	0	0
Ethics (values)	A set of issues or values that include concerns about human and animal rights, such as using animals in science experiments	2	25	3	43	3	60	1	20	1	20

experiments to find the effect of probiotics and the gut bacteria on brain's specialized areas have a practical value in terms of converting theoretical facts into the applicational fields, such as neuroscience, as well as people's life. This kind of approach was also considered as a pragmatist essence of science by some students.

Another observed trend through the students' responses for Text 1 is that while 60% of the high-level students thought that this study has some ethical issues and concerns in terms of violating the rights of animals; 20% of the moderate and low-level students had some comments about the issue. Students' responses reflected their dilemmas in here, because they thought that while the study is really efficient for people with autism, it is also harmful for mice which are used during the experiments to reach some conclusion about the concept. This situation leads contradictions for some students in terms of the rights of animals and made them think about the principle of no harm while doing science. The student with a high-level understanding of NOS had a verbal response suggested that:

> In the text [and the study], I see the aim of serving to people. Researchers worked on autism and found something to help people with autism. They worked with mice which is questionable, but some positive results were obtained for humanity. I think the opportunity of helping people with autism and using science for a good reason are incredible thing. [FED-NSCI-FLED-H] (Appendix E, 4)

This student made a clear emphasis about the main purpose of science which is helping and serving people with problems, such as people with autism. However, the participant also mentioned about the ethical considerations and the possible violations of ethical values in scientific processes.

Overall, responses for Text 1 based questions show that participants' initial answers for the aims and values related questions are similar and proportional to their Text 1 based answers. At this point, it can be said that Text 1 provided a supplementary source for participants to make concepts concrete and express their

real life related comments in an easier way. Additionally, the response frequencies of the high, moderate and low-level students indicated that participants who have a label of high level understanding of NOS tend to mention various points and themes about the concept and they gave more detailed examples and explanations in terms explaining the aims and values of science. They generally represented a better cognitive profile by making connections from their majors and daily lives to reflect their understandings. On the contrary, participants who have a low-level understanding of NOS, couldn't focused on the themes that mentioned by high and moderate level students.

Summing up the results of this section, students held a general perception about aims and values of science. Both science and non-science majors considered the aims of science as serving to humanity, making contributions to society and understanding the universe. The both groups touched upon those points with the similar response rates while explaining the aims of science. Different from those common points, science major students more likely to hold the practical and application-based aims than non-science majors. According to science majors' responses, providing developments in technological fields and working on the research and developmental processes in scientific processes are some of the aims of science. However, non-science majors gave an importance to searching for truth to understand the function of any phenomenon as an undeniable epistemological aim of science. Additionally, when students had an opportunity to express their own ideas through the open-ended questions, differences between high, moderate and low-level students became apparent. Students with high and moderate level understanding of NOS highlighted ethical, pragmatically, practical and epistemological aims and values of science in a more nuanced and sophisticated way.

It can also be said that Text 1 provided a supplementary source for participants to make the concepts more concrete and express their real life related comments in an easier way.

4.2.2 University students' perceptions of scientific practices

Students' perceptions about scientific practices were conceived by using the interview questions of "What comes to your mind when I say scientific practices, could you give some examples?'' and "When you consider the Text 1, which key terms and concepts were raised in your mind in term of the scientific practices?". The RFN based former question aimed to determine students' existing perception about scientific practices and the Text 1 based main question aimed to show students' perception of scientific practices in terms of the context of Text 1. Students' responses for each question were examined separately in details below.

4.2.2.1 Perceptions of scientific practices without using Text 1

Table 14 represents the most frequently used trends for the scientific practices related question. The table includes the common codes that are related to the components of scientific practices. The explanations of the codes which are formed according to the students' responses were also provided.

The table also reflects the response rates for each code in terms of students' majors which are science and non-science; and their level of NOS understandings which are high, moderate, and low levels to provide a clear picture about the similarities and differences between students' majors and their levels of NOS understandings.

As it is observed in the table, participating science and non-science majors held several ideas about the scientific practices. As the most prevalent code, more than 70% of science and non-science majors considered that testing as one of the scientific practices that is used in scientific process. They considered the concept of testing as an experimentation process to gather information about the natural world and it is a kind of practice that is used to test constructed hypothesis. Furthermore, the half of the science majors and 57% of the non-science majors held the view that constructing a hypothesis is one of the essential steps of the scientific practices. According to students, since this step carried out after determining a problem about specific topic and made for testing and explaining the problem, it is important. In the following quote, the student explained his views on scientific practices by focusing on the steps of constructing hypothesis and testing:

> When I say scientific practices, trial and error processes and making experiments came to my mind. We are constructing hypothesis and we are trying [to prove] them. Sometimes the results are gathered in line with our expectations and sometimes they do not. Then, we use different methods and we try to reach results again. [FEN- SCI- CHE- H] (Appendix E, 5)

The response shows that the student from chemistry major tends to regard scientific practices as the kind of scientific methods. Because she mentioned different scientific methods that she used during her studies and major; such as constructing hypothesis, making experiments through trial and error processes and finding some results. In other words, this student prone to make some connections with her personal experiences about her major and the steps that she used in her field.

At this junction, in the light of the response rates for the codes of testing and constructing hypothesis and quotations of the students, it can be inferred that most of the students cannot discriminate the concepts of scientific practices and

Table 14. The Codes for Students' Perceptions of Scientific Practices Without Using Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Constructing hypothesis	A step that carried out after determining a problem about specific topic and made for explaining and testing the problem	4	50	4	57	4	80	4	80	0	0
Testing	Use of experiments to gather information about the natural world and assess whether the constructed hypothesis was correct or not	7	87	5	72	5	100	4	80	3	60
Data collection	Practical and systematic steps to gather and measure information from different sources	3	38	5	72	4	80	3	60	1	20
Observation	Use all the senses to examine people or object in natural settings	1	13	5	72	4	40	1	20	1	20
Prediction	One of the fundamental steps of the scientific method to generate a hypothesis and see what will happen	2	25	1	14	2	40	1	20	0	0
Using simulations and models	Systems that try to explain the real world Through simplification, and performing an experiment that cannot be done in the real world	4	50	0	0	4	80	0	0	0	0
Discussion	The process of talking about something to reach exchange ideas and make a decision	2	25	0	0	2	40	0	0	0	0

scientific methods explicitly. They uttered that these two categories are as the same or similar concepts.

On the other hand, participants from science majors, especially the major of science education declared that prediction, modelling, data collection, and discussion are some of the components of the scientific practices. In other words, the major of science education dominantly explained some components of scientific practices and their relationships with respect to Benzene Ring Heuristic Model (BRH). The possible reason of these participants' more developed and nuanced ideas about scientific practices are that they had a pedagogical course in their undergraduate programs which focuses on the components of scientific practices, and Benzene Ring Heuristic. For instance, a student from the major of science education stated:

> Observation is one of the first things that we should do. After the observation [process], making predictions and comparisons can be made about the results. Modelling can be also used. We can make some small models of the concepts and use these models in science lessons. Additionally, we can collect the data. We can interpret the existing data, or we can construct a new data set. Creating a discussion [environment] about the data also can be made. [FED-SCI- SCED- H] (Appendix E, 6)

The quotation shows that the student from science education department seems aware of the concept and the components of the scientific practices. She mentioned about the making predictions, providing explanations, using models, data collection, and creating discussion environment to present results as parts of scientific practices. While doing this, she referred a course that she took in her program which is about the scientific practices. The situation again supports that students tend to produce answers within the scope of their experiences from their courses and majors. Taking such class possibly made a positive effect on that student's perception to express her ideas about the scientific practices. Additionally, response rates for the codes of using models and simulations and observation show that

students only with the high-level understanding of NOS mentioned about these points. Moreover, these two codes formed the main difference between science and non-science majors in terms of their perceptions about scientific practices. While the half of the science majors focused on using models and developing simulations about the concepts as scientific practices; none of the non- science majors considered these points. Similarly, while 72% of the non-science majors conceived the observation as one of the scientific practices, only 13% of the science majors considered observations as one of the scientific practices.

4.2.2.2 Perceptions of scientific practices through Text 1

The second question aimed to illustrate students' perceptions about scientific practices in a deeper sense by using the real world related and Text 1 based context. Text 1 reflects some points about the components of the scientific practices. The text covers a study about the working mechanism of the brain and its relationship with the gut bacteria. The text mentions about a neuroscience conference in Washington which pointed out the scientists' representations of their works, discourse and social certification process about their studies, and the data collection period while they are working on the gut bacteria. In other words, the text touches upon different components of the scientific practices, such as real life, data collection, prediction, representation, discourse and social certification.

Table 15 shows the most frequent scientific practices related codes for the responses of Text 1 based interview question. The codes and their explanations were formed according to students' answers. Response rates for the students' majors and their level of NOS understandings were also provided.

According to the table, it can be observed that majority of the codes for Text 1 based interview question are the same with the initial interview question codes. For instance, students explained the scientific practices with the concepts of constructing hypothesis, testing, observation and discussion within the consideration of the text. They talked about the steps of determining a problem about the working mechanism of the brain and the nature of autism, constructing hypothesis about the gut bacteria and brain, making experiments to collect data from mice, and making predictions and explaining the effect of probiotics for people with autism. In that sense, it is observed that Text 1 did not help students to differentiate the concepts of scientific practices and scientific method. For instance, a non-science major student from the department of foreign language education stated:

> [In the study], there was an experiment. Scientists made some experiments with mice. When I say scientific practices, experiments came to my mind. They also present their findings in somewhere. This can be also a practice which is about the dissemination process. [FED-NSCI-FLED-M] (Appendix E, 7)

Besides from the points that mentioned above, three additional new codes emerged by the students' responses within the scope of the text. The study given in the text helped some students to see different kind of scientific practices such as real world, explanation and social certification and dissemination process. As can be followed from the table 15, students only from science majors and with the high-level understanding of NOS focused on the concepts of real world and explanation while expressing the scientific practices that are used in the given study. Nevertheless, more than half of the science and non-science majors considered the social certification and dissemination processes as one of the components of scientific practices. Because they underlined the process of discourse among scientists and presenting results at neuroscience conference.

Table 15. The Codes for Students' Perceptions of Scientific Practices Through Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Constructing hypothesis	A step that carried out after determining a problem about specific topic and made for explaining and testing the problem	2	25	2	29	4	80	0	0	0	0
Testing	Use of experiments to gather information about the natural world and assess whether the constructed hypothesis was correct or not	7	87	7	100	5	100	5	100	4	80
Observation	Use all the senses to examine people or object in natural settings	3	38	0	0	2	40	0	0	1	20
Real world	Using the concepts, objects, creatures and incidences of real world to determine a problem and work with it	2	25	0	0	2	40	0	0	0	0
Explanation	A set of statements that used to describe a set of facts by focusing on the causes, context, and consequences of those facts	2	25	0	0	2	40	0	0	0	0
Discussion	The process of talking about something to reach exchange ideas and make a decision	2	25	0	0	2	40	0	0	0	0
Social certification and dissemination	The processes of presenting results and publishing articles after the use of scientific practices in the scientific process	4	50	4	57	2	40	4	80	2	40

In brief, the results of this section provided three main points. The first one is that both science and non-science majors dwelled on the terms of constructing hypothesis, testing and observation while explaining the scientific practices to. This situation shows that these students have an awareness about the different kind of scientific methods, such as observation and experiment-based methods than scientific practices. The second notable point about the results is that students tend to refer their majors while talking about the types of experiments and research steps, because they mainly referred to their disciplines and courses. Hence, what students know about scientific practices generally came from their university education. As a third point, it is observed that students from science majors, especially from science education department reflected better perception of scientific practices than non-science majors. Although, they also considered scientific methods as scientific practices, students from science majors considered the terms of modelling, prediction, real world and discussion while talking about the scientific practices through RFN and text base questions. For the students from science education major, the possible reason of these participants' more developed and nuanced ideas about scientific practices is that they had a pedagogical course in their undergraduate program which focuses on the components of the scientific practices.

It can also be said that Text 1 provided students a real world related context through covering a scientific study and helped them to think about some components of the scientific practices. Students with high and moderate level understanding of NOS also performed a better perception in comparison to low level students.

4.2.3. University students' perceptions of methods and methodological rules of science

Students' perceptions about methods and methodological rules of science conceived through using three different interview questions that "What comes to your mind when I say methods and methodological rules of science, could you give some examples?", "Do you think that different kinds of scientific methods exist and how?" and "When you consider the Text 1, which key terms and concepts were raised in your mind in term of methods and methodological rules of science?". The first two questions asked students as RFN based question to understand their general perceptions about scientific methods and whether different kinds of scientific methods exist or not for them. The last question was Text 1 based question which aimed to show students' perception of scientific methods in terms of the context of Text 1. Students' responses for each question were examined separately in details below.

4.2.3.1 Perceptions of methods and methodological rules of science without using Text 1

Table 16 represents the most frequently used trends for methods and methodological rules of science. It reflects students' general perceptions about scientific methods through the codes. The explanations of the codes are formed according to the students answers

The table shows the response rates for each code in terms of students' majors and students' level of NOS understandings which are high, moderate and low.

As it is given, participating science and non-science students held several ideas about the methods and methodological rules of science. As the most prevalent code, all

the science majors and 85% of the non-science major students considered that testing is one of the scientific methods. They considered the concept of testing as an experimentation process to gather information about the natural world and a kind of practice that used to test constructed hypothesis. Additionally, almost half of the science and non-science majors held the view that determining a problem, constructing hypothesis and data collection process are the essential scientific methods. According to students, identifying a problem and then constructing a hypothesis or developing a research question are important to gain an information and form scientific knowledge. They also pointed out the necessity of data collection in testing process of the hypothesis. In this section, it is also seen that students' answers, and codes show similarity when they explain scientific practices and scientific methods. Most of the students considered that these two categories are the similar or nearly same concepts.

Most of the codes and responses of the students from different majors show that students tend to explain scientific methods in an ordered and stereotypical way as they learnt in their high school years. They mentioned about determining a problem or asking a question about nature, constructing a hypothesis about that problem, collecting data to test this hypothesis and reaching some conclusions at the end of the process. This sequence shows us that students have an awareness about the general rationale and the working mechanism of a scientific study, but they also tend to explain scientific methods within the stereotypic depiction of the scientific methods which is explained by Erduran and Dagher (2014). Another prevalent conception about the scientific methods for both science and non-science majors is that using research methods in a scientific process. The analysis results show that students from both majors prominently expressed the concept of scientific methods

Table 16. The Codes for Students' Perceptions of Methods and Methodological Rules of Science Without Using Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Determining a problem	Identifying a problem or developing a research question to gain a knowledge or information that is needed to be learned	3	38	4	57	4	80	0	0	3	60
Constructing hypothesis	A step that carried out after determining a problem about specific topic and made for explaining and testing the problem	4	50	4	57	4	80	2	40	2	40
Testing	Use of experiments to gather information about the natural world and assess whether the constructed hypothesis was correct or not	8	100	6	85	5	100	5	100	4	80
Data collection	Practical and systematic steps to gather and measure information from different sources	5	63	3	43	4	80	3	60	1	20
Observation	Use all of the senses to examine people or object in natural settings	1	13	6	85	2	40	2	40	3	60
Research methods	The research steps that are used in a study of a given subject or field to discover facts or principles, such as using surveys and interviews	8	100	7	100	5	100	5	100	5	100

with the steps of research methods, such as using surveys and interviews, reviewing the literature, determining sampling procedures, and using statistical methods for data analysis. In other words, they illustrated a broader perception in terms of explaining different kind of scientific methods, its' steps and possible applications. Interestingly, while they were explaining their perceptions about scientific methods, they generally focused on the methods that they are familiar with and they are used in their labs, courses and majors. Hence, their answers reflect their experiences and observations from their university educations. For instance, a student from the department of primary education stated that:

> When I think about scientific methods, research methods come to my mind. That's because I am taking a course about the research methods [in my major] right now. For instance, we use surveys and we make observations. We review the literature and chose our target population [to get some results]. [FED-NSCI- PRED- L] (Appendix E, 8)

This quotation shows that a student in department of primary science education use certain research methods such as making surveys and observation, reviewing the literature and finding results. Hence, the student found a link between scientific methods and research methods as she learnt and used in her major and studies.

Additionally, all the students from both majors and each levels of understanding of NOS gave the same answer for the second RFN based question. The student from the department of psychology uttered:

> When I am working on a behavioral study, there are certain and different procedures that I follow. [Similarly], if I was working on neuroscience, it's procedure would be different, too. For example, for this study, a survey was applied to us. This method is convenient for this study; but when we are working on visual perception, we probably use psychophysics experimentation and try to understand about people's behaviors. I mean, the methods that we use can be different according to our working fields. [FAS-NSCI- PSY- M] (Appendix E, 9)

As can be seen that, a student highlighted that there are different scientific methods in different kind of scientific fields. She mentioned about the potential scientific

methods that are used in behavioral studies and neuroscientific studies separately. By doing that she reflected her background from her major. Another student from the department of philosophy also stated that:

> When we look to history of humankind, we can see that every different branch of science has its' own scientific method. For example, if you make a scientific experiment or make a research, you tend to use laboratory, such as chemistry labs. But in social sciences, these methods cannot work [all the time]. They generally use observation. [FAS-NSCI- PHIL-L] (Appendix E, 10)

This student also pointed out the usage of different kind of scientific methods in different branches of science. He also mentioned that while the studies in philosophy generally use the method of observation, the studies in chemistry possibly use the method of experimentation or testing.

4.2.3.2 Perceptions of methods and methodological rules of science through Text 1

The third question aimed to illustrate students' perceptions about scientific methods in a deeper sense by using the real world related Text 1. Text 1 reflects some main points about the different kind of scientific methods.

As it is mentioned before, the text covers a study about the working mechanism of the brain and its relationship with the gut bacteria. The text provides an information about two different studies that utilized testing process to reach some results. In these studies, scientist worked on a microbiome and gut bacterium to see the effect of these structures on the brain in infancy. To see the effect, scientists made some experiments on mice and provided a testing process. Additionally, they made some observations by using the results of these studies and they tried to observe and understand the effect of gut bacteria on people with autism.

Table 17 shows the most frequent methods and methodological rules related codes for the responses of Text 1 based interview question. The codes and their

explanations were formed according to students' answers. Response rates for students' majors and their level of NOS understandings were also provided. The table shows that all the codes for Text 1 based question are the same with the RFN based question.

For instance, students explained the scientific methods by considering the given study with the concepts of constructing hypothesis, testing, research methods, data collection and observation. They talked about the steps of constructing a hypothesis, the effects of gut bacteria on autism, making experiments by using mice, testing the hypothesis, and making observations about the people with autism. In that sense, it is observed that Text 1 helped students to put their initial ideas in a real context through the given study. For instance, a non-science major student from the department of sociology stated that:

> Constructing hypothesis, data collection, making experiments [to test the hypothesis] came to my mind when I read the text. These are the methods, I think. [FAS-NSCI-SOC-H] (Appendix E, 11)

As can be seen that the student mentioned about the steps that are used in the study, such as experimentation, data collection, reaching results and trying to find some correlations. This situation supports that participants from both science and non-science majors reflected their initial ideas about scientific methods while interpreting the methods that are used in the given study.

Overall, majority of the science and non-science majors held a view that constructing hypothesis, testing and research methods are different kind of scientific methods that are used in the scientific studies. However, while majority of non-science students see the observation as one of the scientific methods, only a small portion of science students held that view. When the response rates are examined and

Table 17. The Codes for Students' Perceptions of Methods and Methodological Rules of Science Through Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Testing	Use of experiments to gather information about the natural world and assess whether the constructed hypothesis was correct or not	8	100	7	100	5	100	5	100	5	100
Constructing hypothesis	A step that carried out after determining a problem about specific topic and made for explaining and testing the problem	4	63	2	29	4	80	2	40	0	0
Data collection	Practical and systematic steps to gather and measure information from different sources	0	0	2	29	2	40	0	0	0	0
Observation	Use all the senses to examine people or object in natural settings	1	13	2	29	0	0	2	40	1	20
Research methods	The research steps that are used in a study of a given subject or field to discover fact or principle, such as using statistical methods, finding correlations and making comparisons between groups	8	100	7	100	5	100	5	100	5	100

students' detailed responses and quotations are bared in mind, non-science majors held more informed perceptions of different kind of scientific methods. Because, these students gave detailed and nuanced examples which cover the observational and experimental steps of the scientific methods. The results also show that students tend to explain the concept of scientific methods by using examples from their majors. Therefore, what students know about the scientific methods is dominantly formed through their major based university education.

4.2.4 University students' perceptions of scientific knowledge

In order to determine students' perceptions about scientific knowledge, four different questions were asked to them. These questions are "What comes to your mind when I say scientific knowledge", "Do you think that scientific knowledge change and why?", "What are the forms of scientific knowledge? Do you think that scientific knowledge has different forms?" and "When you consider the Text 1, which key terms and concepts were raised in your mind in term of the aims and values of science?". Through these questions, students' perceptions about the characteristics and changeable nature of scientific knowledge, the different forms of scientific knowledge, and their reflections about the nature of scientific knowledge aimed to reveal with the consideration of Text 1.

The first three questions asked students as RFN based questions to understand their general perceptions about the definition of scientific knowledge, the forms of scientific knowledge and whether scientific knowledge ever changes or not. The last question was asked to students as a Text 1 based question which aimed to show students' perception of scientific knowledge in terms of the context of Text. Students' answers for each question were examined separately in details below.

4.2.4.1 Perceptions of scientific knowledge without using Text 1

Table 18 represents the most frequently used codes for scientific knowledge. The explanations of the codes are formed according to the students' responses. The response rates for each code in terms of students' majors and students' level of NOS understandings were also given.

The table shows that students used the terms of tested, credible, objective and falsifiable when they are explaining the characteristics of the scientific knowledge as their answers for the first interview question. While all the non-science majors characterized the scientific knowledge as tested and credible, 63% of the science majors mentioned these two characteristics of the scientific knowledge. In other words, students considered scientific knowledge as a fact or information which is acquired through a set of experiments or tests and it is proved by scientific evidence. The other observed code which reflects students' perceptions about the characteristics of scientific knowledge is objectivity. Only 28% of the non-science majors mentioned about the objective nature of scientific knowledge. They claimed that scientific knowledge is not a subjective entity and it is not affected from people's beliefs and ideas. As a last point, only 28% of the non-science majors explained that falsifiable nature of the scientific knowledge. They uttered that scientific knowledge is refutable. Therefore, when we examine the response rates for these codes, it can be said that non-science majors focused some additional points when characterizing the nature of scientific knowledge by comparison to science majors. It is also observed that these codes are formed dominantly with the responses of high and moderate level students. Especially, when the table is checked for the response rates of the codes of objectivity and falsifiability, there is no response from low level students.

For the second question, all students from both majors claimed that scientific knowledge has a tentative structure and it can change over time. The analysis results also show that while 43% of the non-science majors held informed perceptions about explaining the concept of tentative nature of the scientific knowledge by the concept of context dependence and paradigm shift; only 25% of the science majors mentioned about this point. These students pointed out that scientific knowledge can change in terms of social and cultural characteristics and factors of the related context and can be explained with the concept of paradigm shift. For instance, a student from the department of philosophy demonstrated a sophisticated view that:

> I want to use the term of paradigm shift concept [of scientific knowledge] here. Scientific knowledge can change with paradigm shifts. For instance, people believed that human's mental health was depended on the activity of the brain priorly, but now it seems that the mental health is also depended on the bacteria activities in our gut. So, the scientific knowledge [on that concept] can develop and change. [FAS- NSCI- PHIL- H] (Appendix E, 12)

It is observed that participant tends to indicate major bounded answer in his expression. Paradigm shift is a philosophical standpoint that reflects changeable nature of scientific knowledge. The student also mentioned about the effect of the point of time and society on the forming process of scientific knowledge.

Participants' perceptions about the last question which was related to different forms of scientific knowledge revealed quite different results. About 85% of the non-science majors and half of the science majors found a relation between the forms of scientific knowledge and the different branches of science. In other words, these students indicated that scientific knowledge may be classified in different forms in terms of different disciplines of science, such as natural sciences and social sciences. A following statement indicates that:

Table 18. The Codes for Students' Perceptions of Scientific Knowledge Without Using Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Tested	A fact, information or description that is acquired through a set of experiments or tests	5	63	7	100	5	100	4	80	3	60
Credible	A type of knowledge that is proved and depended on scientific evidence, and it reflects the "real world" experience	5	63	7	100	5	100	4	80	3	60
Objective	A knowledge that not subjective, and not affect from people's beliefs and ideas	0	0	2	28	0	0	2	40	0	0
Falsifiable	A refutable nature of knowledge; a possibility of testing or observing that how a knowledge can be false or true	0	0	2	25	2	40	0	0	0	0
Tentative	Changeability of knowledge in the light of new evidence or new interpretation of existing evidence	8	100	7	100	5	100	5	100	5	100
Context based	Context dependence of knowledge: changeability of knowledge in terms of social and cultural characteristics of the related context	2	25	3	43	2	40	2	40	1	20
Theories, laws and hypotheses	Different types of knowledge; tested and observation-based knowledge which reflects the natural world	4	50	0	0	2	40	2	40	0	0
Different forms for different branches	Differentiation of scientific knowledge for different branches of science, such as for natural and social sciences	4	50	6	85	4	80	3	60	3	60

> If it is based on the different branches, I think it can be [categorized]. I mean, we can differ the forms of scientific knowledge according to the different branches of science. For instance, the knowledge can be different in the fields of physics, chemistry and biology. [FED- NSCI- FLED- L] (Appendix E, 13)

The student shared her ideas about the different forms of science by focusing on the different branches of science. She claimed that scientific knowledge can have a different form in physics, biology and chemistry. This view did not completely reflect the different forms of scientific knowledge which are theories, laws and models in terms of RFN. In that sense, students with such perception demonstrated naive understanding while representing their thoughts on different forms of scientific knowledge. However, this student made an implicit comment about the domain specificity of the scientific knowledge by explaining the differences of the scientific knowledge in different disciplines which is valuable.

On the contrary, half of the science majors, especially engineering students held better perception in terms of explaining different forms of scientific knowledge. These students focused on the concepts of hypothesis, theory and law while explaining the forms of scientific knowledge. However, it is also observed that none of the participants consider the concept of the model as a form of scientific knowledge. The example quote in this context is given below:

> Yes, there are different forms of scientific knowledge. For example, hypothesis, law, theory… Laws does not change. Theories also depend on science, but they are not an accurate type of knowledge. [FEN –SCI- CHE-H] (Appendix E, 14)

4.2.4.2 Perceptions of scientific knowledge through Text 1

The fourth question aimed to illustrate students' perceptions about scientific knowledge in a broader sense by using the real world related study. Text 1 reflects some points about the characteristics of scientific knowledge.

The text provides some keyword type information about the characteristics of the scientific knowledge. For instance, scientists conducted studies to form a valuable scientific knowledge about the working mechanism of the brain. They made some experiments and test some hypothesis to gain an ultimate scientific knowledge. By doing that, they also provided some evidences from the previous studies to support the hypothesis.

Table 19 shows the common scientific knowledge related codes according to the responses of Text 1 based interview questions. The codes and their explanations were given in terms of the students' answers. Response rates for students' majors and their level of NOS understandings were also provided.

The table shows that majority of codes for the Text 1 based interview questions are identical with the RFN based interview questions. For instance, majority of the students explained the characteristics of scientific knowledge within the consideration of the given study by the concepts of *tested* and *supported* knowledge. While more than 75% of the both majors focused on the term of tested, all the students from the non-science majors considered the term of supported. They explained the scientific knowledge as a fact that reached by the set of experiments on mice and depended on previous scientific evidences about microbiome and gut bacteria. In that sense, it is observed that Text 1 helped students to put their initial ideas about scientific knowledge in a real context through the given study.

The results also showed that while 28% of the non-science majors considered the nature of scientific knowledge as an objective and changeable entities within the consideration of paradigm shift concept; science major students did not refer those points.

Table 19. The Codes for Students' Perceptions of Scientific Knowledge Through Text 1 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Tested	A fact, information or description that is acquired through the application of set of research methods, such as experimentation or testing	6	75	6	85	5	100	4	80	3	60
Supported	A type of knowledge that is supported by previous studies and references; and depended on scientific evidence	5	63	7	100	4	80	5	100	3	60
Objective	A knowledge that not subjective, and not affect from people's beliefs and ideas	0	0	2	28	0	0	2	40	0	0
Paradigm shift	A refutable nature of knowledge; a possibility of testing or observing that how a knowledge can be false or true	0	0	2	28	2	40	0	0	0	0
Hypothesis	Different types of knowledge; tested and observation-based knowledge which reflects the natural world	2	25	0	0	2	40	0	0	0	0
Tentative	Changeability of knowledge in the light of new evi dence or new interpretation of existing evidence	2	25	0	0	2	40	0	0	0	0

Overall, science and non-science majors held an average amount of perception about the characteristics and tentative nature of scientific knowledge, and the different forms of scientific knowledge. When it comes to characteristics and tentative nature of scientific knowledge, non-science majors held more informed perception than science majors. Because, they additionally expressed the term of objectivity as a characteristic of the scientific knowledge and they talked about the context-based nature of scientific knowledge with paradigm shift concept. On the other hand, the only outstanding point about the science majors' perceptions about scientific knowledge was the different forms of scientific knowledge. The half of the science majors explained these forms with the concepts of hypothesis, theory and law. Nevertheless, when the response rates for RFN and text base questions were taken into consideration, non-science majors held more broader perceptions of scientific knowledge.

4.2.5 University students' perceptions of social-institutional systems of science

Participants' perceptions of the social-institutional systems of science are provided in this section. Several RFN, Text 1, and Text 2 based interview questions were asked to students to understand their perceptions about the concept. Three main interview questions which are "What comes to your mind when I say social and institutional aspects or systems of science, could you give some examples?", "When you consider the Text 1, which key terms and concepts were raised in your mind in terms of the social and institutional aspects of science?" and "When you consider the Text 2, which key terms and concepts were raised in your mind in term of the social and institutional systems of science?" were asked to students. The RFN based first question were used to specify students' general perceptions about social-institutional

systems of science. Text 1 and Text 2 related second, and third questions were used to determine students' real world related perceptions about the contexts.

Besides these three main questions, some sub-questions which reflect the essential parts of the social-institutional systems of science were asked students to deepen their responses and expressions. These sub-questions were related to professional activities, the effects of the social and cultural values in the processes of science, the concepts of social certification and dissemination, financial systems, social organizations, and political power structures in science. Students' answers for each question were examined separately in details below.

4.2.5.1 Perceptions of social-institutional systems of science without using Text 1 and Text 2

Table 20 represents the most frequently used codes for social-institutional systems of science. The explanations of the codes formed in terms of students' responses to the questions. The response rates for each code are formed in terms of students' majors and their level of NOS understandings.

As a first point, students made some comments about the professional activities which cover the activities that are made during the science process. About 63% of the science majors and 58% of the non-science majors focused on these activities in their answers. These answers are dominantly provided by students with high and moderate level understandings of NOS. While explaining the professional activities, students mentioned about attending symposiums and conferences, writing articles to journals, collaborative academic activities among scientists, sharing findings with society, and working in laboratories.

Social certification and dissemination process was another prevalent point for the students in terms of their explanations about the concept. All the non-science and 75% of the science majors held the view that presenting findings to public, peer-reviewing process for scientists and researchers, attending conferences, sharing findings through articles, journals, social media, TV, several internet and popular culture sources are the components of the science which are also the elements of the social certification and dissemination process.

Students also considered the effects of the social and cultural values and contexts on the processes of science preponderantly. All the students from science and non-science majors asserted that social and cultural values and the context of societies have some major impacts on scientific processes and societies' attitudes towards science. They also mentioned about the concepts of gender, race and religion while considering the other relevant exogenous variables of science. For example, a student from primary education department stated that:

> Social and cultural values have an important role [in science process]. For instance, scientists cannot work on any topics and they cannot publish anything in some countries. In societies which are ruled by conservative or religious law, people cannot study on the subjects like sex, evolution, gender issues, race etc. You cannot even see things in media in such places, because of the oppressive approach of the government and people. So, society's traditions and culture affect the research [process]. [FED- NSCI- PRED- M] (Appendix E, 15)

This student directly mentioned about the effect of social and cultural values, ideologies of the government, and traditions of the society in the scientific process. The student also provided some examples to support her argument. For instance, she underlined that these values and the context of the society directly affect the public's understanding and the appreciation level of science.

Table 20. The Codes for Students' Perceptions of Social-Institutional Systems of Science Without Using Text 1 and Text 2 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Professional activities	Activities like attending symposiums and conferences, writing articles to journals, collaborative academic activities among scientist, sharing findings with society and working in laboratories	5	63	4	58	4	80	3	60	2	40
Social certification and dissemination	Presenting findings to public, peer-reviewing processes for scientists and researchers, attending conferences, sharing findings through articles, journals, social media, TV, several internet and popular culture sources	6	75	7	100	5	100	5	100	3	60
Social and cultural values and context	The effect of social and cultural values and context of societies on scientific processes and societies' attitudes towards science; the influence of the concepts of gender, race and religion on science	8	100	7	100	5	100	5	100	5	100
Social organizations and interactions	Organizations that are institutions like universities, and research and development companies; hierarchical structure of the institutions; bureaucratic aspects of science	7	88	6	85	5	100	5	100	3	60
Political power structures	The effect of governments and political figures on scientific process, the structure that shaping the aim and the mission of the science for nations	8	100	7	100	5	100	5	100	5	100
Financial systems	The economic resource that is needed to do science, such as funds, budgets, investments	8	100	7	100	5	100	5	100	5	100

Besides the points that mentioned above, students gave some responses to highlight the concept of social organizations and interactions in science. More than 85% of the students from both majors talked about some scientific organizations, such as universities, and research and development companies. Students thought that these institutions are the places that scientists and researchers make science. These institutions are founded in a hierarchical structure and includes bureaucratic aspects of science.

Political power structures and financial systems are the other most prevalent codes for the responses of the interview questions. All the students from science and non-science majors, and each level of NOS understanding talked about these points to explain their perceptions about social- institutional systems of science.
While doing that, students underlined that strategies of the governments and the political figures of the nations play a significant role in the formation process of science. They also added that strategies of the governments determine the aims of the science and shape the direction of the science for nations. In other words, governmental strategies, such as investing warfare technologies, determining the amount of the financial sources or funds which are given to science departments can be misused or beneficial for the nations.

For the financial systems, students focused on the importance of the money in science doing process. They also emphasized on the terms of budgets, funds, profit focused investments and governmental effects on economic sources. In short, all students aware of the effect of politics and finances on science. They also made a connection between these concepts. For instance, one sophisticated example is provided by the student from psychology department which mentions the effect of political figures in science:

> Scientific process can be directly affected by political powers. For instance, social psychology is a field that can be used by politicians effectively. Milgram experiment came to my mind now. It's about revealing people's perceptions about authorities and it conducted after World War II. The experiment shows that the effect of politicians in wars, people's perceptions and science processes. I mean politicians and governments can use scientific facts to rule and provide an order. They use science and science affected by them. [FAS- NSCI- PSY- M] (Appendix E, 16)

This student gave a specific example about a well-known psychology experiment. As she mentioned in her response, Milgram experiment were conducted to see people's commitment level to authority and correlatively political figures. The student highlighted that the selections and decisions of the high-power figures determine the direction of science and the future of the nations. Another illuminating quotation is provided by the student from the department of computer engineering:

> Of course, these concepts affect science. If the government does not support science, science does not develop. For instance, lets see South Korea. In that country, government directly supports science and provides a fund for science technologies. By their support, Samsung and Hyundai became such a big and important companies. They outperformed Turkey in last 30 years. In that sense, the strategies of the government influence the science. [FEN- CMPE- M] (Appendix E, 17)

As can be seen from the quotation, the student gave a concrete example to explain the effect of political figures and the financial sources in the developmental process of science. Since the government directly supports the development of science in South Korea, they provide an economical source to develop new technologies. Through this example, the student also pointed out the interrelation between the political power structures and financial systems, because if the political figures do not provide a fund or economical source for scientific organisation, scientific progress cannot be achieved.

4.2.5.2 Perceptions of social- institutional systems of science through Text 1 and Text 2

Text 1 and Text 2 related interview questions used to illustrate students' perceptions about social-institutional systems of science in a deeper sense by using the real world related contexts.

Text 1 presents students a real context about the professional activities, and social certification and dissemination process of science. The text directly mentions about a neuroscience conference that scientists come together to share their latest findings about the gut bacteria and autism. Additionally, there is a focus about a peer reviewing process among scientists from Ireland. In that sense, the text potentially provides some key points about the social-institutional systems of science for students.

Additionally, as can be guessed from the title of Text 2, it covers the points about the social-institutional systems of science, such as social organizations and interactions, political power structures, and financial systems. The text mentioned about the mission, future plans and need of money of NASA which is one of the biggest scientific organizations in the world. The governments of Bush and Obama were also mentioned and compared in the text in terms of their political impacts and decisions on science, and their effect on determining the direction of the economical sources for scientific studies in NASA. In that manner, the text was used to provide some ideas for students while they are explaining the concepts of financial systems, political power structures, and scientific organizations in details.

Table 21 shows the codes related to social-institutional systems of science according to students' responses of Text 1 and Text 2 based interview questions. The codes and their explanations were provided in terms of the students' answers.

Response rates for students' majors and their level of NOS understandings were also given.

The table shows that almost half of the science and non-science majors mentioned about the professional activities, and social certification and dissemination process after they read the Text 1. They referred some activities, such as attending neuroscience conference and sharing results with other people, and peer reviewing process among scientists. For instance, a student from computer education and educational technology department stated that:

> This study is about the gut bacteria and their effects on brain. In other words, gut bacteria have an important effect for brain's working mechanism. I think working about this fact is practical and social value of the study. Because, they had an experiment on mice and found some results about their stress levels and the symptoms of autism. So, this study helps people with this disease and increase their life standard. Text also says that scientists are coming together in conference and they are sharing information in here. This is important for the dissemination and communication process. [FED- SCI-CET- H] (Appendix E, 18)

The student mentioned about the social value of the study and professional activities that scientist actualized during the conference.

Besides these points, almost all students from both majors enthusiastically shared their ideas about social organizations and interactions, political power structures and financial systems after they read the Text 2. By pointing out the organization of NASA and hierarchical structures and balances of power in that institution, students expressed their ideas in a better way while talking about the social organizations and interactions of science. The students also talked about the effects of political structures and figures; and the importance of the financial sources to make science. They uttered that the ideology of governments and the decisions of political figures about science are completely change the process. The following statement by sociology student highlighted this perception:

Table 21. The Codes for Students' Perceptions of Social-Institutional Systems of Science Through Text 1and Text 2 (*N=15*)

Code	Explanation of the code	Science N_{sci}: 8		Non-Science $N_{non\text{-}sci}$: 7		High $N_{h:}$ 5		Moderate N_{m}: 5		Low N_{l}: 5	
		#	%	#	%	#	%	#	%	#	%
Professional activities	Activities like attending conferences, publishing articles, peer reviewing process among scientists, sharing findings with society	4	50	3	43	4	80	3	60	0	0
Social certification and dissemination	Presenting findings to public, peer-reviewing processes for scientists and researchers, and attending conferences	5	63	3	43	4	80	3	60	1	20
Social and cultural values and context	The effect of social values on scientific processes; the ethical considerations while doing science	2	25	1	14	2	40	1	20	0	0
Social organizations and interactions	Organizations that are institutions like universities, and research centers, such as NASA; hierarchical structure of the institutions	7	88	5	63	5	100	4	80	3	60
Political power structures	The effect of the ideology of governments and political figures on scientific process, hierarchical power on science, the structure that shaping the aim and the mission of the science for nations	8	100	7	100	5	100	5	100	5	100
Financial systems	The economic resource that is needed to do science, such as funds, budgets, investments	8	100	7	100	5	100	5	100	5	100

> If you have a money you have science, if you have science, you are powerful politically, and if you have a political power, you have a power in economics, too. This is all correlated and connected. In this text, government does not provide a budget for NASA and their trip to Mars. We can also see the importance of the political figures for doing science. When Bush is gone, and Obama came, the strategies about science was completely changed. So, science all depends on politics and economy. [FAS- NSCI- SOC-H] (Appendix E, 19)

As can be seen, the student found a link between the sake of scientific process and politics and economics. According to this student, without the support of the government and money source science cannot be actualized completely. In that sense, there is also connection between politics and finance, too.

In brief, science and non-science majors held perceptions in a good measure about social-institutional systems of science, in comparison to other categories of RFN. Almost all students from science and non-science majors and different understanding levels of NOS expressed their ideas about the concept and talked about to the related trends. One of the main points about the section is that students were really motivated about talking social and institutional systems of science and they gave more detailed and experience-based responses while answering the questions. Response rates also showed that science and non-science majors held similar perceptions about concepts. Hence, there is no strict difference between these groups in terms of their perceptions of social- institutional systems. The responses also illustrated that students found relations between the components of the social-institutional systems. For instance, they underlined that without money and support of the government science cannot be done and all the financial and political sources are connected to each other. The last outstanding point about this section is that the texts became very beneficial for students to explain this category of science. Participants' abstract initial ideas became more neat and sophisticated through the texts. Especially, Text 2 provided students a real case scenario and orientated them to

explain the effects of politics and finance in science in a more nuanced and motivated way.

4.2.6 University students' perceptions on the holistic structure of RFN

In order to determine students' final and assembler perceptions about the five different categories of RFN and the relationship between these categories the questions of "What do you think about the relationship among the five different categories of science?" and "Do you think they are related and effective to explain science concept, and why?" were asked to participants as the last interview questions.

The analysis of the responses showed that all the participants from each major agreed that the categories of RFN are interrelated with each other. They indicated that each category provides an effective perspective to explain the whole concept of science. However, as compared with the science majors, non-science majors explained the relationship among the categories in a more specific way by using analogy-based examples from daily life. For instance, a student from science education stated that:

> We cannot consider these categories separately. They are like the five arms of the tree and they connected to one main point, [as a root]. I am trying to form a concept map in my mind. We can say that they are all connected [and related] to each other. We can also think these [the categories] in a loop or chain. They are connected like a chain, but if one part of the chain breaks off, the all system does not collapse. [FED- SCI- SCED-H] (Appendix E, 20)

As can be seen in the statement, the students use some analogies to show the relationship among the categories of RFN. She associated the categories of RFN to the arms of the tree and the parts of the chain. The student is also mentioned about the importance of the category of the social-institutional systems of science to explain the concept of science in a holistic way.

Additionally, it is observed that while majority of the students who are from high and moderate levels of understanding of NOS held informed view in terms of explaining the relationship among the categories; low level students demonstrated a naive view in terms of expressing their thoughts. The following quotes for the students with high and low-level understanding of NOS are given below:

> They are exactly interrelated to each other. Social aspects of science are related with politics and economy. The methods of science is also related with political power structures of the government. I also think that scientific methods determine the practices of science. There is an exact relation between them. We already found a connection between institutional and social aspects of science. The aims and values of science also determine the scientific methods and social aspects of science. In short, all these categories affect each other [FAS- NSCI- PHIL- H]. (Appendix E, 21)

> I think they are related. For instance, governments provide money to fields that they need. If there is nothing scientific, the science remains in the background and you can not move forward. Because of this, science cannot contribute to society. [FAS- SCI- CHEM- L] (Appendix E, 22)

As it is given in the first quotation, the philosophy student with a high-level understanding of NOS claimed that there is a clear connection between the five categories of RFN. He stated that the social aspects of science relate to the methods that are used in the scientific process and the methods are also shaped the practices and the aim of the study. In that sense, it can be said that when the student talked about the different categories of science, he started to make a connection between the categories automatically. The second quotation also showed that, the chemistry student with a low-level understanding of NOS still found a connection between the categories of RFN. However, her response was limited to some extent in terms of understanding her perception completely, because she only pointed out the relation between social-institutional systems and aims and values of science.

4.3 Summary of the results

University students' understanding of NOS and five different categories of RFN were investigated in terms of their faculties and majors by using the analysis of the quantitative results. The quantitative results indicated that there was no significant difference among students from faculty of arts and sciences, faculty of education and faculty of engineering in terms of their understanding of NOS. In other words, having an education in these three different faculties did not directly affect their understanding of the nature of science. The results also showed that there was no significant difference among students from different faculties in terms of their understanding of aims and values, scientific practices, methods and methodological rules and scientific knowledge. On the other hand, there was a statistically significant difference among the students from different faculties for the category of social-institutional systems of science. Students from the faculty of arts and sciences had a significantly higher understanding of social-institutional systems of science than the faculties of education and engineering.

Additionally, it is found that there was a statistically significant difference between the non-science and science majors with respect to their understanding of NOS. The analysis revealed that students from non-science majors had a higher-level understanding of NOS in comparison to students from science majors. Finally, it can be said that students from non- science majors held a more informed understanding of aims and values, scientific knowledge, methods and methodological rules of science and social-institutional systems of science. Exceptionally, there was no significant difference between the majors in terms of their understanding of scientific practices. Overall, the students from non-science majors differ significantly from

science majors. They dominantly have a better understanding of NOS in terms of their "NOS Questionnaire" scores.

University students' perceptions of the holistic structure of NOS and five different categories of RFN also determined with respect to their majors and levels of NOS understandings. The qualitative results for the category of aims and values indicated that students from both science and non-science majors considered the aims of science as serving to humanity, making contributions to society and understanding the universe. Besides those common points, science majors more likely held the practical and application-based aims of science than non-science majors. However, non-science majors focused more on searching for truth to understand the essence of any phenomenon as an epistemological aim of science. University students' answers to the interview questions showed that both science and non-science majors gave an importance the concepts of constructing hypothesis, testing and observation while explaining the scientific practices. The results also showed that students tend to refer their majors while talking about the types of experiments and research steps that they used in their disciplines and courses. Additionally, students from science majors, especially from science education major reflected better perception of scientific practices than non-science majors.

For the category of the methods and methodological rules, the majority of science and non-science majors held a view that constructing hypothesis, testing and research methods are the different kind of scientific methods. However, while majority of non-science majors see the observation as one of the scientific methods, only a small portion of the science majors held that view. When the response rates, students' detailed explanations and quotations are bared in mind, non-science majors held more informed perceptions about different kind of scientific methods. The

results also showed that students tend to explain scientific methods by using examples from their majors.

Science and non-science majors expressed their ideas about the characteristics and tentativeness of the scientific knowledge, and the different forms of scientific knowledge. However, non-science majors held more informed views about those points than science majors. They additionally considered the concept of objectivity as one of the characteristics of the scientific knowledge, context-based nature of scientific knowledge, and paradigm shift concept. On the other hand, science majors' perceptions about the different forms of scientific knowledge were outstanding. They explained the different forms of scientific knowledge with the concepts of hypothesis, theory and law. Nevertheless, when the response rates for RFN and text-based questions were taken into consideration, non-science majors represented a broader perception of scientific knowledge.

As a last RFN category, university students' responses about social-institutional systems of science showed that almost all students from both majors were really motivated about talking social and institutional systems of science. They gave a detailed and experience-based responses while answering the questions. Therefore, there was no strict difference between these majors in terms of their perceptions of social-institutional systems. The results also illustrated that students found a relation between the components of the social-institutional systems. For instance, they underlined that without money and support of the government, science cannot be done. Therefore, all the financial and political sources are connected to each other.

Overall, most of the university students claimed that there is a clear connection between the five categories of RFN. Additionally, when students had

opportunity to express their own ideas through the open-ended questions, perceptional differences between students with high, moderate and low-level NOS understanding became apparent. Students with high and moderate level understanding of NOS highlighted any concept in a more nuanced and sophisticated way. Students with low level understanding of NOS tend to give more superficial examples and responses about the categories of science. Moreover, Text 1 and Text 2 provided a supplementary source to participants in terms of making each category of RFN more concrete. Through the texts, students expressed their ideas through real life related studies and cases in an easier way. However, students' responses and perceptions did not strictly change after they read the texts, instead texts became very beneficial for students to explain their ideas in a more descriptive way. In other words, participants' abstract initial ideas became more neat and sophisticated through the texts. Especially Text 2 provided students a real case scenario and orientated them to explain the effects of politics and finance on science in a more nuanced way.

CHAPTER 5

DISCUSSION

This chapter includes the summary of the study, discussion of the quantitative and qualitative results, implications for the teaching and learning of NOS in a higher education level, limitations of the study, and recommendations for the further studies. Thus, the purpose, rationale, theoretical background and methodology of the study are provided in the summary section as a reminder. Additionally, the possible reasons behind the quantitative and qualitative results is tried to be explain within the consideration of previous studies and the context of the higher education in Turkey with respect to the directions of "The Council of Higher Education" (YÖK). As a final step, presenting some ideas and strategies in relation to the question of how university students' understanding and perceptions of the nature of science can be developed for the higher education level is discussed.

5.1 Summary of the study

Nature of Science (NOS) is one of the essential research topics that is discussed in science education context. The framework of this study is formed by Erduran and Dagher's (2014) notion of NOS from a "Family Resemblance Approach" (FRA). Kaya and Erduran (2016b) renamed the term of "Reconceptualized Family Resemblance Approach to Nature of Science" or RFN to show the capability of the transformation of FRA in science education field. RFN framework represents all cognitive, epistemic and social institutional categories of science. The study illustrates that how different NOS categories can be understood and perceived by university students from different faculties and majors. The study aims to (a)

investigate undergraduate university students', who are from faculty of education, arts and sciences and engineering, understandings of NOS within the scope RFN framework (b) determine the differences in students' understanding of 5 different RFN categories by considering their majors and faculties, (c) present students' understandings of NOS through questionnaire and in depth individual interviews (d) and suggest effective curricular strategies to improve university students' understanding of NOS. While a total of 637 third and senior year undergraduate university students from 3 different faculties and 12 different majors participated to quantitative part of the study; 15 people out of 637 participated to the qualitative part. A 70-item "NOS Questionnaire" which reflects five different categories of RFN and semi-structured interview questions which are supported by two science related texts were used as the data sources of the study. The quantitative data were analyzed in terms of descriptive and inferential statistics through SPSS. Coding and categorization techniques are also utilized to analyze the qualitative data. Quantitative data analysis results indicate that there is a statistically significant difference between university students' understanding of NOS in terms of their majors which are science and non-science. Qualitative data analysis also shows that while the university students from non-science majors have a broader and comprehensive perception of epistemic, cognitive and social-institutional categories of NOS; science majors have a lower level and superficial perception of different categories of NOS. Overall, the study has implications for research on NOS studies in higher level science education. The study also has some contributions to understand how NOS can be perceived by university students and how these students' perceptions can be connected to their educational background and majors.

The following section reflects the potential reasons behind the quantitative and qualitative results. Each result for each research question is discussed in details. While doing that previous studies in terms of university students' understanding of NOS and the curricular context of the universities in Turkey with respect to "The Council of Higher Education" (YÖK) were considered.

5.2 Discussion of the results

The quantitative analysis of the results indicated that university students' understanding of the nature of science do not change in terms of having an education in different faculties. In other words, students from the faculty of arts and sciences, education, and engineering held similar extent of understanding of NOS. However, it is observed that students from faculty of arts and sciences have a better understanding of NOS within the consideration of the mean score of the faculty. Additionally, studying in different faculties do not lead a difference in students' understanding of aims and values, scientific practices, methods and methodological rules and scientific knowledge. However, students' understanding of the social-institutional systems of science differed with respect to their faculties. Similarly, students from arts and sciences faculty held more informed understanding of social-institutional systems of science compared to other faculties. In other words, while students' understanding of cognitive and epistemic systems of science do not change in terms of their faculty background, their understanding of social-institutional systems of science affected by the education that they had in their faculties. These results showed that university students' understanding of NOS and most of the NOS categories do not strongly depend on their faculties.

The possible reasons of these faculty based quantitative outcomes can be explained by the faculties' course structures and the contents of their courses. As it is declared by "The Council of Higher Education (YÖK)" and the university's specialized curriculum, it is observed that each faculty provides their students an opportunity of learning about natural and social sciences. By offering programs and courses in terms of chemistry, biology, physics, psychology, pedagogy, and sociology, each student has a chance to learn more about the variety of scientific knowledge, methods, philosophy, and science-based applications (YÖK, 2014). In that sense, since each faculty offers several must and elective courses in a similar amount and content for each student, it can be meaningful to not to see a faculty-based differences in students' understanding of NOS. However, when it is looked in a deeper way, the course structure of the faculty of arts and sciences is differed from faculty of education and engineering, because the must courses in the faculty of arts and sciences are offered to education and engineering students as electives ("Faculty of Arts and Sciences", 2018). Since education and engineering students do not have to choose "Humanities and Social Sciences" (HSS) related elective courses, their exposure rates to humanity related courses become low, in comparison to students from arts and science. As it is stated in the faculty of arts and sciences academic programs and course schedules, the students from this faculty having an opportunity to learn more about fundamental laws and theories of the nature, the concept of humanities, political sciences, economy, history, philosophy, and psychology in a deeper sense. Therefore, the result that students from arts and sciences faculty held a more informed understanding of social-institutional systems of science compared to other faculties became more meaningful and logical. This is because, the category of social-institutional systems of science composed of social, cultural, ethical, political

and financial aspects of NOS, and these students have courses that directly reflect these aspects of science.

Besides the faculty based quantitative results, there are another notable outcome with respect to science and non-science majors' understanding of the nature of science and five different categories of NOS. It is found that, science and non-science majors held different levels of understanding of NOS. The analysis revealed that students from non-science majors have a higher-level perception of NOS. Additionally, non-science majors held a more informed perception of aims and values, methods and methodological rules, scientific knowledge and social-institutional systems of science. As can be seen that, non-science majors dominantly held a broader understanding of NOS and most of the categories of NOS. In this picture, non-science majors did not differ from science-majors only for the category of scientific practices. The possible reason of this situation could be that some science majors, such as science education major has an undergraduate course about scientific practices in their 3rd year. Most of the students from this major were aware of the concept of scientific practices since they learned them in this pedagogical course. The course covers the components of Benzene Ring Heuristic and scientific practices (Erduran & Dagher, 2014).

The potential reasons behind these majors based quantitative results also can be explained by the majors' course structures and the contents of their courses. As it is stated in the directions of "The Council of Higher Education (YÖK)" and the university's specialized curriculum for science and non-science majors, non-science majors provide their students a variety of must and elective courses in terms of history, psychology, humanities, language, philosophy, and research and academic orientation related courses for social sciences. Additionally, these majors have a

variety of courses which cover the humanities and social sciences, such as “Research Methods in Applied Linguistics”, “Social and Political Anthropology”, “Politics, Religion and Social Change", “Sociology of Gender”, “Philosophy of Science”, “Scientific Reasoning”, “Applied Ethics”, and ‘Epistemology’ (“Faculty of Arts and Sciences”, 2018). These courses potentially offer students a perspective about the variety of scientific methods, functions and meanings of economic, political and social activities in society, the forms of power, control and authority in different social and cultural settings, and the concepts of gender and social structure in terms of the position of woman in society. These students also have an opportunity to think and discuss about the goals of science, scientific explanation, the use of models, contemporary ethical issues, such as abortion, euthanasia, animal rights, and moral justification of war, and they can examine some philosophical problems through the concept of knowledge with respect to the origins, limits and validity of the knowledge. As can be seen that, all these courses that are given in these non-science majors possibly provide students a better perspective to understand the nature of scientific knowledge and scientific methods, social and cultural values of science, existence of social organizations, and political and economical aspects of science. In that sense, the outcome that non-science majors held a more informed understanding of aims and values, methods and methodological rules, scientific knowledge, and social-institutional systems of science can be justified through their higher level educational background.

Since there was no difference among university students’ understanding of NOS in terms of their faculties, the difference in students’ perceptions of NOS and NOS categories were analyzed and compared in terms of students’ majors to construct the qualitative results of the study.

When qualitative results for non-science and science majors' perceptions of aims and values, scientific knowledge, scientific practices, methods and methodological rules, social-institutional systems and holistic structure of NOS were examined, some major points were stood out. For the category of aims and values, non-science majors seemed more aware of the epistemic and cognitive aims of science. These students focused on the concepts of searching and explaining a phenomenon as a main aim of science. In contrast, science majors, especially majors of engineering, dominantly pointed out the practical and applicational aims and values of science. These students just made an emphasis about the technological developments, such as inventing new technologies and devices, and applicational aims of science. Therefore, it can be said that non-science majors made more nuanced comments and illustrated better perceptions about cognitive, epistemic and social aims and values of science.

For the scientific practices, the results showed that both science and non-science majors cannot discriminate the concepts of scientific practices and scientific methods. Especially non-science majors used the terms of constructing hypothesis, testing and observation while explaining the scientific practices. However, science majors, especially science education department reflected better perception of scientific practices than non-science majors. Although some of them considered scientific methods as scientific practices, they considered the terms of modelling, prediction, real world, and discussion while talking about scientific practices. The possible reason of these participants' more developed and nuanced ideas about scientific practices are that they had a pedagogical course in their undergraduate degrees which focuses on the components of scientific practices and Benzene Ring Heuristics. Therefore, science majors' perceptions about scientific practices were

more clear and informed than non-science majors. The courses that they enrolled completely and positively affected their perceptions about scientific practices. Pomeroy's (1992) empirical study was also in line with this outcome. In the study, the differences among elementary and secondary science teachers', and scientists' beliefs of the nature of science were considered. The results showed that elementary and secondary science teachers had a better understanding of the processes of science, because of the teachers' own construction of knowledge and reflections about NOS.

The results for methods and methodological rules showed that students from both majors tended to explain scientific methods with the ordered and stereotypical steps as they learnt during their secondary school education. They mentioned about determining a problem or asking a question about nature, constructing a hypothesis, collecting data and reaching some conclusions. This sequence illustrated that students had an awareness about the working mechanism of the scientific study, but they also prone to explain scientific methods with the stereotypic depiction which is explained by Erduran and Dagher (2014). However, non-science majors were prevalently highlighted the concept of observation as one of the scientific methods different from science majors. Therefore, they distinguished in terms of making sense of using different types of scientific methods while doing science. Similarly, Parker et al. (2008) explored that science majors have a perception that science as an empirical process, depending on testing and experimentation, processing, reaching facts and finding relationship between theories and laws. Miller et al. (2010) investigated that students from both science and non-science majors relatively informed about scientific theories and observations. However, they have naïve views

about the differences between scientific theories and laws, and the existence of diverse scientific methods.

Non-science majors held more informed perception in terms of explaining the characteristics and tentative nature of the scientific knowledge than science majors. This is because, they pointed out the terms of objectivity of scientific knowledge, social and cultural context based on the nature of scientific knowledge and paradigm shift concept to explain the tentative nature of the scientific knowledge. On the other hand, the only outstanding point for science majors' perceptions about scientific knowledge was their consideration of different forms of the scientific knowledge. They highlighted the terms of hypothesis, theory and law. The potential explanation of these outcomes may be related to the courses that non-science majors enrolled, such as "Philosophy of Science", "Scientific Reasoning" and 'Epistemology'. In these courses, students can examine the aims of science, scientific explanation, theory construction, the use of models, and confirmation of the hypotheses within the context of examples from philosophy and history of science (YÖK, 1998; YÖK, 2014). Griffiths and Barry's (1993) study also supported these results. They investigated university students' views on NOS. The authors found that university students perceive science as an improving mechanism by answering new questions and using the hierarchical relationship among facts, theories, and laws. Additionally, variety of previous studies were in line with science and non-science majors' expressions about tentative nature of the scientific knowledge and non-science majors' approaches towards the different forms of scientific knowledge. For instance, Kimball (1967) claimed that undergraduate students understand the nature of scientific knowledge through the concepts of subjectivity and tentativeness. Welch and Walberg (1972) declared that students' understanding of tentative nature of

scientific knowledge is important to explain their understanding of NOS. Liu and Tsai's (2008) study also suggested that non-science majors' perceptions were more sophisticated in comparison to science majors in terms of considering the nature of scientific knowledge, and social and cultural values of science. Overall, the results of this study and the literature showed that non-science majors held more broader perceptions in terms of explaining the nature of scientific knowledge.

For the last category of RFN, science and non-science majors held a good extent of perception while explaining the social-institutional systems of science, in comparison to the other categories of RFN. Almost all students from science and non-science majors and students with different understanding levels of NOS expressed their ideas confidently for this category. University students were really motivated about talking social and institutional systems of science. Nevertheless, non-science majors gave more specific and nuanced responses while answering the questions. The possible reasons of that these students have a bunch of humanities and research methods related courses (YÖK). Through these courses they learned about the concepts of political and social activities in society, economies of pre-capitalist and pre-modern societies, control and authority mechanisms in different social and cultural settings, the nature of religious belief, social and political dynamics of the society, and ethical issues, such as abortion, euthanasia, affirmative action, the ethics of charity, animal rights ("Faculty of Arts and Sciences", 2018). For instance, a psychology student gave a specific example about a well-known psychology experiment which is Milgram. Through this experiment, she evaluated the people's commitments to the authority and correlatively political figures and gave sophisticated responses about the components of the social-institutional systems of science, such as political power structures, financial systems and social

organizations. On the contrary to this result, Leung, Wong and Yung's (2016) study suggested some inconsistent findings. According to the study, science majors prone to focus more on cognitive aspects of science rather than social aspects of science. They generally focused on empirical and theoretical structure of the science while explaining the NOS. Although, science majors clearly expressed the cognitive aspects of science, they elaborated the social aspects of science in a less detailed way for this study.

For the holistic structure of the RFN and science concept, all the participants from different majors agreed that the categories of RFN are interrelated to each other. They indicated that each category provides an effective perspective to explain the whole concept of science. However, non-science majors advocated the relationship among the categories of RFN through more specific and analogy-based examples from daily life.

The qualitative analysis results were consistent with the quantitative analysis results in terms of two specific points. Firstly, non-science majors illustrated better perception of aims and values, scientific knowledge, methods and methodological rules, and social-institutional systems of science through their responses during the interview. The second point is about the students' level of NOS understanding which were determined as high, moderate and low in terms of their "NOS Questionnaire" scores. The qualitative analysis results showed that students with high level understanding of NOS have a broader perception about the categories of NOS. Similarly, students with low level understanding of NOS performed naïve perceptions about NOS and its categories. This coherency is important and valuable in terms of reflecting the selected interviewees' perceptions of NOS as expected from their questionnaire scores.

In brief, the quantitative and qualitative analysis results of the study indicated that non-science majors have more informed perception with respect to science majors' descriptions of NOS. Non-science majors' expressions about the cognitive and epistemic aims of science, the relationship between the social and cultural values and scientific knowledge, the existence of a different kind of scientific methods, and imagination and creativity in science showed that these students held a better understanding of NOS. However, they have a naive perception while expressing the distinction between theories and laws, different forms of scientific knowledge, and components of the scientific practices. This means that non-science majors have neither completely informed perceptions nor completely naive perceptions about NOS in terms of RFN framework and contemporary science understanding (AAAS, 1993; Erduran & Dagher, 2014). In addition, the findings about the science majors' limited perceptions and expressions about NOS are in line with the previous studies (BouJaoude, 1996; Wong & Hodson, 2009). It is also important that students mostly referred to their majors and courses when they were explaining their background knowledge about the categories of NOS. Additionally, when students had an opportunity to express their own ideas about questions, cognitive differences between high, moderate, and low levels students became apparent. Students with high and moderate level understanding of NOS highlighted any concept in a more sophisticated way. Students with low level understanding of NOS tend to give more superficial responses about the categories. Text 1 and Text 2 provided a supplementary source for participants to explain each category of RFN. In other words, participants' abstract initial ideas became neater through the texts.

All in all, the study has some major contributions in terms of providing further thought for the questions of why university students need to learn the concept

of NOS and how university students' NOS understanding can be measured in terms of RFN framework and in relation to different majors and faculties of the university. In particular, the study provides important insights to show the link between university students' understanding of NOS and their majors in terms of the course contents of the majors and discipline base differences of the majors. As a last point, the study provides some pedagogical insights about the usage of RFN in the higher-level science education settings. In other words, this study tries to provide an empirical evidence of how RFN framework can be perceived by university students and why and how the framework can be transformed to science education settings.

5.3 Implications of the results

The results of the study revealed that majority of the university students can express epistemic, cognitive and social-institutional aspects of the nature of science to some extent. They interpreted the categories, provided some explanations, and gave specific examples from the real life. Most of the science majors have a deficiency in terms of explaining epistemic, cognitive, social, cultural, and philosophical aspects of the nature of science in comparison to non-science majors. Similarly, non-science majors mostly had a difficulty while clarifying the practices of science, different kind of scientific methods and different forms of the scientific knowledge. These results can be linked to students' course backgrounds in their higher-level education. Therefore, a special training is necessary both for science and non-science university students to articulate and integrate epistemic, cognitive and social-institutional categories of science. Providing a course program which covers courses in relation to the nature of science, sociology and philosophy of science, and epistemology and methods of science can be beneficial especially for science majors. Besides those

courses, adding some must courses which include mostly epistemic and cognitive aspects of science can be added in the programs of higher education. In other words, introducing students with the nature of science related courses and activities can help university students to grasp the different aspects of NOS. Since most of the students attributed the characteristics of science in terms of their majors and professions and explained the rationale of science and scientific processes with respect to their background knowledge, it can be efficient to add RFN based course into higher level education curriculum to enhance students' understanding of NOS and provide them a NOS based prior knowledge. Therefore, it can be inferred that the different categories of NOS should be integrated in today's K-12 science teaching and higher-level education efforts. An alternative curriculum should be focused on not only specific aspects of science, but also the five different categories of science. Providing this opportunity to students is important in order to increase students' understanding and awareness about NOS.

5.4 Limitations of the study

There are some limitations for this study to be considered in future studies. Firstly, although the participating university students were from variety of faculties and majors, the study was conducted in only one university. Conducting this study in alternative public and private universities could lead to completely different results.

The second limitation concerns the majors of the university students in the sample. The students from science and non-science majors (five from non-science and seven from science majors) participated into the study. Alternative university students such as from different university and culture, and from many other majors in science (e.g., electronical engineering, molecular biology and genetics, mathematics

education etc.) and non-science (e.g., history, translation and interpreting studies etc.) might influence the results of this study. Although the outcomes of the study provide a general overview on NOS understanding and perceptions of varied university students, it cannot be claimed that these results are valid for all science and non-science majors. Hence, there can be a possible generalizability issue for the findings. Additionally, expansion of the interview questions and using different kind of texts with a different content can also lead to some differences in students' responses and affect the findings of the study.

The final limitation could be related to the lenses of the researcher. In other words, another researcher who are from arts and sciences or engineering majors might investigate the same problem or analyze the similar set of data by conducting different research methods and techniques. In that sense, being a science educator and outsider to the arts and sciences and engineering faculties may lead to researcher bias too because I do not have a certain lens of the majors of arts and sciences and engineering (e.g., industrial or computer engineering, psychology, sociology etc.), and that may cause biases during the research process.

5.5 Recommendations

This study was a valuable experience in itself because it provided an opportunity to hear university students' perceptions and understandings on what science and non-science majors should know about science, and what we can do to help them learn more about it.

In that sense, based on the findings of this study, the following recommendations in terms of teaching the different categories of science in higher

education level, university students' learning of NOS, possible curriculum applications, and further research are discussed below.

Accordingly, the departments, their course programs and instructors play a significant role for science and non-science majors' understanding and perceptions of NOS (Miller et al., 2010). In that sense, it is important for faculties and departments to refine NOS related course objectives, develop some course content and provide efficient methodology to serve more effective NOS understanding for university students. Most importantly, some studies clearly demonstrated that engaging students in the science learning process and teaching the content of science alone does not affect students' deep understanding of the nature of science. University instructors also need to address the NOS concepts in a meaningful context explicitly, and students need to be reflect their own perceptions of NOS (Beck-Winchatz & Parra, 2013; Deng, Chen, Tsai, & Chai, 2011). In this respect, using RFN framework in university courses and incorporation of the visual representations of RFN categories can be recommended to support university students' learning of NOS (Kaya, Erduran, Akgun & Aksoz, 2017; Kaya & Erduran, 2016b). Therefore, the study and RFN framework can provide some methodological approaches and analytical teaching, and learning tools for instructors to provide students a better understanding of NOS.

Besides adding RFN framework in higher level university education settings, it is also important to use RFN framework in secondary and primary school education contexts. The literature supported the case that university students generally held similar nature of science views with high school students and most of the participants held naïve understanding about NOS. In the case of Abd-el Khalick's (2006) study, undergraduate students understanding of NOS examined through their

performances in history of science course and the participants from different majors reflected similar understanding with high school students. Norris and Phillip's (1994) study showed that university students performed nearly the same as high school students in terms of explaining the nature of scientific phenomena. Hence, the previous studies supported that university students' background about NOS perception correlated with the quality of their primary and secondary school education years in terms of expressing informed ideas about NOS. Therefore, using RFN framework and visuals of the categories as a pedagogical tool for science curriculum can be effective to increase high school and correlatively university students' understanding of NOS. Additionally, as it is reported in Kaya and Erduran's (2016b) curriculum study, Turkish curriculum documents (MEB 2013, MEB 2006) emphasized some categories of RFN in science curriculum. Although there is an emphasis about some cognitive-epistemic categories such as scientific knowledge, aims and values and scientific practices, the inclusion of the social-institutional contexts were limited in the both documents. Since, university students' understanding of NOS also shaped by their primary and secondary school years in relation to the content of the primary and secondary level Turkish curriculums, it can be recommended that using RFN framework for the revision of the curriculums of primary and secondary school education can make the NOS instruction more holistic, comprehensive and nuanced (Kaya & Erduran, 2016b). In other words, the framework and the visuals of each categories can be served as a conceptual tool for curriculum development for secondary and higher-level education.

For the future research, the study can be conducted to another public and private universities. Increasing the sample size and diversifying the science and non-science majors can be beneficial to get more representative results and generic

further studies. Using different kind of texts for interview process and conducting workshops or interventions to students from different majors could provide different points of views and perspectives for the further studies.

APPENDIX A

NATURE OF SCIENCE QUESTIONNAIRE

Department: **Faculty:**

Grade Level: **Age:**

Gender: **E-mail address:**

Directions: In this questionnaire, there are 70 statements about the nature of science. Please read the following statements and then select the alternative that best describes your position on the statement. The alternatives are ‘‘Totally Disagree’’, ‘Disagree’, ‘‘Neither Agree nor Disagree’’, ‘Agree’ and ‘‘Totally Agree’’.

	Totally Disagree	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Totally Agree**
1. Science lessons should include financial (economical) aspects of science.					
2. Epistemic, cognitive and cultural values of science cannot be distinctly distinguished from each other.					
3. Scientific knowledge does not change.					
4. Scientists review and assess each other's work.					
5. The power of experimentation comes from testing a scientific hypothesis many times by scientists.					
6. Concept maps can be an effective way of teaching classification as scientific practice.					
7. Science takes place in institutions such as universities and research centers.					
8. All scientific disciplines such as physics, biology and chemistry use the same scientific method.					
9. Science is a social system.					
10. Scientific progress occurs when ideas are evaluated and revised.					
11. Each branch of science has a different nature.					

	Totally Disagree	Disagree	Neither Agree nor Disagree	Agree	Totally Agree
12. Students should determine their methodology themselves.					
13. Politics do not influence science.					
14. Scientists should respect the environment.					
15. Analysis and interpretation of data are components of scientific practices.					
16. Theories and laws are forms of scientific knowledge but models are not.					
17. Teaching scientific aims and values in science classes increases students' cognitive ability levels.					
18. Scientists don't have to share their research with society.					
19. Scientists build and use models to understand complex scientific ideas.					
20. The diversity of scientists solving a problem means less biased results.					
21. Students should understand that theories are a collection of models.					
22. There is no step by step order to doing science.					
23. All branches of science use observations.					
24. Diversity of methods increases scientific understanding.					
25. All hypothesis testing is manipulative.					
26. Some branches of science do not use representations.					
27. Educating students about scientific aims and values improves scientific literacy.					
28. Scientists have to use different methods to produce enough evidence that can solve problems.					

	Totally Disagree	Disagree	Neither Agree nor Disagree	Agree	Totally Agree
29. Students should be encouraged to collaborate with their peers in science lessons because scientists collaborate with other scientists when doing research.					
30. Scientific knowledge consists of a coherent set of ideas.					
31. The curriculum should stress that theories in chemistry and physics are the same.					
32. Scientists need money to do research.					
33. Classification helps scientists explain and predict phenomena.					
34. All scientific disciplines such as physics, biology and chemistry generate values that can contribute to society.					
35. It does not make a difference to students' learning of science when they participate in discussions about experimental data.					
36. The gender of scientists influences how they do science.					
37. There is a universal scientific method that all scientists use all over the world.					
38. Scientific experiments follow a certain set of procedures.					
39. Intellectual honesty in science does not have to be taught in lessons.					
40. Scientists should change their minds when they realize that their ideas are not supported by evidence.					
41. Policies of governments affect the growth of scientific knowledge.					
42. Students should sometimes have the choice to design methods for their investigations.					

	Totally Disagree	Disagree	Neither Agree nor Disagree	Agree	Totally Agree
43. Laws are theories that are confirmed.					
44. Scientific models are tools to represent the real world.					
45. Some scientists earn more money than others, causing tension between scientists.					
46. Scientific facts are not affected by bias and individual subjective prejudice of scientists.					
47. Teaching science should specify that laws are certain and unchangeable.					
48. Race and ethnicity of scientists have nothing to do with science.					
49. Changing variables is a fundamental requirement for a scientific study.					
50. Theories, laws and models work together to produce scientific knowledge.					
51. Teaching epistemic, cognitive, social and cultural values should be the core components of the science curriculum.					
52. Different branches of science like physics, biology and chemistry have the same practices.					
53. Scientists write papers in academic journals.					
54. There are different kinds of theories. Some are accepted, others are still debated.					
55. Science curriculum should not only cover scientific knowledge, but also the social, cultural and epistemic aspects of science.					
56. There is no relationship between scientific facts and values.					
57. Scientists from all branches of science validate scientific knowledge by evaluating each others' ideas.					
58. Scientists participate in conferences to share their research with other scientists.					

	Totally Disagree	Disagree	Neither Agree nor Disagree	Agree	Totally Agree
59. Understanding scientific methodology can help students distinguish between science and non-science.					
60. All scientific disciplines such as physics, biology and chemistry require constructing hypotheses.					
61. There are standards for evaluating the quality of scientific work.					
62. Internalizing scientific aims and values enables students to gain and understand scientific knowledge and issues.					
63. Models can help scientists to explain and predict phenomena.					
64. Scientific practices produce knowledge and are not influenced by cultural factors.					
65. Students should understand that scientists have social values such as honesty.					
66. Laws are more verifiable scientific knowledge than theories.					
67. There are hierarchies among science teams and these can change.					
68. It's not necessary for students to understand how knowledge develops in science.					
69. Scientific aims and values affect scientists' choice of methods.					
70. Scientists socially interact with other scientists while doing research.					

APPENDIX B

INTERVIEW QUESTIONS

1. What comes to your mind when I say aims and values of science? Can you give any examples?
2. What comes to your mind when I say scientific practices? Can you give any examples?
3. What comes to your mind when I say scientific methods? Can you give any examples?
    - What do you think about the methods of science? Are there different kinds of scientific methods or not? Please explain.
4. What comes to your mind when I say scientific knowledge? Can you give any examples?
    - What do you think about the characteristics of the scientific knowledge?
    - What are the forms of scientific knowledge? Please explain.
    - Do you think that scientific knowledge changes? Why?
5. What comes to your mind when I say social and institutional aspects of science? Can you give any examples?
    - What do you think about the professional activities that are actualized in scientific process?
    - What do you think about the role of social and cultural values on science?
    - What do you think about the social certification and dissemination processes? In other words, how scientists spread their works to public and how other scientists and society react to these processes?

- What do you think about the relationship between science and financial systems?
- What do you think about the relationship between science and political power structures?

6. Please read the Text 1. When you read to the text:
    - Which key terms and concepts were raised in your mind in terms of the aims and values of science? Please explain.
    - Which key terms and concepts were raised in your mind in terms of the scientific practices of science? Please explain.
    - Which key terms and concepts were raised in your mind in terms of the methods and methodological rules of science? Please explain.
    - Which key terms and concepts were raised in your mind in terms of scientific knowledge? Please explain.
    - Which key terms and concepts were raised in your mind in terms of the social-institutional systems of science? Please explain.
7. Please read the Text 2. When you read to the text, which key terms and concepts were raised in your mind in terms of the social-institutional categories of science? Please explain.
8. Overall, when you consider the discussion we made and texts you read, what do you think about the relationship between these five categories of science in each other?
9. What do you think about these five categories of science in relation to explain the whole concept of science?

APPENDIX C

TEXT 1

Scientists Find Link between Gut Bacteria and How the Brain Works



A week from today, researchers will gather for a neuroscience conference in Washington D.C. titled "Gut Microbes and the Brain: Paradigm Shift in Neuroscience." As the name suggests, new evidence will present by the scientific community to help establish an emerging link between the health of your gut and the health of your brain.

One team of researchers from University College Cork in Ireland will argue that the microbiome--the name for the billions of bacteria swimming in your large intestine--has the greatest effect on the brain in infancy. In experiments, the researchers found that mice born through their mother's vagina, as opposed to by cesarean section, exhibited less depression and less anxiety. They believe this is because vaginal birth is the first exposure an infant has to bacteria.

Another study conducted in 2013 found that mice with lower levels of the gut bacterium called Bacteroides fragilis showed a tendency toward autism. The

researchers observed that mice were also more stressed, antisocial and had gastrointestinal symptoms associated with autism. When scientists fed B. fragilis to the mice, their symptoms disappeared.

"That observation raises the possibility that some people with autism could be supported with therapies, such as probiotics, that target the gut instead of the brain, which is a much more complex and inaccessible organ."

Image credit: Shutterstock

Jones, 0. (2014). Scientists find link between gut bacteria and how the brain works. Retrieved from http://bigthink.com/ideafeed/scientists-find-link-between-gut-bacteria-and-how-the-brain-works/

APPENDIX D

TEXT 2

Dear Congress: We Need Money. Love, NASA.



Hope was in the air at NASA last month, when, in addition to celebrating the 40th anniversary of landing the first man on the moon, the agency also got a new boss: former astronaut Maj. Gen. Charles Bolden. At his confirmation hearing before a Senate committee, Bolden embraced a bold plan to go beyond Earth orbit and maybe as far as Mars. But even then, the cloud of reduced funding hung over NASA.

The cloud darkened last week. The committee leading the Review of U.S. Human Space Flight Plans, charged by President Obama to review the options for where human exploration could and should go, said there just isn't enough money to send astronauts back to the moon or on to Mars by President Bush's target date of 2020, and probably not in any time soon thereafter.

Despite nominating a four-time shuttle pilot in Bolden to lead NASA, Obama never seemed sure about continuing his predecessor's ambitious human space

exploration plans, and the White House had trimmed NASA's share of the federal budget. In a recession full of bank bailouts and car company takeovers, it appears, there's just too little money to fly to Mars. Instead, the panel recommended sending people to less ambitious targets—a near-Earth asteroid, or the LaGrange points where the Earth's and the sun's gravitational fields cancel each other out.

Space flight isn't the only area where NASA has been charged with an ambitious goal and given too little money to achieve it. Another report, this one by the National Academy of Sciences, recently found that the agency also lacked the funds to complete its near-Earth object project. Congress asked NASA to locate 90 percent of the NEOs bigger than 140 meters in diameter by 2020, but according to the report, we won't get there.

That's not to say the government has totally shafted science; Fermilab and others got millions through the federal stimulus package for their research. But the kind of inspiring, ambitious projects that catapulted NASA to prominence in its heyday of the 1960s require a sustained, large investment. Without it, they'll always be another 5, or 10, or 20 years away.

Image Credit: NASA Earth Observatory image by Joshua Stevens

Moseman, A. (2015). Dear Congress: We Need Money. Love, NASA. Retrieved from http://bigthink.com/articles/dear-congress-we-need-money-love-nasa/

APPENDIX E

INTERVIEW QUOTES (TURKISH)

1) Bence bilimsel pratikler bilimde yapılan uygulamalar olarak düşünülebilir. Mesela deney ve gözlem yapmak gibi. Bunlar bilimin teorik yönleri değil pratik yani uygulamalı yönleri bence.
2) Bilimin amaç ve değerleri en basit aklıma gelen anlamıyla olan bir fenomeni daha iyi açıklamak ve bunun temellerini gösterme olabilir. Bence illa pragmatist bir yaklaşım olmak zorunda değil. Benim çalıştığım alandan kaynaklanıyor olabilir bu bakış açım. Yani bilimde amaç olarak dediğim gibi bir fenomeni açıklama olabilir. Mesela görsel anlamda bir imaj nasıl ayrılıyor retinadan itibaren. Mesela şu baktığımız su şişesinin rengi, biçimi bunlar nasıl ayrı ayrı işlenip bize nasıl ayrı bir bütün olarak dönüyor. Böyle baktığımızda burada direk pragmatist bir amaç göremiyoruz. Burada bir şeyi açıklamaya yönelik bir şey var.
3) Bence bilimin en önemli şeyi yanlışlanabilir olması. Bilimin hiçbir zaman kesin konuşmaması… Bilimi dinden ayıran en önemli şey benim gözümde bu yani. Bilimin her türlü görüşe saygı duyması ve aynı zamanda dogmatik olmaması… Yani bilimi her zaman insanların eleştirebilmesi…
4) Bu metinde insanlığa hizmet etmek ve iyiye götürmek amacını görüyorum. Araştırmacılar otizm üzerine çalışmışlar ve otizmlileri iyileştirmeye yönelik bir şey bulmuşlar. İnsanlık için değerli bir şey bence. Yani farelerle çalışılmış burası biraz şüpheli ama insanlara yardımcı olmak için sonuçlar elde etmişler. Bence burada otizmli insanlara yardım edilmesi ve bilimin iyi yönde kullanması harika bir şey.

5) Bilimsel pratik dediğimizde, en basitinden deneme yanılma ve deney yapma geliyor mesela bilimsel pratik olarak. Sonuçta bir hipotez kuruyoruz ve bunu deniyoruz, bir sonuç elde ediyoruz. Bazen sonuçlar beklediğimiz gibi geliyor, bazen de gelmiyor. Bundan sonra tekrar başka bir metot deneyip sonuca ulaşmaya çalışıyoruz.
6) Gözlem yapılması gerektiğini düşünüyorum öncelikle. Bu gözlemden sonra prediction yapmak yani bir öngörü ve sonra da bunun sonucuyla ilgili bir karşılaştırma yapılabilir. Ondan sonra belki modelleme yapılabilir. Konularla ilgili küçük modeller yapabiliriz ve bunları fen derslerinde kullanabiliriz. Onun dışında elimizde bir data olabilir. Kendimiz ya çıkarılmış bir datayı yorumlayabiliriz ya da kendimiz bir data oluşturabiliriz. Tartışma da olabilir farklı veriler üzerinden.
7) Experiment vardı galiba. Bilim insanları fareler üzerinde deney yapıyorlardı. Bilimsel pratik deyince aklıma zaten deney gelmişti. Buldukları şeyi bir yerde sunacaklar. Bu da bilimsel bir pratik olabilir, o da yayılımı ile alakalı bir bilimsel pratik olabilir.
8) Bilimsel yöntem deyince aklıma araştırma yöntemleri geliyor direk. Mesela biz şu an araştırma yöntemleri dersi alıyoruz. Mesela survey yapıyoruz, gözlem de yapıyoruz. Literatürü tarıyoruz, hangi popülasyonla çalışacağımızı belirliyoruz vs.
9) Ben behavioral study yani davranışsal bilim ile ilgili çalışsam, izleyeceğim belli başlı yöntemler olur. Eğer neuroscience ile ilgili çalışsam da bambaşka yöntemler izlemem gerekir. Bunu örnekle açıklamaya çalışayım. Mesela sen bu study de bize survey uygulamıştın. Bu yöntem senin çalışman için uygundu çünkü. Ama ben visual perception çalışıyor olsam psikofizik deneyleri yapıp

insanların davranışlarını anlamaya çalışırım. Yani çalıştığımız alana göre kullanılan yöntemlerde daha farklı olur.

10) İnsanlık tarihine baktığımızda her disiplinin kendi yöntemi olduğunu görmek mümkün. Mesela eğer bilimsel deneyler yapıyorsanız ya da araştırmalar genelde lab kullanılırsınız. Kimya labları gibi. Ama sosyal bilimlerde bu metotlar kullanılamayabilir. Burada daha çok gözlem kullanılabilir.
11) Hipotez kurmaları, data toplamaları, deney yapmaları aklıma geliyor metni okuyunca. Bence bunlar kullanılan yöntemler.
12) Burada bilimsel bilginin paradigma değişimleri terimini kullanmak istiyorum. Bilimsel bilgi paradigma değişimleriyle değişebiliyor. Öncesinde mesela insanların akıl sağlığının sadece beyinle alakalı olduğu düşünülürken, şimdi daha çok bağırsaktaki bakterilerin de etki edebildiği düşünülüyor. Yani burada bilgi değişiyor ve gelişiyor.
13) Bilimin çeşitli alanlarına göre düşünürsek olabilir. Yani farklı bilim alanlarında farklı türde bilimsel bilgi olabilir belki. Mesela, fizik, kimya biyoloji gibi alanlarda bilgi farklılaşabilir.
14) Evet farklı bilimsel bilgi türleri vardır bence. Bunlar yani kanun, yasa, teorem... Yasa olan kesinlikle değişmiyor. Teori ise yine bir bilime dayanıyor ama sonucuna kesin olarak ulaşamadığımız şey oluyor.
15) Sosyal ve kültürel değerlerin önemli bir rolü var. Mesela, bazı ülkelerde bilim insanlarının bazı şeyleri çalışılması ve yayınlanması yasak. Conservative veya şeriatla yönetilen bir yerde cinsel bilimsel bir şeyi ya da evolution u ve cinsiyet eşitsizliğini çalışamayabilirsiniz mesela. Ya da televizyonda bunu göremeyebilirsiniz. Çünkü baya baskılanmış şeyler oluyor hükümette. Yani toplumların gelenekleri, kültürleri hep etkiliyor araştırma yapılmasını.

16) Bilimsel sürecin politik figürler tarafından direk etkilemesi gibi bir durum var. Mesela sosyal psikoloji gibi bir alan siyasetin çok güçlü bir şekilde kullanabileceği bir alan. Şu an aklıma Milgram deneyi geliyor. Çünkü zaten o deney, insanların otoritelerle ilgili algılarını ölçüyor. Sanırım 2. Dünya Savaşı sonrasında yapılmıştı. Yani politik çevreler ve hükümetler bilimi kullanarak bir sistem ve düzen yaratmaya çalışıyorlar. Bilimi kullanıyorlar ve bilim direk onlardan etkileniyor.
17) Tabi ki bunların çok etkisi var. Devlet sonuçta bir işi desteklemediği sürece bilim gelişmiyor. Burada mesela Güney Kore örneği. Burada devlet kesinlikle bilimi destekliyor ve yeni teknolojilerin gelişmesi için fon sağlıyor. Bu destek sayesinde Samsung ve Hyundai çok başarılı ve büyük şirketler olarak ortaya çıktı mesela. 30 yılda falan Türkiye'ye fark attılar. Böyle düşününce devlet politikası bilimi de etkiliyor.
18) Bu çalışma gut bakterisi ve onun beyindeki etkileriyle ilgiliydi. Yani gut bacteria dediğimiz şeyin beynin çalışmasında önemli bir etkisi var. Bence bu konu hakkında çalışmak bilimin pratik ve sosyal değerini oluşturuyor. Çünkü farelerle deney yapılmış ve beyindeki stres seviyeleri ve otizm semptomları ile ilgili bazı sonuçlar bulmuşlar. Bu çalışma bu hastalığa sahip olan insanlara yardım edecektir ve onların hayat standartlarını yükseltecektir. Metinde bilim insanlarının bir konferans için bir araya geldiği ve bilgi paylaşımı yaptığından da bahsedilmiş. Bu da yayılım ve iletişim için önemli bence.
19) Eğer paran varsa bilimin var, bilimin varsa politik açıdan güçlüsün ve politik açıdan güçlüysen de ekonomin güçlü. Bunların hepsi birbiriyle ilişkili ve bağlantılı. Metinde hükümet NASA'ya para vermemiş mesela Mars gezileri için. Burada politikacıların bilim üzerindeki etkisini de görmüş oluyoruz. Bush gidip

Obama geldiğinde dengeler değişiyor. Yani bilim politika ve ekonomiye bağlı bir durumda.

20) Birbirinden ayrı düşünemeyiz. Bir ağacın dalları sanki 5 tane farklı yere ayrılmış dallar ve hepsi ortak ana bir noktada bağlanıyor. Bir kavram haritası olarak zihnimde kurmaya çalışıyorum. Ama bunların hepsinde birbiriyle ilişkisi var diyebiliriz. Belki bir loop içine alabiliriz bunları. Hepsi birbiriyle zincir gibi bağlı ama eğer zincirin bir parçası koparsa tüm sistem çökmez.
21) Kesinlikle birbirleriyle ilişkililer. Bilimin sosyal yönleri politik ve ekonomik yönleriyle ilişkili. Bilim yöntemlerinin de politik yönüyle ilişkili olduğunu söyleyebiliriz. Ayrıca bilimin yöntemleri zaten bilimin pratiklerini belirlediğini söyleyebiliriz, orada kesin bir ilişki var. Bilimin kurumsal yönleriyle sosyal yönünü ilişkilendirdik zaten. Bilim amaç ve değerleri kullanılacak bilimsel yönleri ve sosyal yönleri belirliyor. Yani bir etkilenme durumu var hepsinin.
22) Yani ilişkili oluyor bence. Mesela ülkenin neye ihtiyacı varsa hükümet ona para veriyor. O şeyde mesela bilimsel bir şey yoksa senin bilimin geri planda kalıyor, ilerleyemiyorsun. O yüzden insanlığa bir şey sağlayacak durum azalıyor.

APPENDIX F

INFORMED CONSENT FORM

KATILIMCI BİLGİ ve ONAM FORMU

Araştırmayı destekleyen kurum: Boğaziçi Üniversitesi
Araştırmanın adı: University Students' Understanding of Reconceptualized Family Resemblance Approach to Nature of Science
Proje Yürütücüsü: Doç. Dr. Ebru Kaya
E-mail adresi: ebru.kaya@boun.edu.tr
Telefonu: (0212)3596914
Araştırmacının adı: Selin Akgün
E-mail adresi: selin.akgun@boun.edu.tr
Telefonu: 05395814812

Sayın katılımcı,

Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü öğretim üyesi Doç. Dr. Ebru Kaya "Üniversite Öğrencilerinin Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımına Dayalı Bilimin Doğası Anlayışları" adı altında bilimsel bir araştırma projesi yürütmektedir. Bu çalışma, farklı fakültelerin farklı bölümlerinde eğitim görmekte olan üniversite öğrencilerinin bilimin doğasına dair anlayışlarını ''Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımı'' çerçevesinde belirlemeyi amaçlamaktadır. Çalışmanın amacını gerçekleştirebilmek adına sizi katılımcı olarak davet ediyoruz. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuduktan sonra araştırmaya katılmak isterseniz lütfen bu formu imzalayıp bize ulaştırınız.

Bu araştırmaya katılmayı kabul ettiğiniz takdirde sizden 70 maddeden oluşan bir anket doldurmanızı rica edeceğiz. Anketin baş kısmında size ait birtakım demografik bilgiler edinmek için sorular hazırladık. Bu sorular katılımcıların bölümlerini, bağlı oldukları fakülteyi, yaşlarını, cinsiyetlerini ve e-mail adreslerini yansıtmaktadır. Bu anket, katılımcıların bilimin epistemik, bilişsel ve sosyal yönlerini nasıl algıladıklarını ortaya çıkarmamızda bize yardımcı olacaktır. Bu anketi doldurmak yaklaşık 15 dakikanızı alacaktır.

İkinci olarak, araştırmaya katılan bazı katılımcılar ile uyguladığımız anket sonuçları doğrultusunda bir mülakat gerçekleştirilecektir. Uyguladığımız anketin demografik bilgiler kısmında belirtmiş olduğunuz e-mail adresleri doğrultusunda, mülakat yapılması istenen kişilerle irtibata geçilecektir. Katılımcıların bilimin doğasına dair görüşlerini daha derinlemesine incelemek için yapılacak olan bu mülakatlar yaklaşık 20 dakika sürecektir. Mülakatlar esnasında katılımcının izni dahilinde ses kaydı alınacaktır.

Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Bu nedenle uygulanan anketlerin dökümleri ve alınan ses kayıtları araştırma projemiz süresince kilitli bir dolapta ve bilgisayarda güvenliği korunarak muhafaza edilecek ve araştırma sona erdiğinde silineceklerdir.

Bu araştırmanın bir parçası olmanız tamamen sizin isteğinize bağlıdır. Katıldığınız takdirde, çalışmanın herhangi bir bölümünde bir sebep göstermeden onayınızı çekme hakkına sahipsiniz. Araştırma projesi hakkında herhangi bir şey sormak istediğiniz takdirde lütfen proje yürütücüsü ile (Ebru Kaya) temasa geçiniz (Telefon: (0212)3596914 Adres: Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü 34342 Bebek, İstanbul). Eğer bu araştırma projesine katılmayı kabul ediyorsanız, lütfen bu formu bize ulaştırın.

Ben (Katılımcının adı) ……, bana verilen metni okudum ve katılmam istenen bu çalışmanın amacını ve içeriğini göz önünde bulundurarak, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım… Çalışma hakkında kafama takılan soruları sorma imkânı buldum. Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir olumsuzluk ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Katılımcının Adı-Soyadı: .....
İmzası: .....
Adresi (varsa Telefon No, Faks No): .....
.....
Tarih (gün/ay/yıl): ...../...../.....

Araştırmacının Adı-Soyadı: .....
İmzası :.....
Tarih (gün/ay/yıl): ...../...../.....

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