TEACHING RECONCEPTUALIZED FAMILY RESEMBLANCE APPROACH TO NATURE OF SCIENCE IN LOWER SECONDARY CLASSROOM

by
Ayşegül Çilekrenkli
B.S., Science Education, Boğaziçi University, 2017

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Secondary School Science and Mathematics Education
Boğaziçi University
2019

TEACHING RECONCEPTUALIZED FAMILY RESEMBLANCE APPROACH TO NATURE OF SCIENCE IN LOWER SECONDARY CLASSROOM

APPROVED BY:

Assoc. Prof. Ebru Kaya (Thesis Supervisor) .....

Prof. Sibel Erduran .....

Assoc. Prof. Sevil Akaygün .....

DATE OF APPROVAL: 07.05.2019

Dedicated to Johannes Kepler's *Somnium*

ACKNOWLEDGEMENTS

I would like to acknowledge the contributions of those whose guidance and support were invaluable in the completion of this thesis. First, I would like to express my sincerest appreciation to Assoc. Prof. Ebru Kaya, my advisor, for those extra miles you have taken in order to make this study established and supported. She consistently allowed this paper to be my own work but also steered me in the right direction. I also thank her for introducing me to science education research by involving me in one of her prior studies. Without the experiences that came after I would not be able to handle the difficulties of this project.

I am also grateful to have the opportunity to be guided by Prof. Sibel Erduran and Assoc. Prof. Sevil Akaygün, the committee members who have generously contributed their time and efforts and advanced this work with their feedbacks. Working with you and learning from you has been an honor.

I would like to pay my gratitude to the teacher in this study who has put her heart in this work along with mine. She has kindly volunteered her time, effort and teaching moments with her students and therefore, given me invaluable opportunities to gain experience and grow as an educator and a researcher. Her emotional support and encouraging words have been woven to the fabric of this work. I would also like to thank the experts, Büşra Aksöz, Selin Akgün and Melike Alayoğlu who were involved in the adaptation of the survey and design of the instructional sequence. Working with you and receiving your support have been inspiring.

Research reported in this thesis is a part of the research project entitled “Integration of Reconceptualized Family Resemblance Approach to Nature of Science in 5th Grade Science Content” and therefore, funded by Boğaziçi University Research Fund (Grant Number: 14922). I would like to thank for their financial contributions.

I am also thankful to have my friends, Canan Türkmen, Uğurcan Gürler, Havva Kuru, Nilüfer İleri, Beril Neoldum and Gizem Küçükaslan who have encouraged, supported, tolerated and believed in me. Jumping through the hoops of graduate school have been the most enjoyable time while I had you by my side.

I am also forever indebted to my parents, Gülçin and Osman Çilekrenkli who have provided years of support and endless love. The way you chose to bring me up gives me confidence while I journey through life. Being your one and only has been the greatest joy.

Finally, last but by no means least, I am also grateful to have my partner, Umut Küçükaslan, by my side. Thank you for your unfailing support when things seemed arduous and insurmountable; thank you for constantly encouraging me to discover and expect more; thank you for sharing my feelings, the good and the bad, and amplifying the joy in our life by keeping things in perspective; thank you for working with me for our dreams; and most importantly thank you for all the best cakes and the default cookies. I feel privileged to have you.

ABSTRACT

TEACHING RECONCEPTUALIZED FAMILY RESEMBLANCE APPROACH TO NATURE OF SCIENCE IN LOWER SECONDARY CLASSROOM

Erduran and Dagher's (2014) Reconceptualized Family Resemblance Approach to Nature of Science (RFN) is a relatively new approach in teaching nature of science (NOS). The purpose of this study is to investigate the effectiveness of RFN approach on 5th grade students' understanding and perceptions of NOS. With an experimental, convergent parallel mixed method study design the change in students' understanding and perceptions of NOS is explored. Participants of the study are 64 female, 5th grade students and their science teacher. Intervention is conducted with RFN based instruction or regular practice in experimental and control groups, respectively. The quantitative data source is adapted from the RFN Questionnaire (Kaya, Erduran, Aksoz & Akgun, 2018). Qualitative data is gathered through semi-structured student interviews before and after the intervention. RFN Student Questionnaire was administered as pre, post and delayed post-test. T-test indicated that groups were initially homogeneous in their total and category-based scores except for the scientific practices category. Mixed ANOVA showed that there was a significant main effect of the teaching method. Pairwise comparisons revealed that the mean changes from the pretest to post-test were significant for the total test scores and methods and methodological rules of science, scientific knowledge, and social institutional categories. Therefore, among the category-based scores, experimental students significantly outperformed their peers except for the aims and values of science and scientific practices categories. Analysis of student interviews with thematic coding and constant comparison of the codes also supported these results. Overall, the study has implications for the integration of a holistic account of nature of science to secondary school science education content.

ÖZET

YENİDEN KAVRAMSALLAŞTIRILMIŞ AİLE BENZERLİĞİ YAKLAŞIMINA DAYALI BİLİMİN DOĞASININ ORTAOKUL SINIFLARINDA ÖĞRETİLMESİ

Erduran ve Dagher (2014) tarafından geliştirilen Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımına Dayalı Bilimin Doğası (ABY), bilimin doğası öğretiminde yeni bir yaklaşımdır. Bu çalışmanın amacı bu yaklaşımın 5.sınıf öğrencilerinin bilimin doğası anlayışları ve algıları üzerine etkililiğini incelemektir. Yarı deneysel, eşzamanlı üçgenlemeye dayalı karma araştırma deseni ile öğrencilerin anlayışları ve algılarındaki değişim araştırılmıştır. Araştırmanın katılımcıları 64 tane 5.sınıfa başlayan kız öğrenci ve onların fen bilimleri öğretmenidir. Müdahale, deney sınıfında ABY, kontrol sınıfında ise yaygın yaklaşım ile gerçekleştirilmiştir. Nicel veri kaynağı Bilimin Doğası Anketi'nden uyarlanmış (Kaya, Erduran, Akgun & Aksoz, 2017) ve ön, son ve ertelenmiş son test olarak üç kez uygulanmıştır. Nitel veri müdahaleden önce ve sonra gerçekleştirilen yarı yapılandırılmış öğrenci görüşmeleri ile elde edilmiştir. T-test aracılığıyla başlangıçta bilimsel pratikler kategorisi hariç, iki grubun öğrencilerinin toplam ve kategori bazlı anket puanları arasında anlamlı bir fark olmadığı bulunmuştur. Karışık gruplar arası-içi ANOVA ise öğretim metodunun öğrencilerin anlayışları üzerinde deney grubu öğrencileri lehine istatistiksel olarak anlamlı bir fark yarattığını ortaya koymuştur. Testler arasındaki çift karşılaştırmaları ise ön testten son teste öğrencilerin toplam anket ve yöntemler ve yöntemsel kurallar, bilimsel bilgi ve sosyal-kurumsal kategori puan ortalamalarında görülen değişimlerin istatistiksel olarak anlamlı olduğunu göstermiştir. Öğrenci görüşmelerinin tematik kodlama ve sürekli karşılaştırma ile analizi de bu sonuçları desteklemektedir. Sonuç olarak, bu çalışma, bilimin doğasının ortaöğretim fen bilimleri öğretimine bütünsel olarak entegre edilmesine katkıda bulunma potansiyeline sahiptir.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iv

ABSTRACT vi

ÖZET vii

LIST OF FIGURES xii

LIST OF TABLES xiii

LIST OF ACRONYMS/ABBREVIATIONS xvi

1. INTRODUCTION 1

1.1. Purpose of the study 3

1.2. Significance of the study 3

1.3. The relevance of working with students 5

1.4. Research questions and null hypotheses 6

1.5. Operational definitions of the key terms 7

2. LITERATURE REVIEW 10

2.1. Major contemporary accounts of NOS in science education 10

2.2. Integration of Family Resemblance Approach (FRA) to science and science education 15

2.2.1. The idea of family resemblance and family resemblance approach 16

2.2.2. Reconceptualized Family Resemblance Approach to NOS 20

2.2.3. RFN categories 24

2.3. Research conducted with RFN as the theoretical framework 32
2.4. NOS as portrayed in the Turkish science education curriculum 33
2.5. Middle school students' views of nature of science 38
2.6. Summary of the literature review 41
3. METHODOLOGY 44
3.1. Research Design 44
3.2. Participants 44
3.2.1. The teacher 45
3.2.2. The students 45
3.2.3. The interviewees 46
3.2.4. The school as the context of the study 47
3.3. Data Sources 48
3.3.1. Quantitative Data Source 48
3.3.2. Qualitative Data Source 50
3.4. Intervention 50
3.4.1. Instructional Sequence of Experimental Group 57
3.4.2. Instructional Sequence of Control Group 65
3.5. Data Collection 68
3.5.1. Quantitative Data Collection 68
3.5.2. Qualitative Data Collection 68
3.6. Data Analysis 69
3.6.1. Quantitative Data Analysis 69

3.6.2. Qualitative Data Analysis 71

3.7. Ethical considerations 71

4. RESULTS 72

4.1. The change in students' NOS understanding 72

4.1.1. Descriptive statistics 72

4.1.2. Students' NOS understanding before the intervention 74

4.1.3. Comparison of mean changes 77

4.2. NOS understanding of the interviewees 85

4.3. The change in students' NOS perceptions 87

4.2.1. Aims and values of science 89

4.2.2. Scientific practices 97

4.2.3. Methods and methodological rules of science 106

4.2.4. Scientific knowledge 111

4.2.5. Science as a social-institutional system 119

4.4. Summary of the results 139

5. DISCUSSION 142

5.1. Summary of the study 142

5.2. Effectiveness of RFN based instruction on students' NOS knowledge 145

5.3. Implications of the study 151

5.4. Limitations of the study 152

5.5. Suggestions for further research 153

REFERENCES 154

APPENDIX A: RFN STUDENT QUESTIONNAIRE 164

APPENDIX B: INTERVIEW PROTOCOL FOR STUDENTS 166

APPENDIX C: CONSENT FORMS 170

APPENDIX D: TURKISH VERSIONS OF INTERVIEW QUOTATIONS AND EXCERPTS 174

APPENDIX E: ACTIVITY 09 180

APPENDIX F: ACTIVITY 11 185

APPENDIX G: ACTIVITY 12 190

APPENDIX H: ADAPTED VERSIONS OF GENERATIVE IMAGES OF SCIENCE 198

LIST OF FIGURES

Figure 2.1. The scope of FRA relative to alternative views of NOS……..16

Figure 2.2. FRA Wheel: Science as a Cognitive-Epistemic and Social-Institutional System……..……..……..……24

Figure 2.3. GIS about Aims and Values in Science……..……..25

Figure 2.4. GIS about Scientific Practices……..……27

Figure 2.5. GIS about harmonious working of evidence from variety of Methods……29

Figure 2.6. GIS about TLM, growth of Scientific Knowledge and scientific understanding……..……..……..….30

Figure 2.7. GIS about Science as a Social-Institutional System…….32

Figure 3.1. Percentages of Religious Lower Secondary Schools……...47

Figure 4.1. Distributions of Pretest Scores for the Control and Experimental Groups..75

Figure 4.2. Estimated Marginal Means of Three RFN Student Questionnaire Administrations……..……..……78

Figure 4.3. Explanation of the Notations Used in Excerpts……..……..87

Figure 4.4. Adapted GIS for Scientific Practices Category……..……105

LIST OF TABLES

Table 2.1. Categories of FRA to NOS framework of Irzik and Nola (2014)……20

Table 2.2. Articulation of FRA categories across science topics in Science: Programme of Study for Key Stage 4 from England……...21

Table 2.3. RFN categories in Turkish middle school science curricula from 2006 to 2013……..……..……..……35

Table 3.1. RFN Student Questionnaire item distribution according to categories……50

Table 3.2. Horizontal articulation of RFN categories in terms of unit content…….53

Table 3.3. Data analysis procedures for each of the research questions……...70

Table 4.1. Descriptive statistics for all three RFN Student Questionnaire administrations……..……..…….73

Table 4.2. Normality values for each category of pretest……..……75

Table 4.3. Levene's Test and Independent Samples *t* Test results for pretest……...76

Table 4.4. Descriptive statistics for all three RFN Student Questionnaire administrations……..……..…….77

Table 4.5. Normality values for each totality and categories of post and delayed post-tests……..……..……..……79

Table 4.6. Levene's Test and independent samples *t* Test results for all three testing..81

Table 4.7. Mauchly's Test of Sphericity results……..……..81

Table 4.8. Summary of the ANOVA statistics for the RFN Student Questionnaire…..82

Table 4.9. Comparison of total and category-based NOS scores in terms of questionnaire administration times……..……84

Table 4.10. Interview students' total and category-based NOS scores in all three tests.86

Table 4.11. The frequency of the codes for students' perception of an example category in terms of the groups and interview times……88

Table 4.12. The frequency of the codes for students' perception of aims of science in terms of the groups and interview times……..……90

Table 4.13. The frequency of the codes for students' perception of values of science in terms of the groups and interview times……..……93

Table 4.14. Change in the number of codes obtained from individual students' answers in terms of aims and values of science……..…….96

Table 4.15. The frequency of the codes for students' perception of scientific practices in terms of the groups and interview times……..……98

Table 4.16. Change in the number of codes obtained from individual students' answers in terms of scientific practices……..……106

Table 4.17. The frequency of the codes for students' perception of methods and methodological rules of science in terms of the groups and interview times……..……..……..…….107

Table 4.18. Change in the number of codes obtained from individual students' answers in terms of methods and methodological rules of science..……..110

Table 4.19. The frequency of the codes for students' perception of scientific knowledge in terms of the groups and interview times……..112

Table 4.20. Change in the number of codes obtained from individual students' answers in terms of scientific knowledge……..…….....119

Table 4.21. The frequency of the codes for students' perception of social certification and dissemination of science in terms of the groups and interview times……...120

Table 4.22. The frequency of the codes for students' perception of scientific ethos in terms of the groups and interview times……..……..125

Table 4.23. The frequency of the codes for students' perception of social values in terms of the groups and interview times……..……..128

Table 4.24. The frequency of the codes for students' perception of professional activities in terms of the groups and interview times…….130

Table 4.25. The frequency of the codes for students' perception of social organizations and interactions in terms of the groups and interview times……...132

Table 4.26. The frequency of the codes for students' perception of financial systems in terms of the groups and interview times……..……..134

Table 4.27. The frequency of the codes for students' perception of political power structures in terms of the groups and interview times……136

Table 4.28. Change in the number of codes obtained from individual students' answers in terms of social-institutional categories……..…...138

LIST OF ACRONYMS/ABBREVIATIONS

AV	Aims and Values of science
BSCS	Biological Science Curriculum Study
FRA	Family Resemblance Approach
FS	Financial Systems
H	High level understanding of NOS
L	Low level understanding of NOS
LP	Lesson Plan
M	Methods and Methodological Rules
M	Moderate level understanding of NOS
MEB	Milli Eğitim Bakanlığı
MoNE	Ministry of National Education of Turkey
NOS	Nature of Science
PPS	Political Power Structures
RFN	Reconceptualized Family Resemblance Approach to NOS
SCD	Social Certification and Dissemination
SE	Scientific Ethos
SI	Social-Institutional systems of science
SK	Scientific Knowledge
SOI	Social Organizations and Interactions
SP	Scientific Practices
SV	Social Values

1. INTRODUCTION

Nature of Science (NOS) has been studied for over decades as one of the fundamental problems of science education (Leden & Hansson, 2017; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Mackay, 1971). Since Matthews (1998) pointed out an increase in studies regarding NOS in the last couple of decades, the trend has been continuing.

One reason for the general interest is the aim of surfacing and attending to hidden assumptions regarding different aspects of nature of science in order to enhance science teaching and learning, and scientific literacy (Arriola, 2017; Driver, Leach, Millar, & Scott 1996). Consensus view tenets which were asserted by Abd-El-Khalick, Bell and Lederman (1998) has been widely used in science education research and science teaching. On the other hand, this view has also been gaining opposition on several grounds.

One major criticism is in regard to oversimplification and shallow coverage of the issue in contrast to the intricate nature of science (Alters, 1997; Dagher & Erduran, 2017; Hodson & Wong, 2017). With this concern, Matthews (2012) has questioned the choice of the tenets to be pronounced among many other epistemological, historical, psychological, social, technological and economic characteristics.

The seven tenets have been also found counterproductive for classroom use. Criticizing the ambiguous reconciliation of seemingly contradicting tenets by the students, Allchin (2011) expanded on the seven-item list by deepening the items into contextualized dimensions. A study conducted by Allchin and his colleagues has also underscored teaching NOS in context for that NOS understanding needs to be functional, not declarative (Allchin, Andersen, and Nielsen, 2014).

Another concern is that the underlying assumptions based on the students' developmental levels behind the seven tenets lead to unnecessary constraints for NOS teaching in general through omission of certain NOS aspects (Bell, 2006; Metz 1995). For example, Akerson, Buck, Donelly, Nargund-joshi, & Weiland (2011) found that third-grade students were better able to understand concepts such as tentativeness and empirical nature of science in comparison to social-cultural nature of science. Results like these can direct

curriculum designers and teachers alike to abandon these issues till later grades. On the other hand, even Akerson and her colleagues (2011) suggest otherwise. The possible detrimental effect of outright rejection of science content by focusing rigidly on the developmental stages of the students is also underlined by Metz (1995).

Erduran and Dagher (2014) have also affirmed the need for "promoting a relatively broad and inclusive account of nature of science for science education" (p. xiv). According to Erduran and Dagher (2014), NOS, as represented in science education, should not diverge too far from the way it is accounted in the philosophy of science and other relevant disciplines. As such, it must also include domain-specific characteristics of science as well as the commonalities, and it should be done so on a firm theoretical foundation. With this aim, they have reconceptualized family resemblance framework of Irzik and Nola (2011; 2014) and expanded the categories proposed by them in order to build a holistic picture of science as cognitive-epistemic and social-institutional system. They have also proposed pedagogical tools and strategies for NOS teaching in science education classrooms.

Erduran and Dagher's framework (2014) emphasize a widespread integration of all categories they have proposed into science education. They suggest the articulation of the categories to be both vertical and horizontal as the family categories emerge in the curriculum content. On the other hand, in the survey of monumental curricula through the years from the USA and England (e.g. NGSS, 2013; NRC, 2012) they found the documents to be inadequate in various categories. This deficiency is also affirmed by Kaya and Erduran (2016) in the case of Turkish curriculum (MEB, 2006; MEB, 2013).

At this point, Akerson and her colleagues' (2011) notion of appropriate instructional strategies and 'a teacher who can scaffold' should be revisited. Based on their findings the researchers state that even younger students can build their understanding of more abstract aspects of NOS with an instruction conducted by a capable teacher. On the other hand, even an experienced teacher would face the issues of imprecise connections to NOS in many curricula and "a lack of robust teaching traditions in the area" (Leden & Hansson, 2017). Previous research indicates that teachers need resources along with experiences, planning time, knowledge of NOS, knowledge of subject matter and pedagogical knowledge (Abd-El-Khalick *et al.*, 1998; Lederman, Schwartz, Abd-El-Khalick and Bell, 2001). Because of the imprecise representation of NOS in the curricula in contrast to empirical studies that

advise more holistic and contextualized approaches, befittingly, there is a long-standing gap between research and teachers' practice in terms of NOS teaching and it can be alleviated with material development (Akerson *et al.*, 2011; Leden & Hansson, 2017; Mackay, 1971).

Among various accounts and approaches regarding describing, teaching and learning of NOS developed by philosophers and educators of science, reconceptualized family resemblance approach to NOS (RFN) that has been proposed by Erduran and Dagher (2014) is the focus of this study. When previous criticism with regard to the aforementioned assumptions widely held in the science education milieu considered, RFN approach is more likely to surpass them. The fact that this approach also suggests educational practices is an added strength for the goal of creating science classrooms in which nature of science is holistically transferred to the students. On the other hand, with the empirical adequacy value of scientific reasoning at heart, empirical data is needed in terms of practical use of RFN in classrooms. During such efforts, systematic horizontal articulation of various family categories should be carefully considered and, appropriate classroom activities and materials should be designed for open access of teachers in order to align classroom practice with research.

1.1. Purpose of the study

For the purpose of investigating the effectiveness of RFN approach in teaching NOS to 5th grade students this study aims to assess experimental group students' understanding and perceptions of NOS before, immediately after, and two months after they complete 13 weeks of intervention with an instructional sequence designed based on RFN approach, in comparison to that of control group students who were taught with regular practice. Assessment of students' understanding of NOS was done both qualitatively and quantitatively at these times in order to form a fuller image of change in students' understanding of nature of science.

1.2. Significance of the study

This study contributes to the science education research literature in four distinct ways. First, few studies have used RFN approach in teaching NOS to K-12 students. RFN approach has been used in teacher education research (Cullinane & Erduran, 2015),

investigations regarding university students' understanding of NOS (Akgun, 2018), and also analysis of curricula (Erduran & Dagher, 2014b; Kaya & Erduran, 2016) and textbook (BaouJaoude, Dagher, & Refai, 2018, McDonald, 2018). It has also been used in studies that involve school science teaching, but they focus only and discretely on scientific practices and social-institutional categories among the 5 main categories of RFN (Alayoglu, 2018; Karabas, 2017). Therefore, the gap remains for studies that holistically cover all categories of RFN framework in teaching NOS. This gap is significant because RFN is a holistic approach and the suggestions for systematic horizontal and vertical articulation is one of its key contributions. Although it is not required by its designers to address all categories in every school year or unit, targeting all of them as intended in this study will be instrumental for assessing the effectiveness of RFN framework as a whole.

Second, conducting classroom observation and assessing the intervention process itself makes the results of this study more reliable and therefore significant. Meichtry's (1992) attempt to assess then newly developing Biological Sciences Curriculum Study curriculum underscored the process assessment since the seemingly negative effect of the education program was found to be a consequence of teachers' failing to form explicit connections to NOS during the instruction (BSCS, 1990). With this reasoning, during this study, a great emphasis is put in for a reliable assessment of instruction. Otherwise, the outcome assessment of the study would heavily depend on self-perceived behavior of the teacher while such data is found questionable in the literature (van Driel, Meirink, van Veen, & Zwart, 2012).

Third, there is a gap between research and practice about representations of NOS. Although a review of literature implies contextualized, holistic and explicit approaches to be more beneficial in teaching NOS, references to NOS in curricula are neither specific nor comprehensive (Erduran & Dagher, 2014, Kaya & Erduran, 2016; Leden & Hansson, 2017). Therefore, there is a longstanding need for creating resources that can systematically develop students' understanding of NOS (Mackay, 1971). Such materials can serve as activity plans or just guides that lead teachers in issues such as using examples and explicit connections in contexts that are accessible and meaningful for their students. From Duschl and Wright's (1989) perspective, relieving teachers' responsibility of selecting appropriate content (at least for some similar contexts) would be a crucial contribution of this study since studies show that teachers lack adequate NOS understanding to take on such toll.

Fourth and last but not least, the questionnaire adapted in this study will be instrumental in getting timely quantitative descriptions of students' understanding of NOS. Quantitatively assessing younger students' NOS understanding with multiple choice or Likert-scale items has found opposition on the grounds that it wouldn't be reliable since students' meanings of the abstract concepts regarding NOS cannot be accounted (Allchin *et al.*, 2014). From a constructivist point of view, students' pre-instruction understandings are important and should be addressed (Mackay, 1971). On the other hand, while the teachers can spare so scarce a time (if any) for such assessment, conducting interviews or open-ended examinations with their students would be an unattainable goal. Therefore, this questionnaire is expected to be instrumental in assessing lower secondary students' NOS understanding especially when the available time frame is narrow.

1.3. The relevance of working with students

Selection of NOS categories to be taught at different grade levels is a central issue for science education (Leden & Hansson, 2017). Among various approaches in articulating NOS related issues throughout science content and education years, views of Abd-El-Khalick (2012) and Erduran and Dagher (2014) stand out. While the former suggests an additive scheme which implies that based on students' readiness different issues of NOS to be introduced, the latter proposes an enrichment type of scheme which entails introducing these issues early on as the opportunities arise in the content. It should be acknowledged that Erduran and Dagher (2016) still does not suggest for the articulation of the NOS aspects to be free from consideration of students' age. On the contrary, they suggest that "selecting and packaging FRA components to achieve specific goals and with developmentally appropriate NOS content" (Erduran & Dagher, 2014, p.36). There are results from empirical studies that can support either of these views.

Age can be a limiting factor in students' learning including students' understanding and perceptions of different aspects of NOS. Still, some educational approaches can be used to foster students' abstract thinking for issues that are found controversial for an early introduction (Leden & Hansson, 2017). Metz (1995) asserts that these efforts would be fruitful because if different educational strategies are not used to accommodate students' thinking with a rigid attitude in terms of students' developmental stages as in the stage theory

of Piaget, valuable opportunities can be lost. Educational strategies such as more guided structures, experiential learning and tackling NOS issues in contexts which are relevant and meaningful for the students should be implemented to mediate developmental appropriateness of the students in order to prevent unnecessary omissions. (Akerson *et al.*, 2011; Erduran & Dagher, 2014; Leach, Driver, Millar, & Scott, 1997; Leden & Hansson, 2017). By systematically addressing all categories of RFN some of which has been found controversial to be taught in early grades, this study can yield empirical support for the hindrances or affordances for the teaching of these categories.

Since the participants of this study are from 5th grade, which is the lowest grade in lower secondary schools in Turkey, lower secondary school science teachers can benefit from the educational strategies used in this study while they are also working with later grades. In this regard, working with 5th grade students is relevant for future use of the measurement tool and materials developed in this study.

1.4. Research questions and null hypotheses

For the goal of examining the effectiveness of RFN approach in teaching NOS, this study is guided by the following questions and they are tested through the associated null hypotheses:

1. How does using RFN approach in teaching NOS affect students' *understanding* of NOS?

a) How do NOS understanding of the students from the experimental group who were taught with RFN based instruction and the control group who were taught with regular practice compare in *pretest*?

H_{01a}: There are no statistically significant differences between the control and experimental group students' understanding of NOS before the intervention.

b) How do the control and experimental group students' understanding of NOS change from pretest to post-test and to delayed post-test while they learn NOS with regular practice or RFN approach, respectively?

H_{01b}: There will be no statistically significant difference between the mean changes of the control and experimental group students' NOS understanding scores from pretest to post-test and to delayed post-test.

2. How does the control and experimental group students' *perception* of NOS change after learning NOS with regular practice or RFN approach?

   H_{02}: There will be no discernable patterns in the responses experimental and control group students give regarding nature of science.

Both of the sublevels of the first research question are investigated by considering the total questionnaire scores of the students and also their category-based scores in terms of five main categories of RFN: aims and values of science, scientific practices, methods and methodological rules and social-institutional categories. The second research question is investigated separately in terms of main categories of RFN and also for each of the social-institutional categories: social certification and dissemination, scientific ethos, social values, professional activities, social organizations and interactions, financial systems, and political power structures.

1.5. Operational definitions of the key terms

- Nature of science (NOS): An umbrella term that refers to cognitive-epistemic and social-institutional aspects of science such as its aims, values, norms, practices, techniques and outcomes, and how it is conducted by scientists in institutional settings under the influence of financial and political power structures.

- Family Resemblance Approach (FRA): A philosophical solution for the problem of universals which refers to the identification of properties that are shared by separate entities (Hacking, 1996). It has been applied to the demarcation issue of science and reconceptualized for use in science education (Irzik & Nola, 2011; Erduran & Dagher, 2014).

- Reconceptualized-FRA-to-NOS (RFN): The framework developed by Erduran and Dagher (2014) in order to holistically represent NOS in science education classrooms and research.

- Understanding of NOS: As operationally defined in this study, making appropriate responses that are in line with the RFN framework.

- Perceptions of NOS: As operationally defined in this study, a participants' unique contextual descriptions of NOS.

- NOS knowledge: This term is used to refer to the combination of NOS understanding and perceptions of the students.

- Novel mention: As operationally defined in this study, a code given to each student only once, and on the condition that their answers to the interview questions present proof of attainment of a learning goal or a unique perception on a targeted issue.

- Regular practice: Control group's instruction which is based on the latest science education program and textbook published by MoNE (MEB, 2018a; MEB, 2018b)

- RFN based instruction: Experimental group's instruction which is a reframed version of regular practice in Turkey in line with the RFN framework

- Aims and values of science: "The key cognitive and epistemic objectives of science, such as accuracy and objectivity"

- Scientific practices: "The set of epistemic and cognitive practices that lead to scientific knowledge through social certification"

- Methods and methodological rules of science: "The manipulative as well as non-manipulative techniques that underpin scientific investigations"
- Scientific knowledge: "Theories laws and explanations that underpin the outcomes of the scientific inquiry"

- Social-institutional systems of science: Mechanisms, norms and values through which science is conducted by scientists such as influence of peers, public and organizations, and financial and political power structures

- Social certification and dissemination: “The social mechanisms through which scientists review, evaluate and validate scientific knowledge for instance through peer review systems of journals”

- Scientific ethos: “The norms that scientists employ in their work as well as in interaction with colleagues”

- Social values: “Values such as freedom, respect for the environment, and social utility”

- Professional activities: “How scientists engage in professional settings such as attending conferences and doing publication reviews”

- Social organizations and interactions: “How science is arranged in institutional settings such as universities and research institutes”

- Financial systems: “The underlying financial dimensions of science including the funding mechanisms”

- Political power structures: “The dynamics of power that exist between scientists and within science cultures”

(Erduran & Dagher, 2014)

2. LITERATURE REVIEW

2.1. Major contemporary accounts of NOS in science education

Nature of Science (NOS) has been one of the central topics studied in science education for the past few decades (e.g. Matthews, 2012; McComas & Olson, 1998). Accordingly, there are various accounts and approaches regarding describing, teaching and learning of NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Allchin, 2011; Erduran & Dagher, 2014; Irzik & Nola, 2014; Matthews, 2012). Three of the major contemporary accounts are briefly discussed in this section. These are Consensus View, Features of Science and Whole Science. It should be acknowledged that a discussion of these three views per se does not cover all perspectives that reside in literature. For such effort, other works such as Sandoval's (2005) epistemological themes, Hodson's (2009) understanding scientific practice, and Yacoubian's (2012) critical thinking CT-NOS framework along with the vast amount of empirical research can also be revisited for further reading. The three accounts discussed here were chosen because they represent significant milestones for change in the discussion towards more holistic approaches in teaching NOS.

The dominant view in literature for the past two decades is known as the *Consensus View*. Some of the major proponents of the consensus view, Abd-El-Khalick *et al.* (1998) assert that some issues of philosophy of science may be too abstract to be included in K-12 education years. In this line of reasoning, they would be struggling for students to understand and they are not an immediate necessity for their lives. For example, differences in opinion for descriptions of NOS would not be relevant for K-12 education years. For these reasons, Abd-El-Khalick *et al.* (1998) identify seven aspects of NOS which should be taught since they are understandable by the students and relevant to the students' daily lives. These seven aspects known as the consensus tenets were later explained in more detail by Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) as follows:

(i) The Tentative Nature of Scientific Knowledge: Scientific knowledge, although reliable and durable, is never absolute or certain. This knowledge, including facts, theories, and laws, is subject to change.

(ii) Observation, Inference, and Theoretical Entities in Science: Observations are descriptive statements about natural phenomena that are directly accessible to the senses (or extensions of the senses). By contrast, inferences are statements about phenomena that are not directly accessible to the senses.

(iii) The Theory-Laden Nature of Scientific Knowledge: The development of scientific knowledge is based on theory. Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations actually influence their work.

(iv) The Creative and Imaginative Nature of Scientific Knowledge: Science is empirical. Nonetheless, generating scientific knowledge also involves human imagination and creativity.

(v) The Social and Cultural Embeddedness of Scientific Knowledge: Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture.

(vi) Scientific theories and laws: Scientific theories are well-established, highly substantiated, internally consistent systems of explanations. Laws are descriptive statements of relationships among observable phenomena. Theories and laws are different kinds of knowledge and one does not become the other.

(vii) Myth of The Scientific Method: The myth of the scientific method is regularly manifested in the belief that there is a recipe-like stepwise procedure that all scientists follow when they do science. This notion was explicitly debunked (Lederman *et al.*, 2002, p. 500–502).

Although widely used, this view has also been gaining opposition on several grounds including their oversimplified nature and shallow coverage of the issue in contrast to the intricate nature of science (Alters, 1997; Bell, 2006; Dagher & Erduran, 2017; Hodson & Wong, 2017; Metz, 1995). For instance, according to Allchin (2011), because of the declarative nature of these statements, reconciliation of seemingly contradicting tenets by the students would be ambiguous.

General criticism about the consensus view is linked to the assumptions which are explicitly or implicitly presented in the works of the proponents of this view. The following assumptions are synthesized from several works that were theoretically based on the

consensus view (Abd-El-Khalick *et al.*, 1998; Akerson, Pongsanon, Rogers, Carter, & Galindo, 2015; Eflin, Glennan, & Reisch, 1999; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Schwartz & Lederman, 2002):

(i) From some "acceptable level of generality", philosophers, historians and educators of science have reached a consensus for some aspects of NOS
(ii) Contradictory issues regarding NOS is of no interest to K-12 students
(iii) NOS can be accurately conveyed to students through a collection of simple statements,
(iv) Students are unable to understand some of the more abstract aspects of NOS,
(v) NOS teaching should be based on the essentialist consensus tenets for presupposed pedagogical reasons.

One major concern is that these underlying assumptions behind the seven tenets may cause unnecessary constraints for teaching NOS through omission of certain NOS aspects (Bell, 2006; Metz, 1995). For example, the study of Akerson and her colleagues indicated, subjective and socio-cultural aspects of science is often considered more appropriate for later stages in the school system while they could be accommodated with appropriate instructional strategies and a competent teacher (Akerson, Buck, Donelly, Nargund-joshi, & Weiland, 2011). Erduran and Dagher (2014) also affirm the need for "promoting a relatively broad and inclusive account of nature of science for science education" (p. xiv).

The seven tenets have been also found counterproductive for classroom use by the teachers. Allchin, Andersen, and Nielsen (2014) state on the part of the teachers in their study that "while they perceived the NOS tenets as informative, helping them to sharpen their own understanding of NOS, none regarded the 'consensus list' operationally as an entry into NOS teaching. The teachers preferred to teach NOS in context" (p. 463). Accordingly, teachers chose a more concrete and elaborate approach than a list of principles because they thought that aspects of NOS should be related to students' own contexts in order for them to go beyond merely recalling from memory by implementing their newly acquired ideas.

Allchin (2011) extended the ideas in the consensus view by turning the list of tenets into contextualized dimensions. The dimensions he had proposed spanned from experimental to social aspects, therefore he called this view *Whole Science*. His argument is

that there is too heavy an emphasis on the credibility that the curricula fail to recognize other issues related to NOS such as selection and funding of research programs. According to Allchin *et al.* (2014) for students to be able to accommodate seemingly conflicting tenets in a meaningful way, NOS teaching should be functional, not declarative.

Like the consensus view, Allchin also supports the view that philosophical issues related to NOS are not a required territory for the students. According to Allchin (2011) "Philosophizing about the abstract nature of experiment can be left to ... well, philosophers." (p. 523). Consequently, a philosophical perspective was not included in the list of deficiencies asserted by Allchin (2011) along with "the role of funding, motivations, peer review, cognitive biases, fraud, and the validation of new methods" (p. 524).

Even without the inclusion of philosophical roots, Allchin's approach is a more holistic approach in contrast to the declarative list of tenets. Whole Science because of its more comprehensive approach can accommodate seemingly conflicted tenets such as 'scientific knowledge is durable' and 'scientific knowledge is tentative' in the classroom (Allchin, 2011). According to the Whole Science account, problematizing NOS in example cases may be a more effective way of teaching NOS than describing nature of science with simple statements such as "science is X".

Matthews (2012) prefers the term features of science when it comes to describing the seven tenets and advocates for changing the terminology. He also highlights the necessity to change the focus of research from the essentialist and epistemologically focused Nature of Science (NOS) to a more "relaxed, contextual and heterogeneous" *Features of Science (FOS)* in order to avoid

- "The confused jumbling together of epistemological, sociological, psychological, ethical, commercial and philosophical features into a single NOS list.
- The privileging of one side of what are contentious and much-debated arguments about the methodology or 'nature' of science.
- The assumption of particular solutions of the demarcation dispute.

- The assumption that NOS learning can be judged and assessed by students' capacity to identify some number of declarative statements about NOS." (Matthews, 2012, p.4)

Additionally, Matthews also criticizes the narrow selection of tenets among a long list of epistemological, economic, technological, historical, social, and psychological characteristics of science, especially if the known tenets were originally put forth with an intention to depict features of science. Therefore, in his account experimentation, idealization, models, values and socio-scientific issues, mathematization, technology, explanation, worldviews and religion, theory choice and rationality, feminism, realism and constructivism aspects were added to the incomplete aspects addressed by the consensus view. Matthews (1998) also underscores the intertwined nature of science and philosophy and asserts that learning science necessitates including philosophical issues whether it be explicitly or implicitly. For teaching NOS, Matthews (2012) also suggests fostering students to do research of successful scientists and reflect on their cases by themselves since this would enhance their self-regulation.

To sum up the three major views for NOS in science education literature, previously, a simpler acknowledgement of the agreed-upon principles was seen as the appropriate method of representation of science in the classrooms. This simpler articulation is known as the consensus view. Reviewing Whole Science and FOS accounts indicates that, this widely held view has been changing to a more comprehensive direction based on the criticism of shallow coverage of the intricate nature of science. Another major milestone on the road to accurately teaching NOS is reconceptualized family resemblance approach (FRA) to nature of science by Erduran and Dagher (2014). Since it is the theoretical framework of this study, Erduran and Dagher's (2014) reconceptualized FRA will be investigated more in-depth with its theoretical roots and cognitive-epistemic and social-institutional categories in the following sections. For brevity, to refer to this approach, the term of 'Reconceptualized FRA-to-NOS (RFN)' which has been coined by Kaya and Erduran (2016) will be used.

2.2. Integration of Family Resemblance Approach (FRA) to science and science education

From the previously mentioned approaches to NOS, this study builds on family resemblance approach (FRA) and more specifically RFN framework of Erduran and Dagher (2014) because RFN proposes

- a systematic approach and an organizational scheme for relating different characteristics of NOS in a coherent manner,
- widespread integration of NOS into science education through both vertical and horizontal articulation,
- the coherent theoretical justification for the relevance of each category to educational settings through review of science education literature and education policy documents
- simultaneous recognition of domain-specific and general characteristics of different branches of science,
- generative images of science as guides for instruction and curriculum design
- wider web of categories encompassing epistemic-cognitive and social-institutional aspects of science (Dagher & Erduran, 2017, p.47-49)

Based on the previous discussions of assumptions underpinning the consensus view, an opportunity for broader scope may be the most crucial contribution of using family resemblance as an approach to NOS. Consequently, RFN which builds on FRA focuses not only on the scientific methods, practices and knowledge or any sample combination of these aspects, but it also encompasses all of the aspects proposed by science educators who advice a holistic coverage. In their commentary, Dagher and Erduran (2017) compared the scope of their framework with alternative approaches of Hodson, Sandoval, Allchin, and Matthews. According to the cluster illustration (Figure 2.1) they have presented, the scope of FRA accommodates all the aspects represented by other approaches. In the figure, only the circle representing FOS has an edge over the FRA. This is due to realism, constructivism and feminism philosophical positions taken by Matthews (2012) while FRA remains neutral on such grounds (Erduran & Dagher, 2014).

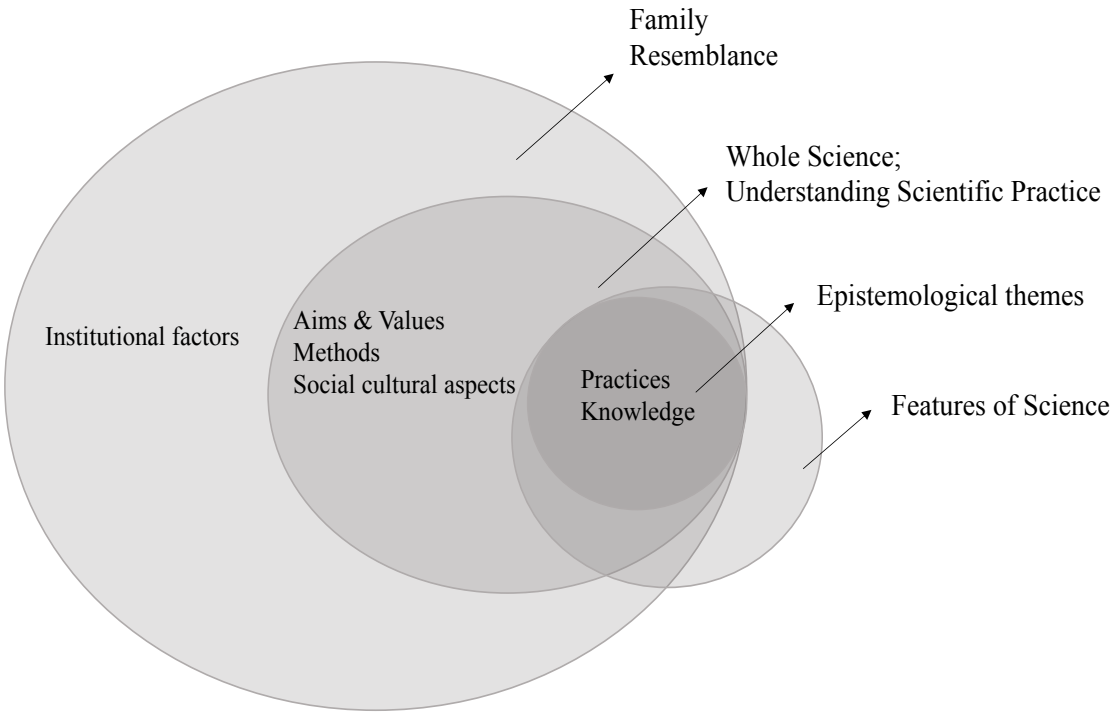


Figure 2.1. The scope of FRA relative to other alternative views of NOS.
Source: [Kaya, Erduran, Aksoz & Akgun, 2018, p.5]
Adapted from: [Dagher & Erduran, 2017, p.49]

In order to understand the significant contributions of RFN framework, its theoretical background should be further investigated. For this aim, firstly, family resemblance notion, FRA to sciences as rationalized by Hacking (1996), and FRA to NOS of science education as proposed by Irzik and Nola (2011; 2014) will be explored in the next subsection. Then, in the following two subsections, Erduran and Dagher's (2014) reconceptualization of FRA to NOS and family categories they have proposed will be presented separately.

2.2.1. The idea of family resemblance and family resemblance approach

The family resemblance is a philosophical notion whose popularity is attributed to Ludwig Wittgenstein although it is known to be in use since the 1930s in taxonomy and philology. Wittgenstein (1958) explains the use of family resemblance notion for the philosophical problem of universals through the example of games. Accordingly, there is no one essential trait which all games share. For example, while playing different games people use different tools and different parts of their body, and they abide by different rules.

Likewise, there is no one criterion that can separate games from other human activities. For this reason, he proposes the use of family resemblance to elucidate the boundaries between complex constructs that are hard to demarcate as in the example of games.

The family resemblance has been also used to alleviate the issue of demarcating science from non-science and pseudoscience, and different domains of science from each other. Appreciating and addressing domain specific characteristics of science is crucial in understanding the nature of science because they are so diverse that some scientists and philosophers of science consider domains of science to be *sciences* (Hacking, 1996). On the other hand, they also share some traits such as observation, experimentation and classification although they are conducted in various ways specific to those domains. Therefore, the family resemblance approach is a good way to systematically and accurately represent the nature of science.

Eflin, Glennan and Reisch (1999) describe the essentialist view of science which presupposes that there is "one essence of nature or set of criteria that describes all and only the activities and inquiries that count as science." (Eflin *et al.*, 1999, p.107). According to Eflin *et al.* (1999), this view cannot be maintained therefore philosophers and educators of science turn to philosophically pluralistic accounts of science such as the family resemblance approach. On the other hand, they also call for caution when a philosophically pluralistic account is presented to the students since it can lead to overly simplistic pluralism that would raise issues for demarcating science, non-science and pseudoscience.

Hacking (1996), and Irzik and Nola (2011; 2014) both advocate for using family resemblance as a philosophical approach to conceptualize science but they come up with different frameworks. In the following, both of these accounts will be presented in order to exhibit how FRA can be used to represent science and present the ground on which theoretical framework of this study, RFN, is settled.

2.2.1.1. Hacking's conceptualization of science. In his attempt to describe science accurately Hacking (1996) asserts a metaphysical sentiment, metaphysical unity, three practical precepts and six scientific reasoning styles under which he discusses how different sciences use them from the perspectives and disputes of historically well-known scientists and philosophers of science such as Comte, Aristotle, Carnap, Popper and Lakatos. From his

survey of these perspectives, he suggests using a philosophically pluralist account which is the family resemblance approach of Wittgenstein in his choice when it comes to the the reconciliation of various issues he presents. Therefore, in a sense, unity, practical precepts and reasoning styles are the family categories in his conceptualization of science.

In the words of Hacking metaphysical sentiment is that “there is one world susceptible of scientific investigation, one reality amenable to scientific description, one totality of truths equally open to all scientific inquiries who may share their techniques and experiences.” (Hacking, 1996, p.44). This metaphysical sentiment is carried by unifiers and declined by proponents of disunity. He explains metaphysical unity through four theses: structure, interconnectedness, taxonomy and instrumentalist thesis. Accordingly, for unifiers, all systems of classification should mesh and there should be one structure that binds the causes of phenomena and laws of nature. Although he contests unity by asserting that unity connotes singleness and therefore it cannot be a virtue of perfection, he regards harmony in high esteem. Therefore, he believes that harmony is what scientists seek in the structure of explanations for natural phenomena. He also mentions that instruments also bring innumerable branches of science together in that there are widely shared family of experimental practices and instrumentation between them.

Practical precepts are global reductionism, local reductionism and linguistic precept that regulates methods, aims and logic of scientists. Through global and local reductionism precepts some scientists converge in logical and methodological maxims. The methodological maxim refers to the scientific method myth and it is opposed by Hacking along with logical maxim of unifiers. Linguistic precept refers to a maxim which connects sciences with a scientific language which according to Hacking (1996) is not attainable because of the specificity of the language used in different sciences.

In order to dispute the existence of only one acceptable way to find out about the world and how it works, Hacking (1996) presents six scientific reasoning styles used by various scientists differently depending on the nature of phenomena with which they work. These six reasoning styles as listed by the author are “(a) postulation in the axiomatic mathematical sciences, (b) experimental exploration and measurement of complex detectable relations, (c) hypothetical modeling, (d) ordering of variety by comparison and

taxonomy, (e) statistical analysis of populations, and (f) historical derivation of genetic development." (Hacking, 1996, p.65).

2.2.1.2. Irzik and Nola's family resemblance approach to NOS. Irzik and Nola (2011) have also resorted to Wittgenstein's family resemblance approach to describe nature of science in hopes to resolve the demarcation issue of science from other human endeavors without sacrificing its rich complexity. Their rationale for using this approach was that defining the boundaries of science and non-science is not as clear cut as a declarative approach would demand since "there are a few core characteristics that all the sciences share (data collection and inferences, for instance), but they are not sufficient either to define science or to demarcate it from other human endeavors." (Irzik & Nola, 2011, p.595).

The two philosophers of science had initially described science in terms of its activities, aims and values, products, methodologies and methodological rules. In their later work, Irzik and Nola (2014) have expanded the reach of their first conceptualization by also emphasizing 'science as a social system' through the additional categories of professional activities, scientific ethos, social certification and dissemination of scientific knowledge and social values. Moreover, they have also changed the names of the categories of activities and products to processes of inquiry and scientific knowledge, respectively. Table 2.1 below shows the later version of their family resemblance framework (Irzik & Nola, 2014, p. 1009). All in all, in their comprehensive approach they represent science both as a cognitive-epistemic and social system. But they also leave room for improvement based on the suggestions of other philosophers and educators of science. They also report that the categories they propose are not mutually exclusive, on the contrary, they are complementary for building a fuller representation of science. Categories in the framework of Irzik and Nola (2014) broadly coincide with those of RFN framework. Therefore, their individual investigation is left to the review of respective RFN categories under the second subsection of the next part.

All the aspects discussed by Hacking (1996) and both conflicting and complementary perspectives he shares builds a comprehensive picture of science. Likewise, the argument he builds is grounded in the philosophy of science literature. On the other hand, his organizational scheme is not very clear. In contrast, the framework of Irzik and Nola (2014) conveys a clear structure. It also includes both domain-specific and general characteristics

of science, practical precepts and changing of scientific reasoning, at varying degrees under the eight categories. For these reasons, it would be easier to benefit from Irzik and Nola (2014) FRA framework in the contexts of science education research and classroom.

Table 2.1. Categories of FRA to NOS framework of Irzik and Nola (2014).

Science as a Cognitive-Epistemic System	1 Processes of inquiry 2 Aims & Values 3 Methods & Methodological Rules 4 Scientific Knowledge
Science as a Social System	5 Professional Activities 6 Scientific Ethos 7 Social Certification & Dissemination of Scientific Knowledge 8 Social Values

2.2.2. Reconceptualized Family Resemblance Approach to NOS

Erduran and Dagher (2014) extended the Irzik and Nola's family resemblance approach to nature of science in order to make it more holistic by highlighting science as a cognitive-epistemic *and* social-institutional system. In their reconceptualized version, the category of "processes of inquiry" category became scientific practices, aims and values became the touchstone of the teaching approach, and the social aspect was broadened with following institutional categories: social organizations and interactions, political power structures and financial systems. With this reconceptualization, they have built a meta-level perspective to conceptualize NOS for science education and built a holistic picture of science as cognitive-epistemic and social-institutional system. In the words of its authors "One of the appealing aspects of the FRA is its ability to consolidate the epistemic, cognitive and social aspects of science in a wholesome, flexible, descriptive but non-prescriptive way." (Dagher & Erduran, 2017, p. 24). This reconceptualization has significantly changed the FRA to NOS framework of Irzik and Nola, therefore Kaya and Erduran (2016) coined the term "Reconceptualized FRA-to-NOS" and RFN abbreviation in order to signify this transformation.

Table 2.2. Articulation of FRA categories across science topics in Science: Programme of Study for Key Stage 4 from England.
Source: [Erduran & Dagher, 2014, p.172]

Category	**Science Topic**		
	Cell biology	Periodic table	Energy
	The importance of stem cells in embryonic and adult animals and of meristems in plants	*Predicting chemical properties, reactivity and type of reaction of elements from their position in the Periodic Table*	*National and global fuel resources, renewable energy sources*
Aims and values *e.g. Empirical adequacy*	Use data on stem cells to determine how they influence embryo development	Use data on the physical and chemical properties of elements to conclude which elements they belong to	Use data on fuel resources and how they provide energy
Practices	Discuss similarities and differences between experiments and simulations performed in class and those done in academic or industrial labs	Generate classifications of elements on the basis of their physical and chemical properties; consider how different classification and arrangements of the elements in the Periodic Table illustrate different trends in properties	Generate classifications on the pros and cons of different energy sources and their risks to environment. Generate representations of data produced by scientists noting aspects of practices that explain differences between communities
Methods	Compare the different methods scientist use to conduct stem-cell research. Discuss manipulative methods, compared to non- manipulative methods	Conduct experiments to compare chemical reactions of different elements e.g. oxidation and solubility in water	Discussion and comparison of energy production techniques based on a range of energy sources like solar, wind and nuclear energy

Table 2.2. Articulation of FRA categories across science topics in Science: Programme of Study for Key Stage 4 from England (cont.).
Source: [Erduran & Dagher, 2014, p.172]

Category	**Science Topic**		
	Cell biology	Periodic table	Energy
	The importance of stem cells in embryonic and adult animals and of meristems in plants	*Predicting chemical properties, reactivity and type of reaction of elements from their position in the Periodic Table*	*National and global fuel resources, renewable energy sources*
Knowledge	Consider how stem cell theory fits in with other theories, and how new explanatory models in this area revised our understanding about cell growth and development	Consider the variation between the columns and periods of the Periodic Table and what they indicate about chemical and physical properties of elements	Consider the nature of different sources of energy and compare their efficiency in generating energy
Social-institutional *e.g. Economical, ethical*	Discuss impact of stem cell research on the health sector, medical field, and personal decisions; ethical issues arising from stem cell research; funding issues (public *v* private) and knowledge ownership	Predict the personal and environmental safety of chemicals and hold institutions responsible for ethical disposal of chemical waste Consider the economic impact of some chemicals (e.g. in food processing industry, in air) on personal and public health	Consider the political and economic interests governing the use of national and global energy resources, investment in researching green energy sources

Erduran and Dagher's (2014) approach emphasis a widespread and systematical integration of all categories they have proposed into science education. They suggest the articulation of the categories to be both vertical and horizontal as the family categories emerge in the curriculum content. One example they have shared can be found in Table 2.2 on the previous two pages. In this table, they have shown the ways in which five family categories could be articulated in three different contexts during the key stage 4. They could identify opportunities for inclusion of scientific practices in all of these contexts: cell biology, periodic table and energy. While making connections, they have chosen to highlight experimentation in the cell biology context and classification in the periodic table and energy contexts. These choices show that the context is an important factor in choosing appropriate connections to NOS categories for the RFN framework. It is also worth mentioning that Erduran and Dagher (2014) were able to establish connections for all RFN categories. This shows that incorporating RFN categories into science education classrooms is a matter of noticing and framing of the content and activities rather than an issue of lack of context.

According to Erduran and Dagher (2014), NOS, as represented in science education, should not diverge too far from the way it is accounted in the philosophy of science and other relevant disciplines. In their epistemologically grounded characterization of NOS, disagreements between scientists and philosophers of science for the characteristics of various domains of science is also a part of the science education. This is a quality that differentiates RFN approach from Consensus View and Whole Science accounts discussed earlier and connect to other proponents of family resemblance approach, Hacking (1996) and Irzik and Nola (2011).

RFN framework has also introduced Generative Images of Science (GIS) for different family categories as pedagogical tools. The suggestions and examples for the articulation of RFN categories in formal education along with other educational implications regarding instruction, curriculum and assessment issues made RFN framework more applicable in educational settings in contrast to the alternative approaches. Therefore, through Erduran and Dagher's (2014) efforts educational applications of the family resemblance approach became more grounded.

2.2.3. RFN categories

In this subsection, five family categories proposed by Erduran and Dagher (2014) are further investigated. These are aims and values of science, scientific practices, methods and methodological rules of science, scientific knowledge, and science as a social-institutional system. The latter includes seven subcategories which are scientific ethos, professional activities, social certification and dissemination, social organizations and interactions, political power structures, and lastly, financial systems. All main five categories are represented in the FRA Wheel (Figure 2.2) which is one of the six GIS developed as a part of the RFN framework. The other five will be introduced under the respective categories. The following is a brief discussion of key philosophical and educational issues regarding these categories.



Figure 2.2. FRA Wheel: Science as a Cognitive-Epistemic and Social-Institutional System. Source: [Erduran & Dagher, 2014, p.28]

2.2.3.1. Aims and values of science. Aims and values of science represented in the RFN framework have epistemic, cognitive, cultural, social, political, and ethical aspects. Cognitive-epistemic values guide research and they are hard to discriminate. Science as an activity of scientists is bounded by the values of social-cultural milieu. It is also dominated by politics which can hinder or foster the growth of scientific knowledge through legislation.

Moral and ethical norms mediate the socio-cultural context in which science functions although science does not aim to reciprocally alter their course. Nonetheless, science can produce or necessitate a new set of values as a consequence of controversies created in society by new discoveries. RFN's triangular representation (Figure 2.3) of epistemic, cognitive and social values refers to this intertwined nature.

When there is an equal amount of evidential support for opposing theories, individual priorities of the scientists can cause conflict and create ambiguity over theory choice. Therefore, individual subjectivity of the scientists has been a concern for objectivity and accuracy of scientific knowledge. On the other hand, Allchin (1999) and Longino (1995) assert that diversity caused by individual points of views makes science a self-correcting mechanism and therefore more objective. FRA promotes the understanding of this self-correcting mechanism by explaining the family resemblance between the aims and values guiding science and scientists (Irzik & Nola, 2011). From this point of view, like different domains of science values cannot be demarcated with clear-cut boundaries. An obligation highlighted by Popper (1957), addressing anomalies and counter instances, is crucial in achieving objectivity through a kaleidoscope of individual points of views. This process has been also referenced in the social certification and dissemination category of RFN and Longino's (1993, 2002) procedural standards.

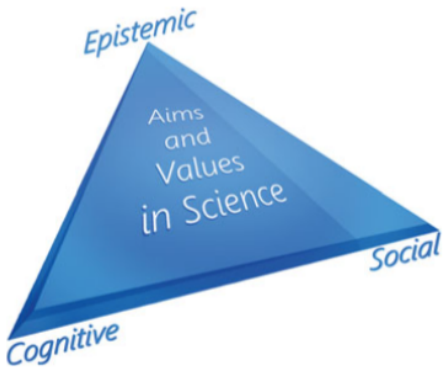


Figure 2.3. GIS for Aims and Values in Science.
Source: [Erduran & Dagher, 2014, p.49]

Erduran and Dagher (2014) assert that contextualizing the discussions within the works of philosophers adds to the fruitfulness of the educational applications. According to them, aims and values of science is a must to transform for classroom by cultivating

knowledge from the philosophers of science in order to (1) inform students that science is a discipline bound by the aims and values of those involved, (2) facilitate sustainable acquisition of epistemic values as a habit of mind, (3) forewarn about the bias that may lay in data and information that could stem from values and aims of the people involved in generation and communication processes of scientific knowledge. Therefore, even though RFN is an educational perspective, in discussing issues such as the aims and values of science, references to the philosophy of science is frequent. This is also the reason why they have given priority to aims and values of science in the sequential order of their framework while reconceptualizing Irzik and Nola's FRA.

Centralized education systems tend to focus on easily assessable, knowledge-level skills in the expense of deeper understanding. Since it is hard to critique the aims and values one might hold or have knowledge of, this aspect of NOS is frequently overseen. Moreover, students also come to the classroom with their personal belief systems and their beliefs might clash with the scientific ones. Therefore, delving into the aims and values of science might be time demanding for teachers. Various curricula such as AAAS document (1989) have focused on promoting an understanding of aims and values of science but their attempts were vague and they were not engraved throughout the learning processes such as assessment and revision (Erduran & Dagher, 2014). Inclusion of this aims and values of science could be more effectively done by integrating them into the classroom culture and using sample statements in scaffolding or assessment rubrics (Longino, 1990). Another way to underscore the values guiding scientific reasoning would be to have discussions on historical conflicts by contextualizing them through biographies of major figures.

2.2.3.1. Scientific practices. In the preceding years, science curricula would represent science through either its products or as a functioning process. This mutually exclusive approach to products and processes of science would not be fruitful in representing holistic nature of science. Therefore, Erduran and Dagher (2014) re-expressed them as scientific practices by integrating these two aspects. Among the scientific practices listed by Erduran and Dagher (2014), scientific activities which are experimentation, observation and classification already have a place in science curricula although their representation is too narrow and detached from the processes of scientific knowledge growth. Consequently, their implementation in the classroom does not go beyond cookbook investigations (Chinn & Malhotra, 2002).

Irzik and Nola (2011) first mentioned about scientific practices as scientific activities which they have separated into two: material practices and mathematical practices. Then, in their later work, the authors' scientific activities became the processes of inquiry (Irzik & Nola, 2014). While making the transition to scientific practices, Erduran and Dagher (2014) asserted that "embeddedness in broader theoretical frameworks and interconnectedness in epistemic, cognitive and social-institutional mechanisms are the defining features of scientific practices" (Erduran & Dagher, 2014, p. 71). In this regard, observation as a scientific practice diverges from observation as an everyday activity by its theory-ladenness and at times by the use of instruments such as microscopes and telescopes.

Classification "is the meaningful clustering of experience" in order to facilitate the production of knowledge (Kwasnik, 1999, p. 24). Branch structures and maps are already commonly used in classrooms as schemes of classification. Periodic table of elements could be given as an additional example since its contextualization in the history of science anecdotes can also emphasize the socio-cultural elements in its development. Like observation, classification differs from its everyday counterpart, sorting, through its reliance on theory.

According to Radder (2009), experimentation is intervening in the world of materials and producing new processes, substances, objects and phenomena. It often takes place in the classroom as a demonstration by the teacher or cookbook procedures followed by the students. On the other hand, this practice can reinforce the myth of scientific method.

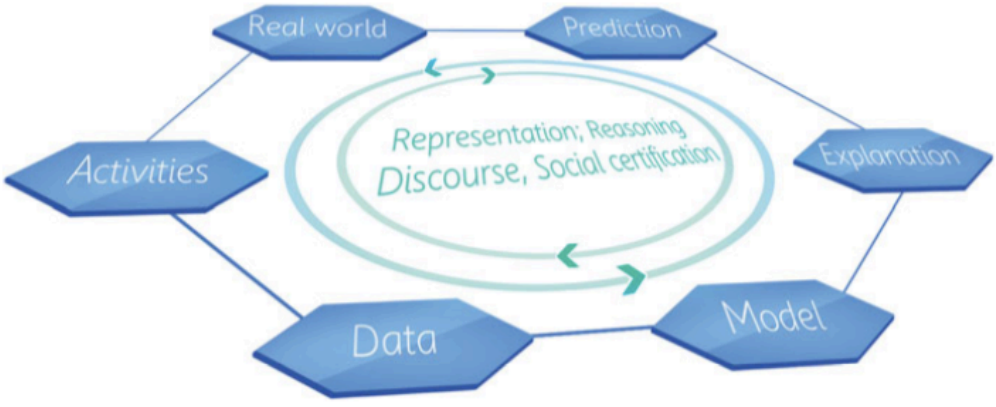


Figure 2.4. GIS for Scientific Practices.
Source: [Erduran & Dagher, 2014, p.82]

The GIS which presents all of the scientific practices asserted by Erduran and Dagher (2014) is shared as Figure 2.4. *Activities* embody observation, classification and experimentation. As shown in the figure, other scientific practices in the framework are *real world*, *prediction*, *explanation*, *model*, *data*, *representation*, *reasoning*, *discourse* and *social certification*. The GIS was generated with an analogy to the benzene ring in which carbon atoms represent scientific practices and the constantly flowing electrons are analogous for the interrelatedness of the practices. Therefore, representation, reasoning, discourse and social certification was located in the middle to draw resemblance to the behavior of the electrons since they are engraved into all of the scientific processes. In its designers' words, the image (a) communicates a dynamic set of interactions between the data, models, explanations and predictions that underlie the characterizations of phenomena occurring in the real world, and (b) it integrates the social-institutional and cognitive processes that mediate such interactions through discursive practices like argumentation as well as norms such as social certification." (Erduran & Dagher, 2014, p. 85).

2.2.3.3. Methods and methodological rules of science. In order to conduct authentic inquiry activities, diversity of scientific methods and complexity of methodological rules should be introduced in the classroom. The prevalent instruction in classrooms reinforces an algorithmic image of science and therefore, devaluates the credibility of studies which does not follow the steps of 'the scientific method' such as studies on the theory of evolution on the basis that they don't involve manipulation of variables or testing hypothesis. Moreover, the way the teachers and public refer to doing something scientifically can unintentionally reiterate this confusion without knowledge of the plurality of scientific methods. Still, there are opponents of pluralism in the classroom who claim that it would be cognitively demanding and therefore side with a simpler articulation.

Choice of methodology is affected by the aims of the studies and cognitive-epistemic and social values and scientific ethos. For example, the ethos of doing no harm and accuracy as a cognitive-epistemic value of science can guide the choice of methodology. Likewise, method choice can be affected by available technological instruments.

Emphasis on this diversity of methods and how and in which situations they are utilized is important for students to understand. Likewise, students should also know that there are different sources of evidence: direct, circumstantial and historical that go through

the process of evidential consilience. These can be pointed out in the historical examples of theory, law and model building by the renowned scientists. Involving students in authentic problem solving activities can give them opportunities to experience the necessity and credibility of the non-manipulative and descriptive methods of investigation for the growth of scientific knowledge. An explicit emphasis on the theoretical background of the scientific practices such as observation and classification can also build trust.

The GIS developed by Erduran and Dagher (2014) for methods and methodological rules of science category (Figure 2.5) demonstrates how scientific methods interact with each other and it can aid the attainment of this learning goal. For example, the image could be altered based on the methods used by the students during the activities. Likewise, Brandon's (1994) matrix can also be used to represent the intertwined relationship between data, testing and manipulation.



Figure 2.5. GIS for harmonious working of evidence from variety of Methods.
Source: [Erduran & Dagher, 2014, p.101]

2.2.3.4. Scientific knowledge. Scientific knowledge is the product of the scientific enterprise. It consists of theories, laws and models which when combined become a whole (TLM) that is bigger than its parts in predictory and explanatory capacity. Scientific endeavors enrich this dynamic body of knowledge leading to knowledge growth. One aim of science education is to help students understand the processes behind the growth of scientific knowledge. On the other hand, this aim has not been widely achieved in the classrooms. To alleviate this problem Erduran and Dagher (2014) propose to present scientific knowledge as TLM, a framework that underscores the growth of scientific knowledge and interdependency of theory, laws and models in explaining real world phenomena. TLM approach also entails involving discussions regarding classification of knowledge forms (e.g. levels of theories,

nature of models), their relationship with each other and domain-specific nuances between them, as well as explanatory pluralism and evaluation of scientific knowledge. Figure 2.6 below presents the GIS developed by Erduran and Dagher (2014) for the scientific knowledge category. It is aimed to transfer the interdependency of theories, laws and models in explaining natural phenomena and development of scientific understanding through paradigm shift and cumulative development. Each block containing a set of theories, laws and models constitute a state of understanding and addition of other blocks is evocative of other sources of knowledge such as different domains of science and a shift in paradigm with new discoveries. In contrast, the upward spiral connotes cumulative development in scientific understanding.

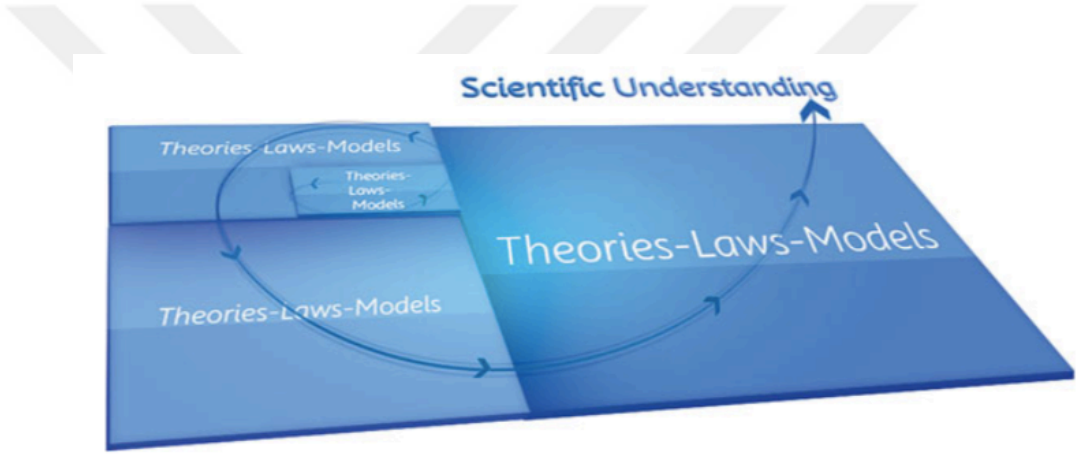


Figure 2.6. GIS for TLM, growth of Scientific Knowledge and scientific understanding. Source: [Erduran & Dagher, 2014, p.115]

Widely used expressions of daily language such as “It is *just* a theory!” can give rise to the misbelief that theories are inferior to laws. One solution to this problem could be revisiting epistemological foundations of knowledge forms and introduce the levels of theories from fringe theories to established theories and acknowledge the developmental process between them. This stand can be illustrated by introducing the background of the renowned theories. It would be also helpful if students are familiar with the aims and methods of scientific knowledge development. Moreover, students should also know about the nature of models and the functions of different types of models as proposed by different philosophers of science so that the ultimate aims of explaining and predicting natural phenomena can be emphasized in contrast to the prototypes. Another distinction to be made is domain-specific nuances in the articulation of theory, laws and models. Such differences are (a) being universally true versus having many exceptions, (b) being axiomatized in

mathematical terms versus being expressed qualitatively, (c) reaching approximate or ultimate explanations and (d) whether if the predictions made from TLM in the domain follows a deductive order. Any of these domain-specific characteristics do not indicate inferiority in the part of one domain to the other. What is of importance here is the interconnectivity between TLM components in and between different domains.

Considering the preceding discussion, a good classroom application would require emphasizing explanatory and predictory capacities of TLM components, engaging students in evaluation of TLM and its components, building on textbooks instead of religiously following them, considering and representing models as conceptual tools and enabling students to experience consilience of different kinds of explanations in the case of explanatory pluralism by proposing their own justifications for possible different explanations of the same phenomena. The ultimate aim would be to embed the idea that "science has a 'family' of scientific knowledge forms and at the same time, possesses diversity in its articulation in different disciplines." (Erduran & Dagher, 2014).

2.2.3.4. Science as a Social-Institutional System. Conducting and evaluating science is not simply utilizing discrete sets of information and therefore the learning of science should not be solely based on memorization. Instead, holistically conveying nature of science and its practices should be the goal of science education in order to promote critical review of scientific findings, ethical awareness and a broader understanding in students. With this reasoning, Erduran and Dagher (2014) have built on the framework suggested by Irzik and Nola (2014) by adding wider institutional, political, and economic aspects of science which are placed in the outer shell of the FRA Wheel. All social-institutional categories proposed by Erduran and Dagher (2014) for a holistic account of nature of science can be seen in Figure 2.7.

Students may benefit when how scientists organize science socially and their professional activities are recreated in an inquiry-based classroom environment. For example, by being involved in authentic activities they can learn different social values and norms that drive scientific communities. Presentation and sharing of students' own work, evidence-based reasoning and argumentation is already being used to a degree by science teachers. Additional student activities suggested by Erduran and Dagher (2014) include "attending meetings outside the perimeters of the classroom, publishing findings, reviewing research

papers, grant applications, writing research proposals and seeking funding" (p. 161). These activities would yield better opportunities to engage with science and understand its foliated nature and the political, financial and institutional factors that are often overseen.



Figure 2.7. GIS for Science as a Social-Institutional System.
Source: [Erduran & Dagher, 2014, p.143]

Erduran and Dagher (2014) suggest educators try and better integrate these components of science to the teaching content by using different teaching materials and approaches instead of adding them on top of the current content. By integrating nature of science throughout the years, students could have more motivation and realistic expectations for going into science-related areas. Another goal of teaching science holistically would be educating the future citizens and giving them a voice by making them realize their important contributions to the economy and democratic rights for decision-making in issues such as allocation of tax-revenues to development of scientific enterprise.

2.3. Research conducted with RFN as the theoretical framework

RFN approach has been used in teacher education research (Cullinane & Erduran, 2015; Kaya, Erduran, Akgun, & Aksoz, 2017; Saribas & Ceyhan, 2015), investigations regarding university students' understanding of nature of science (Akgun, 2018), and also

analysis of curricula (Erduran & Dagher, 2014b; Kaya & Erduran, 2016) and textbook (BaouJaoude, Dagher, & Refai, 2018, McDonald, 2017). There are also conference papers that report from studies that were built on RFN framework (Akgun *et al.*, 2017; Aksoz, Erduran, Kaya, & Akgun, 2018; Cilekrenkli, Kaya, Erduran, Akgun, & Aksoz, 2019; Tas, Cetin, Kaya, Erduran, Akgun, & Aksoz, 2016).

RFN framework has been also used in studies that involve school science teaching. Karabas (2017) investigated the effect of scientific practice-based instruction (SPBI) on fifty-six 7th grade students' perceptions of scientific practices and conceptual understanding of electric circuit concepts in a quasi-experimental study. The results of the study indicate that although the SPBI group performed better than the control group, the difference was not statistically significant.

Alayoglu (2018) working with her forty-two 5th grade students as a teacher-researcher, studied the impact of teaching science as a social-institutional system with RFN approach on students' understanding of the social dimension of science and their attitudes towards science. After the 4 weeks intervention period, she has found that teaching social-institutional aspect of science with RFN approach had a statistically significant positive effect on students' understanding.

Although there have been various empirical and theoretical studies concerning the RFN framework including its effectiveness in school science teaching, those studies focus only on social-institutional or scientific practices aspects of the framework. Since its holistic nature is one of its strengths, there should be studies investigating RFN framework as a whole. Such investigation would yield results about the relationship of different categories while also informing about horizontal articulation issues that other studies could not provide.

2.4. NOS as portrayed in the Turkish science education curriculum

Since RFN is a relatively new approach, there are only a few studies in the literature regarding curriculum analysis from the holistic perspective of RFN and only one of them is based on the Turkish curriculum (Erduran & Dagher, 2014; Kaya & Erduran, 2016). In their analysis of curricula, Kaya and Erduran (2016) have investigated the previous two middle school science education programs from Turkey: 2006 and 2013. Since then there have been

several changes to the lower secondary science education program while the latest has been published recently in 2018 (MEB, 2018a). Science education textbooks which are distributed by the Ministry of National Education to all students have been also changed following the changes in the curriculum. The latest Turkish science education program and the textbook will form the baseline of this study especially for the control group therefore, they will also be discussed in this section.

In order to investigate the inclusion of NOS through the scope of RFN framework, Kaya and Erduran (2016) firstly determined keywords that would represent respective RFN categories and then used those keywords to analyze the curriculum. As a result, they have summarized their findings in a comprehensive table, discussed the implications of these findings and made suggestions for revision. The table (Table 2.3) they have presented is shared here as it was presented by them in order to accurately convey their findings. Accordingly, while cognitive-epistemic categories were found to be embedded in the two curricula to some extent, the question marks indicate that they could not find any references to social-institutional categories of professional activities, social organizations and interactions, financial systems, and political power structures.

Moreover, 2013 curriculum (MEB, 2013) was reported to be more improved in terms of dealing with scientific practices as enactments in the classrooms through argumentation and discussion which is a more elaborate approach than merely scattering the key terms such as observation and experimentation. Kaya and Erduran (2016) also found that some statements attributed to some of the categories were vague in nature and accordingly, they have suggested that more explicit connections should be made.

According to the most recently published lower secondary science education program, students are expected to become competent citizens who contribute to ‘financial culture’, scientific research, technological advancement, competitive power and socio-economic development of the country (MEB, 2018a). These couldn’t be achieved without literacy and more specifically scientific literacy of the citizens. This issue is recognized in the program as ‘scientific competency’ which is defined as aptitude and attitude to utilize and enhance scientific knowledge accumulation and methodology with the aim of defining questions and finding evidence-based solutions by explaining the natural world. Additionally, there are 10 explicit items for specific aims of science education program.

Table 2.3. RFN categories in Turkish middle school science curricula from 2006 to 2013. Source: [Kaya & Erduran, 2016, p.1124-1125]

RFN category	Definition	Curriculum statements from 2006 (MEB 2006)	Curriculum statements from 2013 (MEB 2013)
Social certification and dissemination	The social mechanisms through which scientists review, evaluate, and validate scientific knowledge for instance through peer review systems of journals	"In the academic discussions in which the participants deal with the issue in detail, a reciprocal dialog and persuasion process happens." (pp. 61–62)	"To enable students' appreciation of how science is developed collaboratively among scientists from different cultures" (p. II)
Scientific ethos	The norms that scientists employ in their work as well as in interaction with colleagues	?	?
Social values	Values such as freedom, respect for the environment, and social utility	".to educate constructive, creative and productive individuals who are respectful of human rights and who value initiative, have social responsibility" (p. 2)	"Scientifically literate person is aware of how social values of the culture and societal structures and beliefs influence how knowledge is cognitively processed" (p. I)
Professional activities	How scientists engage in professional settings such as attending conferences and doing publication reviews	?	?
Social organizations and interactions	How science is arranged in institutional settings such as universities and research institutes	?	"The students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country" (p. 34)
Financial systems	The underlying financial dimensions of science including the funding mechanisms	?	?
Political power structures	The dynamics of power that exist between scientists and within science cultures	?	?

Table 2.3. RFN categories in Turkish middle school science curricula from 2006 to 2013. Source: [Kaya & Erduran, 2016, p.1124-1125] (cont.).

RFN category	Definition	Curriculum statements from 2006 (MEB 2006)	Curriculum statements from 2013 (MEB 2013)
Aims and values	The key cognitive and epistemic objectives of science, such as accuracy and objectivity	"The aim of science is to understand world and try to explain it; the aim of technology is to make changes in natural world in order to supply people's demands and needs" (p. 8)	"The teacher shares the value and importance of science, and the responsibility and excitement of arriving at scientific knowledge with his/her students and s/he leads research processes in the classroom" (p. III)
Methods	The manipulative as well as non-manipulative techniques that underpin scientific investigations	"Scientific methods include the processes of observing, constructing hypothesis, testing, gathering knowledge, interpreting data, and presenting findings" (p. 7)	"Inquiry process is addressed not just as exploration and experimentation but also as explanation and argument" (p. III)
Scientific practices	The set of epistemic and cognitive practices that lead to scientific knowledge through social certification	"- Observe objects and events by using sense organs or observation equipment. - Based on observation, inference, or experiments, suggests possible consequences. - Suggest an experiment to test a hypothesis. - Gather qualitative and quantitative data to test the hypothesis." (p. 77)	"In written and verbal discussions including opposing arguments, teachers' guide and support students in basing their claims on valid evidence and present them with substantiated justifications" (p. III) "The following skills that scientists use while doing science are included: observation, measurement, classification, data collection, hypothesis formation, use of data, construction of models, variation and control of variables, experimentation" (p. V)
Knowledge	Theories, laws, and explanations that underpin the outcomes of the scientific inquiry	"- Give examples for how scientific knowledge change and improve when new evidence are found. - Know the importance of using models to generate scientific knowledge and to present them to other people with the aim of explaining this scientific knowledge" (p. 73)	"To help understand how scientists formulate knowledge, what processes knowledge formulation undergoes and how scientific knowledge is used in new research" (p. II)

These are, in summary, obtaining information from various scientific disciplines; gaining scientific process skills and scientific approach to problems; raising sustainable development mindset for society, economy and natural resources; using acquired knowledge and skills in everyday life, career awareness and entrepreneurship skills; gaining knowledge of how scientists construct scientific knowledge, which processes does scientific knowledge go through, and how scientific knowledge is used in new studies; building curiosity towards natural phenomena; acknowledging importance of safety measures while conducting scientific studies; developing critical thinking and judgement by building on socio-scientific issues; and internalizing universal, national and moral values and scientific ethos (MEB, 2018a, p.9). For the purview of this study, especially the acknowledgement of scientific knowledge generation process, its use in future studies, and scientific ethos are significant.

Scientific practices such as model (5.1.1.2, 5.1.4.1), experimentation (5.3.2.2, 5.4.2.1, 5.4.3.2), classification (5.2.1.1), prediction (5.7.2.1), explanation (5.4.1.1, 5.4.3.2) and argumentation (5.1.2.2, 5.4.4.1) are also embedded in the program as learning goals (MEB, 2018a). Although the teaching of science still needs to be more explicitly contextualized in nature of science as a process, it has some aspects of science integrated into the activities. On the other hand, while the following scientific process skills are listed and covered in theory: observation, measurement, classification, data collection, forming hypotheses, controlling variables, using data, modelling, experimentation *as used by scientists,* this implicit inclusion may result in the omission of certain aspects in teaching and assessment. Likewise, because of this approach, teachers may conduct these activities as cookbook procedures and fail to link them to nature of science and the work of scientists.

Although cognitive-epistemic aspects of science are incorporated to some extent, socio-institutional aspects are not acknowledged in the program. On the other hand, the textbook yields opportunities for inclusion of scientific practices and scientific ethos. Nevertheless, these connections are vague and largely left to teachers' noticing of these opportunities since they are not well grounded in the texts or acknowledged in the learning goals of the program. This finding indicates that since the curriculum analysis conducted by Kaya and Erduran in 2016, there was little improvement in terms of representing a holistic image of science since social-institutional dimensions are still underrepresented.

2.5. Middle school students' views of nature of science

Views of nature of science is a frequently explored area of science education. On the other hand, a large portion of the associated literature is based on theoretical studies and most of the existing empirical research focuses on NOS understanding, perceptions and epistemological beliefs of teachers and upper-secondary students (Akerson *et al.*, 2019). For example, among the 105 research studies examined by Deng and his collogues only 7 of them were concerned about the K-6 students' views of NOS (Deng, Chen, Tsai, & Chai, 2011). Going forward, this poses a significant concern because as Akerson and her collogues (2011) pointed out there is a prevalent belief in science education milieu that some aspects of NOS are too complex for young students to comprehend and based on this presumption social-cultural embeddedness of science is underrepresented in the science education classrooms. This section aims to present empirical studies found about elementary and middle school students' views of nature of science conducted in Turkey and in the world.

Çelikdemir (2006) investigated elementary students' understanding of NOS. A total of 1026 sixth grade and 923 eighth grade students from six different middle schools participated in this study. The students' views of NOS were collected with a 10-item questionnaire focusing on tentative, subjective, and creative aspects of nature of science, social-cultural embeddedness of science, the difference between observation and inference, the difference between scientific theories and laws, describing science, demarcating characteristics of science, and the scientific methodology. The data gathered were elaborated with the interviews conducted with 12 volunteer students. The results of the study indicate that most of the students possess a traditional view of science. Accordingly, most of the students do not have an understanding that theories and laws are different scientific knowledge types. Moreover, most of the students believe in the scientific method myth that all scientific studies follow a predetermined set of methodological steps to achieve an accurate result. The results of the study may indicate a pattern of age-related learning progressions in NOS understanding as the sixth and eighth-grade students' scores for each aspect was significantly different. On the other hand, these results may also be caused by the extent of NOS related content the students had up until that point rather than a developmental readiness.

Bülbül and Küçük (2007) examined 50 fourth and fifth-grade students' views of scientific knowledge. The data was gathered with the "Scientific Knowledge Questionnaire". The researchers found that the students believe scientific knowledge to be certain. Students' inability to perceive the tentativeness of science as a body of knowledge may affect their attitudes towards science. Therefore, tentative nature of science has been a common theme in various accounts of NOS such as Consensus View, Whole Science, Features of Science, Family Resemblance Approach and Reconceptualized Family Resemblance Approach (Abd-El-Khalick, Bell, & Lederman, 1998; Allchin, 2011; Erduran & Dagher, 2014; Irzik & Nola, 2014; Matthews, 2012). As the issue of tentativeness of scientific knowledge has been found crucial and appropriate by all of these educators and philosophers of science to be included in their frameworks for NOS, the results of Bülbül and Küçük's (2007) study exposes the necessity to create learning opportunities for middle school students to enhance their understanding of growth of scientific knowledge.

Bağcı Kılıç and her collogues (2007) investigated the effectiveness of a summer camp program on NOS views of 38 students from grades 6th to 8th. The camp program included theoretically and conceptually grounded workshops on various disciplines. The students also conducted open-ended inquiry activities with the guidance of their program advisors. VNOS-D questionnaire (Lederman & Khishfe, 2002) was used to assess the effectiveness of the program. Accordingly, there was an improvement in students' views on the tentative and creative nature of science. On the other hand, although some students become able to grasp why individual scientists think differently, none of the students could differentiate observation and inference. These results are in line with those that were obtained by Khishfe and Abd-El-Khalick (2002). In their study, they have found that 4th and 6th grade students are not aware that scientists make inferences about appearances of the dinosaurs and the structure of the atom. These students believed that in order to learn about a natural phenomenon, scientists had to see it first. For example, they thought that scientists were sure about the structure of atom because they are able to see them with microscopes. The results of the two studies indicate that middle school students may have difficulty in grasping subjectivity of scientists. However, objectivity in science can be approached from two directions: the subjectivity of the individual scientists and global objectivity of science. These two values may seem clashing if they are not addressed with contextualized teaching approaches (Allchin, *et al.*, 2014). Therefore, the apparent difficulty of students from these contexts in understanding subjective nature of science may be caused by the instructional

strategies used with these students rather than being a direct consequence of students' cognitive ability to learn these ideas. The results of the study conducted by Özer, Doğan, Yalaki, Irez and Çakmakçı (2019) supports this view. Özer *et al.* (2019) designed and implemented a continual professional development program and assessed its effectiveness on 10 science teachers' and also their students' outcomes. The researchers obtained 5th, 6th and 7th grade students' views of NOS through VNOS-D (Lederman & Khishfe, 2002). As a result, the researchers found that when the teachers use contextualized activities with explicit-reflective instruction and formative assessment, the even the youngest (5th grade) students' views of subjective NOS statistically significantly enhanced as well as their views of empirical NOS, tentative NOS, observation-inference duality, and scientific models. Therefore, it can be inferred that students as early as 5th graders can learn about subjective NOS when appropriate instructional strategies are used.

Boz, Aydemir and Aydemir (2011) studied the relationship between students' epistemological beliefs regarding science and their grade level. A total of 427 students participated in the study and they were from fourth (*N*=147), sixth (*N*=160) and eighth (*N*=120) grades. Epistemological Belief Questionnaire of Conley, Pintric, Vekiri and Harrison (2004) was used as the data source. The results of the study suggest that students from all age groups had naïve views about the source of scientific knowledge. The naïve views of middle school students in terms of their epistemological beliefs regarding nature of scientific knowledge were also supported by Sadıç, Çam and Topçu (2012) and Özbay and Köksal (2015). Interestingly, Boz *et al.* (2011) found that as the students go through middle school education program their beliefs become less sophisticated in terms of development and justification of scientific knowledge. This might indicate that the education program or its poor enactment by the teachers may be imposing a narrow view of science especially in terms of the necessity of evidence in arriving at conclusions and difference of opinions among experts. Moreover, results obtained by Sadıç *et al.* (2012) and Özbay and Köksal (2015) in the following years may indicate that the problems of the planned or enacted curriculum has not been alleviated although the middle school science education program has been significantly changed at two times during this time (Kaya & Erduran, 2016).

Griethuijsen, van Eijck, Haste, Brok, Skinner, Mansour, Gencer and BouJaoude (2015) implemented a self-developed questionnaire in order to probe students' views of science and investigated its relationship with the students' interest in science. Participants of

the study were from 6 different countries: United Kingdom, Netherlands, Lebanon, Turkey, Malaysia and India. A total of 9171 student participants were dispersed across different primary and secondary grade levels. As a result, the researchers observed large differences between the NOS views of students from different countries. The students from outside Western Europe including Turkey presented an empiricist view of science. These students tended towards believing that scientists could solve most problems that they face, and scientists' explanations are indubitably true. Among all students, participants from Turkey were the ones who least frequently addressed that science is a collaborative endeavor. It should still be pointed out that highly empiricist views were detected among participants from all countries, although the desired views of science which are advocated by philosophers and educators of science are broader.

As can be seen from the reviewed literature, middle school students can struggle with various aspects of NOS. Presented studies indicate that it might be harder for students to understand subjective aspects of NOS such as different interpretations by the scientists based on the same data. Still, while shortcomings are pervasive in students' views of NOS, these can be alleviated with appropriate instruction during the middle school years. On the other hand, it should be pointed out that found empirical literature concerning middle school students' views of science is also narrow in its scope. Researchers generally focus on empirical, tentative, creative-imaginative, and subjective nature of science and characterization of observation, inferences and scientific models. Therefore, the resultant research focuses only (a part of) cognitive-epistemic and social aspects of science while there are no references for the institutional mechanisms. Going forward, researchers may focus on science from a higher vantage point, observing and fostering a more holistic view of science.

2.6. Summary of the literature review

In this chapter, various accounts and approaches regarding describing, teaching and learning of NOS were presented. Later, one of these approaches, Reconceptualized Family Resemblance Approach to Nature of Science (RFN) has been highlighted as the theoretical framework of this study with its theoretical foundations and the cognitive-epistemic and social-institutional categories it presents. It was followed by an analysis of the Turkish science education curriculum based on the RFN framework since it is related to the context

of this study. Lastly, the chapter was concluded by presenting studies related to middle school students' views of nature of science.

Three of the major contemporary accounts are briefly discussed in the first section. These are Consensus View, Features of Science and Whole Science (Abd-El-Khalick *et al.*, 1998; Allchin, 2011; Matthews, 2012). An argument has been built for a change in NOS teaching strategies from simplistic ones to more epistemically grounded, contextualized and holistic approaches based on the criticism and concern around solely depending on declarative statements. These concerns are related to oversimplification and shallow coverage, counterproductive nature for classroom use, posing unnecessary constraints for NOS teaching and diverging too far from the way science is accounted in philosophy of science and other relevant disciplines (Akerson et al, 2011; Allchin et al, 2014; Bell, 2006; Erduran & Dagher, 2014; Matthews, 2012, Metz, 1995).

The second section has been structured around an in-depth investigation of theoretical foundations of the theoretical framework of this study, Reconceptualized Family Resemblance Approach to Nature of Science (Erduran & Dagher, 2014). Firstly, the rationale for choosing RFN as the theoretical framework has been discussed. Then, the idea of family resemblance has been introduced. Accordingly, Hacking (1996) and Irzik and Nola's (2011; 2014) conceptualizations of family resemblance concept for describing nature of science were reviewed. The section concluded with an overview of the RFN framework and its cognitive-epistemic and social- institutional categories, respective explanatory images, and suggestions for their integration into educational settings.

The third section provides information about research conducted with RFN as the theoretical framework. The review of the literature indicated that although a part of research focusing on RFN approach has been conducted, there is a gap for studies that focus on RFN framework as a whole with its all cognitive-epistemic and social-institutional aspects in order to build a holistic picture of science. This way, issues regarding the horizontal articulation of categories could be addressed while trying to achieve widespread integration of all categories with respect to the curriculum subject matter.

Investigation of the NOS as portrayed in the Turkish science education curriculum in the fourth section indicated that the NOS connections in the curriculum were imprecise

and their articulation throughout the curriculum was not systematical. While the teaching of the scientific knowledge generation process and scientific ethos were mentioned as two of the specific aims of the Turkish science education program, the references for these aspects were again limited and vague. Likewise, social-institutional aspects of the NOS were underrepresented both in previous curriculum documents and the current one (Kaya & Erduran, 2016; MEB, 2018a).

The fifth section presents studies from Turkey and the world concentrating on middle school students' views of NOS. Review of literature suggests that while studies focusing on the views of teachers, teacher candidates and upper secondary students are abundant, the studies with younger students is scarce. Nonetheless, middle school students' views of NOS are generally found to be naïve. Still, students have the potential to improve with appropriate instruction. Lastly, the existing research narrowly focuses on cognitive-epistemic and social aspects of NOS and institutional aspects are not in scope.

Previous research indicates that students' views have potential to improve with appropriate instruction but teachers need resources along with experiences, planning time, knowledge of NOS, knowledge of subject matter and pedagogical knowledge (Abd-El-Khalick *et al.*, 1998; Lederman *et al.*, 2001). Because of the imprecise representation of NOS in the curricula in contrast to empirical studies that advise more holistic approaches, befittingly, there is a gap between research and teachers' practice in terms of NOS teaching. Therefore, more robust teaching approaches and materials are to be developed and tested so that a holistic view of science can become prevalent in science classrooms.

3. METHODOLOGY

3.1. Research Design

Design of this study is convergent parallel design mixed method study which is based on concurrently collecting and analyzing quantitative and qualitative data and interpreting them together in order to best understand a research problem (Creswell, 2012). The two strands of data inform each other as well as be separately used in assessing both outcomes and process of intervention as suggested by Greene and Caracelli (1997, p.7). Both qualitative and quantitative parts of the study followed a quasi-experimental design.

On the quantitative part, pretest, post-test and delayed post-test design was used in order to form a fuller image of change in students' understanding of nature of science (Creswell, 2012). The intervention lasted a total of 13 weeks and the post-test was conducted at the end of the intervention (Table 3.2). Delayed post-test was conducted 8 weeks after the implementation of post-test. The classes were previously formed by the school administration and therefore individual students were not randomly assigned to the experimental and control groups by the researcher. Instead, two of the already established classrooms was randomly assigned as control or experimental groups.

The qualitative part of the study was used in assessing "how the experimental intervention actually worked" (Creswell, 2012, p.535). Interviews with the students were conducted before and after the intervention in order to obtain a deeper understanding of the students' perceptions about NOS.

3.2. Participants

The data presented in this study was gathered from a total of 64 female students. In the following subsections firstly, characteristics of the teacher are presented since she was a major factor in the implementation of the designed instructional sequence and the selection of the student group. Then, the selection of the general student population and the interviewees is explained in detail. At last, relevant information the school in which the study conducted is presented in order to depict the context of the study.

3.2.1. The teacher

The participants of the study consist of a science teacher and students in two classes which she teaches. The teacher has been working for two years in the same school. She has also worked as one of the researchers on a project entitled “Nature of science in science teacher education: A comparative research and development project”, funded by Bogazici University Research Fund (Grant Number 10621) from 2016-2018 and conducted by Assoc. Prof. Ebru Kaya. In this project, they worked with pre-service science teachers for 14 weeks to investigate the changes in their RFN based NOS understanding through a teacher education intervention. They have also designed and conducted workshops for pre-service teachers in other universities. Hence, the teacher is familiar with this approach and its applications in science lessons. While this study was conducted, she was continuing her education in Adult Education Master program at the Boğaziçi University. She is published in academic journals and she participates in academic conferences. She is also working full-time as a science teacher. She had a total of 2.5 years long full-time science teaching experience at the beginning of this study.

3.2.2. The students

A total of 64 female, 5th grade students participated in this study and their age ranged from 10 to 11. The student participants in the study were chosen conveniently because of their teacher. The reason for choosing this specific teacher as the focus was her experience with RFN framework. In the school in which the teacher works, the grade level teachers work is assigned by the school administration. The teacher has been assigned to work with 5th grade students for the past year. Accordingly, two of the 5th grade classrooms were randomly assigned as experimental and control groups. These classes consisted of 40 students initially but some of the students dropped out of the school, changed classes for personal reasons or declined to participate in the study. A part of the initial participants were refugees who were attending grades that are below the norm for their age. These students were later relocated to upper grades by the school administration as an acceleration policy. As a result of this change, there was only one Turkish as a second language learner, and she was initially assigned to the control group. Since her second language skills were yet developing and she could not communicate her ideas well, her data were excluded.

Remaining participants whose data have been accounted for here were nearly equally distributed to control ($N = 33$) and experimental groups ($N = 31$).

In the current Turkish compulsory education system, students do not continue elementary and lower secondary classes in the same school. Fifth grade is the first-grade level of lower secondary school in this system and therefore participants of the study were adjusting to a new school. This might have affected the implementation of the instructional sequence because the teacher was not familiar with the students and she did not have any knowledge of the students' prior knowledge about science.

3.2.3. The interviewees

A total of 6 students from experimental and control groups were purposefully selected for the pre-intervention interviews based on their RFN Student Questionnaire score levels. Consequently, three students were interviewed from each group. These same students were also interviewed after the intervention. The score ranges for the low, middle and high understanding levels for the RFN Student Questionnaire is determined based on the distribution of overall grades of students who took the RFN Student Questionnaire in the piloting phase. In the second piloting procedure, the questionnaire was applied to 376 lower secondary school students. Overall grades of piloting study students have a mean of 127,57 and a standard deviation of 12,97. It has been observed that the overall grade distribution of control and experimental groups in this study is very similar to the normal distribution as expected with kurtosis values presented in Table 4.2 under the results section. Therefore, in order to represent the data, a normal distribution with the same mean and standard deviation is used instead. Then, two cutoff points separating students in three groups is determined in a way that the expected number of students in each group will be the same. This is done by choosing cutoff points such that the integral of the probability distribution function over the grade range is 1/3 for each group. This ensures that the probability of a student being assigned to one of any group is the same. After this calculation, split positions of the distribution were found to be 118.3 and 127.87. One student from each of the three score ranges was randomly selected for each of the control and experimental groups. These interviewees' scores were shared in Table 4.10.

3.2.4. The school as the context of the study

The school in which students are enrolled in is a religious lower secondary school in an underdeveloped region of Istanbul. According to the most recent statistics published by the Ministry of National Education (MoNE) regarding 2016-2017 school term, there are 2671 religious lower secondary schools and a total of 17879 lower secondary schools in Turkey. 287 of the total 1467 lower secondary schools in Istanbul are of this kind (MEB, 2017). This comparison is shown as percentages in Figure 3.1 below.

In comparison to general lower secondary schools in Turkey, religious schools differ in their heavier emphasis on religion-related courses. On the other hand, according to recently published MoNE reports there is no difference between the weekly science class hours which is determined to be 4 hours weekly for both school types (MEB, 2018c). On the other hand, while general lower secondary schools have 35 compulsory class hours weekly, religious schools have 36. Another difference is that religious schools are gender segregated. For this reason, in the school which is the setting of this study, while male students attend morning classes, females attend night classes. Consequently, the participants of the study are all female.

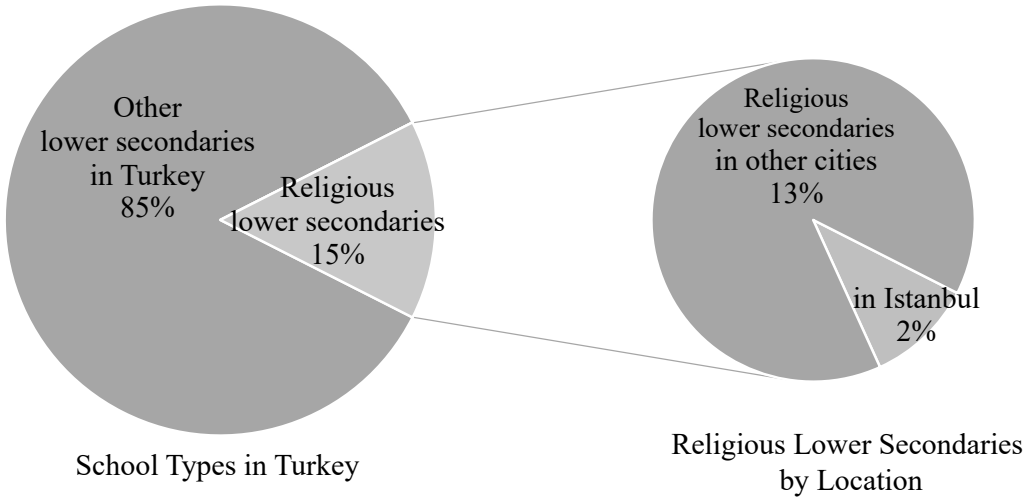


Figure 3.1. Percentages of Religious Lower Secondary Schools. On the left religious lower secondary schools in comparison to other lower secondary schools is shown. On the right percentages of religious lower secondary schools is shown based on their location in Turkey

3.3. Data Sources

Design of this study benefits from the use of both quantitative and qualitative data. The quantitative data source is the RFN Student Questionnaire. The qualitative data source is the student interviews.

3.3.1. Quantitative Data Source

3.3.1.1. RFN Student Questionnaire. The RFN Student Questionnaire (Appendix A) was administered as pre, post and delayed post-tests in order to assess students' understanding of cognitive-epistemic and socio-institutional aspects of science. Multiple administrations yielded results regarding the progress or regression in the understanding of students as a result of the intervention. This is a substantial aspect of the study for a thorough assessment of the outcomes. Results of the questionnaire were also used in comparing experimental and control groups.

Adaptation of RFN Student Questionnaire.

RFN Student Questionnaire was adapted for the purposes of this study from the 'RFN Questionnaire' that was developed by Kaya, Erduran, Akgun and Aksoz (2017). The RFN Questionnaire is a 5-point Likert type instrument which includes 70 items reflecting all five of the RFN categories: aims and values of science, scientific practices, methods and methodological rules, scientific knowledge, and science as a social and institutional system. The original RFN Questionnaire have reliability value of alpha .791. English version of the RFN Questionnaire may be found in their later paper Kaya, Erduran, Aksoz and Akgun (2018).

Original and adapted questionnaires were both devised in Turkish and the adaptation was required for age appropriation. The adaptation was done in an iterative process. In the first adaptation, some items were discarded based on relevance since they were pedagogically oriented questions directed to the teachers. After the linguistic appropriation for age was done by the researcher, the items were reviewed by two content experts in terms of their inclusivity of RFN categories and diverse issues for content validity. The first version of the revised questionnaire was piloted with 5 fifth grade students individually and 35

students as a group in order to get their feedback on the clarity of the items' meaning for them. Then, based on their feedback, the number of items was reduced, and the items were revised again. This second adapted version was then piloted with a total of 232 (160 male, 72 female) fifth-grade students and has been found internally consistent as a whole with the reliability value of .731 which indicates high reliability.

After the first phase of piloting, clarity of items was reviewed again. For this purpose, three 5th grade students from a public school in Istanbul has been interviewed. These interviews lasted about one hour, and they have guided the third cycle of revisions. One example of the suggested changes is for item number 33. The item was changed as following

- Piloted version: "Theory, law and models enable scientists to explain and predict different phenomena."
- Changed version: "Already established scientific knowledge enable scientists to explain and predict new phenomena."

The adaptation of the questionnaire was finalized to be piloted for a second time when an expert and the researcher reached an agreement in all items. After these final revisions, RFN Student Questionnaire was piloted for the second and last time. A total of 376 students from 5th to 8th grade and from three different schools in Istanbul took part in this assessment. As a result, the RFN Student Questionnaire, as used in this study, has been found reliable with Cronbach Alpha value of .733.

In the RFN Student Questionnaire, there are 5 items reflecting the category of 'Aims and Values of Science', 6 items reflecting 'Scientific Practices', 5 items reflecting 'Methods and Methodological Rules', 7 items reflecting 'Scientific Knowledge' and 14 items reflecting 'Social and Institutional Systems of Science'. The distribution of the number of items in the original and adapted questionnaires can be found below in Table 3.1.

As can be seen in Table 3.1, during the adaptation process the percentage of questions related to cognitive-epistemic categories has decreased. As a result, the RFN Student Questionnaire is more social-institutional category oriented than the RFN Questionnaire. This is not seen as an issue for the purposes of this study since the SI category includes 7 subcategories and the intention is to represent them in the assessment as much as possible.

Table 3.1. RFN Student Questionnaire item distribution according to categories.

RFN categories	Non-pedagogical questions in the RFN questionnaire	% Total	Questions in the RFN Student Questionnaire	% Total
Aims and Values	6	12	5	13
Scientific Practices	12	23	6	16
Methods and Methodological Rules	9	18	5	14
Scientific Knowledge	8	16	7	19
Socio-Institutional System	16	31	14	38
Total	51	100	37	100

The answers of five-point Likert scale change from "Strongly disagree" to "Strongly agree". The total score of the questionnaire change from 37 to 185. Increase in the score shows an increase in the understanding of NOS. The measure of this instrument is understanding (of NOS) and definition of understanding is taken as the 6th definition asserted by Lee (1947) such that "Understanding is the making of appropriate responses." (p.82). Accordingly, a student is said to have a better understanding of NOS when his responses to the questionnaire items are in line with the theoretical framework of the instrument, RFN.

3.3.2. Qualitative Data Source

3.3.2.1. Student interviews. Pre and post intervention interviews were conducted with the students. Students were selectively interviewed based on their RFN Student Questionnaire scores in the pre-testing. The aim of conducting interviews with students was to (a) get a fuller image of their understanding and (b) identify some factors related to the change in their understanding. Sample questions may be found in Appendix B.

3.4. Intervention

The intervention lasted a total of 13 weeks. It included the first 3 units of the 5th grade science curriculum: Sun, Earth, Moon and Their Movements; Classification of Living Things; and Measuring Force and Friction. In choosing these units it was aimed to start from the very beginning of secondary education. There were 4 lessons weekly with each of the

control and experiment groups and both of the groups were taught by the same teacher. RFN was used as a framework in order to determine learning goals, design activities and rubrics to assess students' competence in NOS in a holistic way. Planning of the lessons and development of teaching materials such as classroom activities, activity sheets and rubrics were done with the guidance of results from classroom observations, and student artifacts from previous weeks.

Lesson plans for the experimental group targeted specific learning goals extracted from the RFN framework and they were addressed with explicit connections to the curriculum subject matter during all classroom activities. RFN categories which were incorporated into lesson plans of the experimental group are aims and values of science, scientific practices, methods and methodological rules, scientific knowledge and social-institutional systems of science (Erduran & Dagher, 2014). While integrating these categories to already existing science content there was an effort to recreate scientific processes during the activities, involve historical case studies, give students opportunities to reflect on issues related to NOS, involve these issues also in the assessment, and benefit from the GIS developed by Erduran and Dagher (2014) as supportive visuals by using adapted, more simplified and Turkish versions of them. Especially the adapted version of the FRA Wheel was frequently referred to since it was used as a poster in the classroom. The original GIS were shared under the second section of the literature review and the adapted versions are presented in Appendix H.

As advised by the literature, contextualization of NOS learning in science content by recreation of scientific processes and historical case studies, reflection, use of visuals, assessment of NOS learning, a repeated structure, and systematical articulation of the RFN categories throughout the science content were key elements in design of the experimental group's instructional sequence. To benefit from the repetition structure of the lessons were generally the same. The teacher started the lesson by engaging the students with the lesson content by posing questions related to the content they have learned in the previous weeks or the content of the day. Sometimes these questions were about NOS related issues such as "How would scientists decide if stars are turning around the Earth or if the Earth is rotating?" or "What would be the aim of conducting space explorations?". After the activities are conducted the class would return to the FRA Wheel poster and try and connect some ideas of the day to the categories on the FRA Wheel. Through this repetition, students had frequent

opportunities to retain and refurbish their prior understanding of the NOS related issues just like they do with the science content. As a result of systematical articulation, the experimental group's instruction, RFN based instruction, was highly contextualized in the science content to be taught.

The lesson plans for control group differed from the experimental group only in terms of lack of additional explicit connections to NOS other than those suggested in the Ministry of National Education (MoNE) learning program for 5th grades. In the lessons with the control group, regular practice of the teacher was not interrupted, and the activities suggested in the textbook given by MoNE were not revised for explicit connections to NOS categories in the RFN framework. In the restructuring of some activities, Alayoglu's (2018) activities for connecting content of the Sun, Earth, Moon and Their Movements unit to social-institutional aspects of science has been used. Instructional strategies used in both groups and the general structure of the activities were the same. Some of the instructional strategies that were used are brainstorming, think-pair-share, small group and whole class discussions, graphic organizers, modeling, roleplay, and generating and testing hypothesis. In order to show the structure of the activities, activity sheets 9, 11 and 12 are also shared in Appendix E, F and G, respectively. Appendix G includes activity sheets of both experimental and control groups, unlike the others. All activity sheets could not be shared due to space limitations.

Before the instruction started, pre-intervention assessments were conducted. These are the pre-interviews with the 6 purposefully selected students, and the administration of the RFN Student Questionnaire to all students in experimental and control groups. After these, 13 weeks of instruction followed. At the end of the 3 units, post-intervention assessments were conducted. Again, RFN Student Questionnaire was implemented to all students right after the intervention and two months later. The previously selected 6 students were interviewed once again right after the intervention.

Table 3.2 provides a summary of connections between curriculum content matter and RFN categories used in the design of the instructional sequence. As can be seen from this analysis, while making connections to the RFN categories there was no need for

Table 3.2. Horizantal articulation of RFN categories in terms of unit content.

Week	Content	AV	SP	M	SK	SI	Instructional Techniques
0	Introduction & Warm up Administration of NOS Questionnaire (Pretest) Pre-interviews What science is about Introduction of FRA Wheel						Think-pair-share Advance organizers
1	Sunspots	Aims of space studies				Social organizations and interactions Social certification and dissemination (aim of sharing scientific study results)	Brainstorming Think-pair-share Whole group discussion
2	Rotation of Earth and Stars Properties of Sun, Earth and Moon Classification as celestial bodies Galileo v. Church	Theory choice, Simplest explanation, Explanatoriness, Empirical adequacy Addressing anomalies and counter instances Equality of intellectual authority	Model (explanatory) Classification	Non-manipulative methods		Political power structures Social values (ideological and religious constraints, freedom)	Brainstorming Think-pair-share Debate Whole group discussion
3	Phases of Moon		Collecting data Reaching explanations Model	Historical data		Professional activities (Peer review)	Drawing diagrams Demonstration Peer review Whole group discussion

Table 3.2. Horizantal articulation of RFN categories in terms of unit content (cont.).

Week	Content	AV	SP	M	SK	SI	Instructional Techniques
4	Movements of Sun, Earth and Moon		Model Classification				Brainstorming Notetaking Modeling Roleplaying Whole group discussion
5	Space Explorations	Aims of conducting scientific studies				Professional activities (acting as a team) Financial systems (finding monetary resources) Social certification and dissemination (importance of disseminating results of scientific studies)	Group work Whole group discussion
6	Diversity of living things Different schemes for classification of living things proposed by Aristotales		Classification Observation Domain specificity		Scientific knowledge accumulation		Watching video Notetaking Classification Whole group discussion
7	Classification of plants		Classification	Non-hypothesis testing		Scientific ethos (respect for the environment)	Examining plant samples Classification Whole group discussion

Table 3.2. Horizantal articulation of RFN categories in terms of unit content (cont.).

Week	Content	AV	SP	M	SK	SI	Instructional Techniques
8	Classification of animals		Classification Observation Discourse			Scientific ethos (Respect for the environment, animal care, human subjects' protection, non-discrimination, respect for intellectual property) Professional activities (reporting findings)	Examining animal images Small group discussion Classification Whole group discussion
9	Classification of fungi	Addressing human needs	Observation Classification Model Data Real World Reasoning			Financial systems (commercialization of science)	Microscopic observation Drawing diagrams Think-pair-share Whole group discussion
10	Discovery of microorganisms				Growth of scientific knowledge	Political power structures (government intervention) Social values (social utility)	Reading Think-pair-share Whole group discussion
11	Force				Theory- Law Model Explanatory and predictive capacity of models TLM Inference		Whole group discussion Answering questions Writing

Table 3.2. Horizantal articulation of RFN categories in terms of unit content (cont.).

Week	Content	AV	SP	M	SK	SI	Instructional Techniques
12	Force of friction	Addressing anomalies Accuracy Precision Reproducibility	Prediction Experimentation Data Model Explanation Reasoning Representation Discourse	Manipulating variables Hypothesis testing		Professional activities (reporting results)	Whole group discussion Collaborative learning Experimentation Answering questions Reporting
13	Air and fluid friction Altering the effect of friction	Finding solutions Repetitive testing	Prediction Experimentation Data Model Explanation Reasoning Representation Discourse	Manipulating variables Hypothesis testing		Social values (social utility)	Whole group discussion Collaborative learning Experimentation Answering questions Reporting
14	Unpacking the term Administration of NOS Questionnaire (Post-test)	+	+	+	+	+	Collaborative learning Advance organizers
15	Post-interviews						
23	Administration of NOS Questionnaire (Delayed post-test)						

disruption of the regular sequence of events. In the design of these lessons, there was no effort for molding the curriculum subject matter into carrying the RFN categories, on the contrary, links to RFN categories were made based on the ample opportunities already existing in the curriculum. The point of restructuring was rather an issue of framing the activities and discussions that take place in the classroom in ways that would open them for critical reflection in terms of nature of science. Therefore, the planned changes go beyond merely adding text boxes in the appropriate places of the textbook (Dagher & Erduran, 2017). As suggested by Erduran and Dagher (2014) time allocated for each category was determined based on their relevance to the curriculum content. Furthermore, while making connections to RFN categories they were not taken as mutually exclusive links, rather connections were made to all of the relevant categories as they naturally occur. This is the reason why while the activities of the fourth week only relate to scientific practices, activities of the seventh week are connected to scientific practices, methods, scientific knowledge and scientific ethos, and relationships between these categories all at once. This is also in line with the suggestions of Dagher and Erduran (2017). It should also be acknowledged that the issues addressed in the instructional sequence of this study are open for diversification by teacher's noticing of unplanned connections to the RFN categories during the instruction. Methods and methodological rules of science and scientific knowledge are the least frequently addressed categories. Even if these could not be accommodated frequently in these units, they can be addressed in the following units of 5^{th} grade science or in the following years. In the following subsections, examples of activities are discussed in detail. While all of the activities from the first unit is shared, only one activity is presented from each of the other two units.

3.4.1. Instructional Sequence of Experimental Group

The lessons conducted with the experimental group involved RFN learning goals in addition to the content objectives asserted by MoNE in lower secondary science education program (MEB, 2018a). The aim was to build a holistic picture of science, therefore, there were frequent revisits to the FRA Wheel as connections to categories arise during the activities. Before the instruction of unit content started, a think-pair-share activity was done to discuss what science is about from the students' perspective in order to engage students with the broader context of the intervention. During the whole class sharing the teacher introduced FRA Wheel and marked the categories as they are mentioned by the students, but

she only stated that “There might be more to science then what initially comes to mind and we will further investigate this during the term.” without going further into the details of the categories. This way FRA Wheel and RFN categories were introduced. The FRA Wheel which is printed on a large poster remained on one of the walls in the classroom so that the class can return to it and make additions as students come across a piece of related information during the classes.

3.4.1.1. Unit one: Sun, Earth, Moon and Their Movements. The aim of the first week of instruction was to get a sense of students’ prior knowledge about the unit subject, engage students with the upcoming issues and start with the properties of the Sun. In order to resurface students’ prior knowledge about Sun, Earth, Moon and their movements, the class started with a brainstorming activity in which students’ answers to the question “What do you know about Sun, Earth and Moon?” were turned in to a word cloud through the aid of smart board. Students’ answers could also include questions that they wonder about these celestial bodies. The word cloud was kept in order to return at the end of the unit to create concept maps that extend from these initial words and get answers from the students to their initial questions. Afterwards, students were presented with the telescope images of sunspots as something that the teacher wonders about. Students were asked to guess what those images are, and they were guided to arrive at the scientific explanation by their teachers during the whole class discussion. Then, the Activity Sheet 01 accompanied by a reading text about sunspots and their detection by Solar Dynamic Observatory (SDO) was given to the students. Students read the text and answered the related questions in pairs and shared their ideas with the class. These questions involved “What is the purpose of the studies conducted at SDO?”, “What is the purpose of NASA in sharing results of the scientific studies that they conduct with other scientists and the public?” and “Where else could scientific studies be conducted?”. During the discussion, the teacher wrote some keywords to summarize the students’ ideas. These ideas were later transferred to the FRA Wheel poster with suggestions from the students for connection to various RFN categories. At the end of this lesson, students should be able to pose ideas about aims of science, social organizations and interactions, model as a scientific practice, social certification and dissemination, and social organizations and interactions.

The aim of the second week was to model the rotational movement of the Earth. Firstly, students were presented with a long exposure photograph which clearly shows that

the sky and resultantly the stars are rotating. Students were asked to assert arguments for opposing sides of the questions that ‘which is revolving around which: Earth or the stars. This opened a discussion about theory choice, the simplest explanation, explanatoriness and empirical adequacy in science while students asserted arguments that support these claims. This was connected to a text about Galileo, in which the predicaments he lived through for using Copernicus’s solar centered universe theory were presented. Based on this text students labeled the Sun and Earth centered models of the planetary system and then discussed who supports which model: Galileo, Copernicus, and the church. By this way, students were also engaged in a think-pair-share discussion about the aims and values of science, and the relationship between social values and science. In order to stimulate students’ discussions and help them gather evidence, the teacher showed a simulation in which she manipulated the flow of time and recreates the long exposure photograph. Afterwards, students with their pairs drew stars on a piece of cardboard and one by one revolved around themselves under the cardboard. By conducting this activity, students experienced how they can feel like the stars are moving in a circular path on top of them, although the stars are fixed on the cardboard. Therefore, students had an opportunity to model the rotational movement of Earth. While students share their ideas about how the views of the society may interfere with or foster ongoing scientific activities, how to choose between two opposing ideas and aims and values of science such as empirical adequacy, addressing anomalies and counter instances, and accuracy, the keywords were written on the FRA Wheel poster. In the following weeks, as same issues are repeatedly brought forward in class discussions they were shown on the FRA Wheel and additional significant keywords and statements were written (Erduran & Dagher, 2014). The categories and subcategories included in the activities and discussions are aims of science, political power structures, and non-manipulative observation of celestial bodies.

The aim of the third week was to relate the phases of the Moon to its revolution around Earth. The teacher started to lesson by questioning students’ learning in the previous weeks. Afterwards, in order to attract the students’ attention, the teacher reminded the Blood Moon which occurred a couple of weeks before and asked “Do you ever get to observe the Moon in different shapes? When and how?”. After getting some answers she announced that they will be working on the different shapes that Moon seems to have throughout a month. To learn about the phases of the Moon, students worked on the hypothetical case that for some reason they cannot make observations for investigating the different shapes the Moon

takes in a month. Since they could not make the observation themselves, they needed to rely on the historical data written by a curious astrophysicist sharing her observations about the phases of Moon. In order to make her explanations more understandable, students were supposed to draw diagrams of which parts of the Moon is bright as they read the notes of the astrophysicist. After students individually read the text and draw the diagrams, they exchanged their diagrams with their pairs. This way students were involved in peer review professional activity of scientists. After students reviewed each other's work, a whole class discussion took place in line with the questions in the activity sheet: "What is the reason in collecting data while studying a natural phenomenon? (collecting data, reaching explanations) Can scientists always make direct observations? (observation as a method) What else can they do if a direct observation is not possible? (working on historical data as a method)". During the discussion, the teacher says, "you have depicted the data and as I understand your purpose was to explain the situation, so why does Moon look different all through the month?". In order to explain she reminds that Moon reflects the light that comes from Sun, therefore if some parts of it look darker then somehow something must be blocking the sunlight from reaching to Moon. She helps the students to see that that something is Earth by demonstrating it with 3 volunteering students. Lastly, students answer the last questions on their activity sheet which aids them to reflect on the NOS related aspects of their discussions and share their answers. Again, the students' ideas are transferred to the FRA Wheel poster. The categories and subcategories included in the activities and discussions are data and explanation from scientific practices, working with historical data as different scientific methods and peer review as a professional activity.

The aim of the fourth week was to further investigate the properties of Sun, Earth and Moon and their movements. The teacher began the lesson by asking students what celestial bodies they know. Then among these, she specifically asked about what they know about Sun, Earth and Moon such as their shapes, sizes and colors. Then, the class watched a video which introduced information about their surface, atmosphere and distance from each other. While watching the video they took notes on the appropriate places on the activity sheet. After the video, students discussed the relative sizes of these objects according to what they have seen in the video and what they see in the sky. In order to ground this information to objects from students' everyday life, the teacher showed a basketball, a hazelnut, and a lentil which will also be occasionally referred to in the upcoming lessons. The lesson ended with a discussion of why Sun, Earth and Moon look so similar in size all the while they are

so different, and this was tied to their distance from each other. Later in the week, students built their own scale models of Sun, Earth and Moon from the materials given such as playdough, colorful paper, and wool balls in small groups. They also fashioned face masks that they can wear. Then students wearing the masks and carrying the scale models acted as Sun, Earth and Moon and try to reenact their rotation and revolution movements in scaled distances from each other with guidance from their teacher. This activity was conducted in the garden in order to have enough space for all students to get a chance to take part in roleplaying. In the last lesson of the week, students discussed and summarized what they have learned from the previous activity about the curriculum subject matter and also about models with the aid of an activity sheet. In the first part of the activity sheet properties of Sun, Earth and Moon were summarized and the definitions of star, planet and satellite were given. Based on this information students were asked to identify Sun, Earth and Moon as star, planet and satellite. Then classification was presented as a scientific activity and contrasted with merely sorting. Students have also drawn models of the movements of these celestial bodies and their orbits. In the second part, they have answered the following questions: “Why do scientists determine and use groups such as stars, planets and satellites? What is the importance of using these definitions in scientific studies?” and “Why do scientists use models?”. As is tradition, these discussions were translated into keywords and statements on the FRA Wheel. The categories and subcategories included in the activities and discussions are modeling as a scientific practice and classification as a scientific activity.

The aim of the fifth week was to discuss space explorations and the possibility of life on the Moon. The teacher started by reminding the students that the celestial bodies are so far away that humans cannot really comprehend the distance so instead use models. In order to engage students in the day’s activity, the teacher asked, “Would you like to go on a space journey?”, “If you were going to do it what do you need to make it possible?”, “If you are going to design your own spacecraft what would you need to consider in the process?”. Then, the teacher told the students that they are going to build their very own spacecraft for this purpose. She explained that during this activity groups will act as scientific teams and each team will make their own designs which will be presented to the scientific community (class) at the end of the lesson. In the activity sheet, various materials required to build a durable spacecraft were introduced (such as fuel, plastic or carbon fiber body, and different version of radio system) and their prices were presented. Each team had a given budget and they could not exceed it. Therefore, students needed to make judgement calls for the materials

they use in their design in order to stay below the financial limits. After a given time, leaders of each scientific team presented their design and justification for using or omitting each material. During the presentations, the teacher tried to make students realize that since different groups had different priorities, every design is unique in its own way. After each group presented, the teacher explained the links between what they have done and the work of the scientists by describing scientific teams (student groups), hierarchical relationships between team members (the leader) and science community (the class). Then a whole class discussion took place in which students discussed how budgets can become a constraint for scientific studies, why was it important to share their results with the science community, and how it felt to have a leader speaking for the whole group. In order to sum up their understanding, students answered the questions on the activity sheet regarding science as a social-institutional system: "Where and how can scientists find the money that they need for their studies?", "What is the importance of sharing scientific study results with the science community?" and "How can scientists reach out to other scientists and the public to inform them about their studies and findings?". The categories and subcategories included in the activities and discussions are political power structures, social organizations and interactions, financial systems, professional activities, and social certification and dissemination.

3.4.1.2. Unit two: Classification of Living Things. The aim of the seventh week is to classify plants based on their similarities and differences. For this purpose, students learn about the properties of different plant species and match them with sub-categories of plants. In the previous week, the teacher had asked students to bring examples of plants to the classroom. She also brought enough samples herself in order to have diversity and keep the discussion broad. The lesson started with the teacher wondering about the last week's big idea: "Scientists classify living things based on their similarities and differences with each other". She also asked about the types of living things that they had previously mentioned. As students suggest examples that they remember, she wrote the 4 groups of living things. "How did we arrive at this conclusion? What was our activity last week?" (we made an observation from the video). "As you know scientists also conduct observations. How do they do this?". "Do scientists always look at nature to test some ideas?". "What is the difference between testing and just exploring?". She gave the observations conducted by Darwin as an example. He was an explorer, he would take notes about what he sees and after a while, he has realized a pattern in differences and similarities between these living creatures". "How can scientists

learn about plants?". Lastly, she announced that today they will work on the similarities and differences between the samples that the students have brought, and they will try to understand why scientists classified the plants in the way they did. First, students examined the plant samples they have brought in groups of 2-4 students. Then, the teacher spread the activity sheets. She asked students to fill the empty table with the characteristics of their plant such as "Does it have leaves? Does it have roots? How do they look like?". After students finished examining their plants, she gives out the plant images. This time students focused on examining the three plants in the images. When all groups completed their investigations, the teacher went through the questions with the students. Firstly, the students told about their own plants and then the plants in the given images. At this point, the teacher categorized the plants as flowering and flowerless. At last, students individually identified their plant samples as flowering and flowerless and gave their justifications. The teacher called the attention of the students once again to discuss the scientific ethea that are at play when scientists conduct their studies. She started from having respect for the environment while working with plants and animals and also called students' attention to other examples such as intellectual property, showing respect for their colleagues and ideas of others. Afterwards, the students reflected on two of the scientific ethos in writing by answering the last question in the activity sheet. As a tradition, the teacher returned to the FRA Wheel poster at the end of the lesson and asked students to make a connection with the day's activities and the categories on the wheel. The teacher also showed the adapted GIS for scientific practices to elaborate on students' ideas about the practices that they have used during this week. The categories and subcategories included in the activities and discussions are non-hypothesis testing as a scientific method, scientific ethos and classification and observation as scientific practices.

3.4.1.3. Unit three: Measuring Force and Friction. The aim of the twelfth week was to explore the effect of friction force on the motion of a small toy car by conducting experiments. The teacher started the lesson by asking the different types of forces that they had learned in the prior week. She asked what the students already know about friction force such as whether it is a contact force or an action-at-a-distance force and where and how can it be observed. Then she declared that today they will investigate friction forces and asked students what they would like to know about it. She then went on writing their research question for the day: Does the magnitude of the friction force acting on a moving object depend on the surface on which the object is moving?. The teacher introduced the activity

and activity sheet. As they had done before students would work as scientific teams. The teacher reminded that sometimes scientists use hypothesis testing as a method in their studies. In this study they were going to use hypothesis testing; therefore, as a team, they needed to transform the research question into a testable hypothesis. She also explained and gave examples to independent, dependent and controlled variables. So, the students first wrote the research question on their sheets and worked on it with their team members by measuring how much time it takes the car to go down from inclined planes covered with different materials. As they obtained the distance and time data for a set distance for each case, they recorded it on the activity sheets. After all groups obtained data for all three instances, they verbally reported their results and the teacher marked them on a distance-time graph on the board. This way there was more data gathered and they discussed how their collaborative effort made it easier for reaching an explanation for this phenomenon. The teacher invited students to point out any anomalies that they cannot make sense of so that they can find any false or faulty results. She emphasized that there is always a possibility of error while having measurements and conducting experiments therefore, scientists should always address anomalies that they detect in data or other scientists' interpretations. The teacher summarized the process as "What we have done today is exactly like the practices and the methods that scientists use while conducting scientific studies. We have first made predictions, which is called hypothesis in the scientific terms, and then tested our hypotheses by manipulating variables. This is a scientific method for studying natural phenomena and it is called experimentation. What makes experimentation a scientific study unlike a casual process of trial and error is that while experimenting we base our study in the previous knowledge we already have, and we control other factors that we don't want to interfere with our dependent and independent variables.". The teacher also introduced the scientific methodology matrix (Appendix H) and asked students to locate the methodology of the day's study on the matrix shared in their activity sheets. Lastly, she wanted students to reflect on the accuracy and trustworthiness of scientific studies and how to assure them by answering the last question on the activity sheet. The categories and subcategories included in the activities and discussions are manipulation of variables and testing hypothesis as methods; prediction, scientific reasoning, data, explanation and experimentation as scientific practices; addressing anomalies, accuracy, precision and reproducibility as aims and values of science; and reporting results as a professional activity of scientists.

3.4.2. Instructional Sequence of Control Group

Activity plans for the control group and how the different content matter is related to each other is similar to a large extent to that of the experimental group. Therefore, in this section, only the parts where the control group's instruction will differ from that of the experimental group will be explained.

As the aim of this study is to investigate the effectiveness of RFN approach in comparison to regular practice in teaching NOS in the context of a school in Turkey, the latest science education program and textbook published by MoNE is taken as the guideline for the *regular practice* implemented in the control group. In order to study only the effect of NOS teaching approach, instructional strategies and content of the activities used in both groups were designed congruently.

There are 13 learning goals for the first three units of the 5th grade science education program (MEB, 2018a). Five of them are already tied to scientific practices such as model, experimentation, classification, and argumentation. These connections were kept as they are shared in the textbook. In the absence of connections to nature of science in the textbook or the MoNE learning goals, unitlike the activity sheets of the experimental group, RFN related questions were not added in the activity sheets of the control group. Likewise, during the discussions with the control group the teacher did not deliberately attempt to guide students to make connections to the NOS related aspects of the activities that they conduct. In the following, differences in the adjoining activities of the control group's instruction are presented in the order that they were shared for the experimental group's instruction to ease tracking the differences between the instructions of the two groups.

<u>3.4.2.1. Unit one: Sun, Earth, Moon and Their Movements.</u> In the first week, activities of the control group were same as the experimental group up until the point where students were asked about aims of conducting space studies and dissemination of study results to the public and other scientists. Therefore, control group students have also brainstormed about what they know about Sun, Earth and Moon and the teacher prepared a word cloud. They were also presented with the sunspot images and the text. In contrast to their counterparts in the experimental group, the control group students only answered and discussed the following questions in relation to the text: "What is a sunspot?", "What are the properties of

Sun?" and "What is the purpose of using telescopes?". Likewise, the class did not return to the FRA Wheel to unpack the NOS related ideas as the experimental group students did as the FRA Wheel was not introduced to them. Instead of discussing these questions and making connections to the FRA Wheel, students read the passages and answered the related true and false questions in the textbook.

In the second week, control group students also read the text about Galileo, and they have labeled the Earth and Sun-centered models of the planetary system based on the descriptions in the text. They have articulated their understanding for who supports which model. They have also discussed evidence from their daily life for or against the two models and answered the related question. These students have also watched the Stellarium simulation and modeled the rotation of Earth with the cardboard activity and wrote down their observations. On the other hand, the control group students did not answer the questions related to Galileo's imprisonment or manipulation of the time.

In the third week, control group students also read the report of the astrophysicist's report and draw diagrams of the phases of the Moon to make her observations more understandable. They have also checked their pair's diagrams for any misunderstandings. But this activity was not related to the work of the scientists by their teachers. They have directly continued on with the demonstration of movements of Earth, Sun and Moon to understand that Earth blocks the rays coming from Sun from reaching to Moon. Instead of answering questions related to nature of science and discussing them, control group students answered the questions on their textbook which asked them about four main phases of the Moon and a short summary of the movements of Sun, Earth and Moon.

In the fourth week, control group students also started by articulating what they already know about various celestial bodies, Sun, Earth and Moon in particular. These students have also watched the same video, took notes and compared the sizes of these celestial bodies. Afterwards, the teacher showed them a basketball, a hazelnut and a lentil to make their relative size more understandable. Control group students also discussed why Sun and Moon similar in size when they look at the sky while they are so drastically different in size. They have also made scale models and fashioned face masks to represent these celestial bodies to use while modeling their movements in the roleplaying activity that took place in the garden. Later in the week, they have read the descriptions of stars, planets and

satellites and matched these concepts with Sun, Earth and Moon. They have also drawn models of their movements and orbits. But they did not answer the NOS related questions that were listed in the experimental group's instruction. Instead, they have answered the fill-in-the-blanks and multiple-choice type of questions in their textbooks.

In the fifth week, control group students have also talked about going to space exploration missions. They have also read the same text that presents various materials that are needed to build a durable spacecraft and tries to build a spacecraft with their group members based on the budget given to them. This was again a fun activity for the students, and they had the opportunity to reiterate their knowledge about different weather conditions in the space, sequence of the planets and their distances from each other. But there was no emphasis asserted by the teacher for why they needed to stay under the monetary limit or how their groups functioned just like scientific teams to connect their activities to that of the scientists. Moreover, control group students did not discuss which organizations conduct space studies or how to find funding to support scientific activities or how to disseminate their results to the science community and public.

3.4.2.2. Unit two: Classification of Living Things. In the seventh week, control group students also discussed how scientist learn about plants. They have also brought and examined plant samples and took notes about their characteristics as well as the characteristics of the plants in the given images. They have also compared the similarities and differences between their plants and the plants in the images to decide the type of plant they have: flowering or flowerless. They were also told that the activity they have conducted is classification and scientists classify living things and other stuff to make their investigations of these things easier and more understandable. Lastly, they talked about how scientists should not pose unnecessary harm to the living things that they study with just as it was mentioned in their textbooks. But they did not discuss or reflect on other scientific ethea that were mentioned in the experimental group. Likewise, they did not learn about non-hypothesis testing as a scientific method.

3.4.2.3. Unit three: Measuring Force and Friction. In the twelfth week, the control group students have also written their hypothesis based on the research question given by their teacher. Normally, this was not directly in the MoNE learning goals but the 5th students are expected to conduct independent research projects. The textbook includes a checklist and

one of the items is about hypotheses, variables and testing their products in their studies. Therefore, this activity was mostly the same in the two groups. The Activity Sheet 12 is shared under Appendix G in the two separate versions that were given to the experimental and control groups. As can be seen in the activity sheet, there was no connection made to the scientific practices of collecting and analyzing data, modeling, explanation, reasoning although students were involved in these practices while answering the questions. Likewise, control students were not presented with the scientific methodology matrix or the aims and values of science that support accountability and trustworthiness as they were not in the scope of the MoNE learning goals or the textbook.

3.5. Data Collection

The data were collected from September 2018 through February 2019. Before starting the data collection process, official permissions from the Ministry of National Education and school administration were obtained. Afterwards, parents of all students received informed consent forms (Appendix C) and consents were obtained for all participants of the study. The aim was to notify them about the purpose of the study and that they have a choice for opting out at any time without any repercussion on their part. On the other hand, identities of all participants and the school are protected; therefore, any ID numbers and names reported here are fictitious and does not reflect participants' real identities.

3.5.1. Quantitative Data Collection

Data collection started in September 2018 with pretesting in which students were asked to complete the paper and pencil form of the questionnaires in 40 minutes. RFN Student Questionnaire was also implemented as the post-test at the end of 13 weeks of the intervention and also as the delayed post-test, 8 weeks after the end of the intervention in the same manner.

3.5.2. Qualitative Data Collection

Collection of the qualitative data regarding students started with the pre-intervention interviews with the 6 purposefully selected students. These lasted 30-40 minutes with each

student depending on the length of students' answers. After the intervention, the researcher returned to the field in order to conduct the second cycle of student interviews. Selected students were interviewed in the school, in an appropriate office. These interviews took 30-50 minutes. All interviews were audio-recorded and transcribed. All interviews took place in the school for students' comfort, needed supervision and time efficiency reasons.

3.6. Data Analysis

In this section, the analysis of the quantitative and qualitative data will be discussed separately. The first sub-section contains information about the analysis of RFN Student Questionnaire, and the second one introduces the analysis procedures of the interview data. The procedures used in the analysis of quantitative and qualitative data with respect to the research questions are shared in Table 3.3.

3.6.1. Quantitative Data Analysis

Analysis of RFN Student Questionnaire was conducted through descriptive and inferential statistical techniques in SPSS 25.0. In order to answer the first sub-question, t-test was conducted with pre-test data in order to determine if there is a significant difference between the experimental and control groups' initial understanding of NOS. With the addition of post- and delayed post-test data, the total scores and the scores of five categories of the questionnaire were analyzed with mixed model ANOVA to compare students' understanding of nature of science with themselves and their peers throughout the term with test administration time as the within-subjects factor and teaching method as the between-subjects factor. The mean, standard deviation, minimum and maximum scores of the questionnaire initially served to investigate students' progress over time. For the analysis of the difference in students' understanding, mixed model analysis of variance was conducted since the pretest scores of the two groups were not significantly different and parametric test assumptions were held. These analyses were done separately for the total test scores of the students as well as their 5 different category-based scores: aims and values of science, scientific practices, methods and methodological rules of science and social-institutional categories.

Table 3.3. Data analysis procedures for each of the research questions.

Research Question	Null Hypothesis	Data Analysis Method	Variables†
1. How does using RFN approach in teaching NOS affect students' understanding of NOS?			
a) How do NOS understanding of the students from experimental group who were taught with RFN based instruction and control group who were taught with regular practice compare in *pretest*?	H_{01a}: There are no statistically significant differences between the control and experimental group students' understanding of NOS before the intervention.	Separately conducted *t-test*s for total scores and 5 category-based scores	PRE, AVpre, SPpre, Mpre, SKpre, SIpre scores for control and experimental groups
b) How do control and experimental group students' understanding of NOS change from pretest to post-test and to delayed post-test while they learn NOS with regular practice or RFN approach, respectively?	H_{01b}: There will be no statistically significant difference between the mean changes of the control and experimental group students' NOS understanding scores from pretest to post-test and to delayed post-test.	Separately conducted *mixed model ANOVA*s for total scores and 5 category-based scores with time of test administration as the within-subjects factor and teaching method as the between-subjects factor	PRE, POST, DPOST, AVpre, AVpost, AVdpost, SPpre, SPpost, SPdpost, Mpre, Mpost, Mdpost, SKpre, SKpost, SKdpost, SIpre, SIpost, SIdpost scores for control and experimental groups
2. How does control and experimental group students' perception of NOS change after learning NOS with regular practice or RFN approach?	H_{02}: There will be no discernable patterns in the responses experimental and control group students give regarding nature of science.	Open coding Thematic coding Constant comparison	codes, subcategories, themes, number of novel mentions

† pre, post and dpost abbreviations accompanying category names indicate that they are corresponding category-based score sets that were obtained at pretest, post-test and delayed post-test, respectively

3.6.2. Qualitative Data Analysis

Interview data were transcribed from audiotapes and coded. Initial codes were the words and phrases as used by the respondents (in vivo codes). While re-reading the interviews similar codes were rewritten to match the similarities. From these, categories were organized in order to see the patterns in the participants' thinking by constantly comparing respondents' answers and codes with that of others (Glaser & Strauss, 1967). These codes and categories were assigned to the themes which were the RFN categories as put forth by Erduran and Dagher (2014). By quantification of these codes, the changes in students' perceptions of science was determined in terms of breadth. In this quantification, 'meaningful mentions' were used as the unit of analysis. Therefore, each code could be attributed to individual students' answers only once. Then, the sums of the number of mentions pertaining to each category were compared based on the students' group and initial NOS understanding levels. When similar numbers are obtained, students' answers which received these codes were assessed in terms of their depth. These thinking patterns were then assessed in the scope of RFN framework and the epistemological views cited in the literature.

3.7. Ethical considerations

Ethical guidelines of the Institutional Review Board for Research with Human Subjects (INAREK) were taken as the standard for ethical considerations in the design of this study. Approval of the ethical committee was received based on an application that has been made on May 18th. The anonymity of the school and the participants is ensured. Accordingly, pseudonyms and ID numbers were assigned to all participants and they were used instead of the personal identities when such information is deemed necessary in analysis, interpretation and reporting of the data. This is also necessary for matching data gathered all through the school term in order to observe individual trajectories of learning and make sense of the data. Participation and data sharing were based on informed consent of the teacher herself, the students themselves, and parents of the students since the students are under legal age. Since the context of the study is a school, legal permissions from the Ministry of Education were also obtained before starting the data collection and intervention procedures. Voluntary participation is documented with consent forms (Appendices C) that officially inform all participants about the aim and process of the study.

4. RESULTS

In this chapter, results are presented under two main parts: the change in students' NOS understanding, and the change in students' NOS perceptions. Each part provides answers for the main research questions and their sub-problems.

4.1. The change in students' NOS understanding

This section aims to answer the first main research question, "*How does using RFN approach in teaching NOS affect students' understanding of NOS?*" and its 4 sub-questions. RFN Student Questionnaire has been implemented before, immediately after and two months after the intervention in order to measure students' NOS understanding. Accordingly, descriptive statistics; students' NOS understanding before the intervention; the comparison of the mean changes of the experimental and control group students' NOS understanding; and the total and category-based NOS understanding scores of the interview students are presented under the following headings.

4.1.1. Descriptive statistics

This section aims to present descriptive statistics pertaining to the three RFN Student Questionnaire administrations: pre, post and delayed post-tests. In the following Table 4.1, total available score, minimum, maximum, mean (*M*), standard deviation (*SD*), skewness and kurtosis values are presented separately for control and experimental groups for each testing. The explanations of the shorthand notations used in this table, as well as the whole results section, has been shared in the list of abbreviations at the beginning pages. Additionally, PRE, POST and DPOST abbreviations connote for the *total* scores of the pretest, post-test and delayed post-test, respectively.

Table 4.1 shows that the students' total pretest scores varied from 99 to 144 for the control group and from 101 to 153 for the experimental group. The mean of total pretest scores was 123 for the control group and 126 for the experimental group. Category based scores of the experimental group were higher than the control group also for scientific practices (SP), scientific knowledge (SK), and social-institutional (SI) categories. Mean

Table 4.1. Descriptive statistics for all three RFN Student Questionnaire administrations.

Testing	Group		Total	*Min.*	*Max.*	*M*	*SD*	Skewness	Kurtosis
I	Control (*N* = 33)	PRE	185	99	144	123	11.3	-.115	-.720
		AV	20	8	18	13	2.3	.513	-.092
		SP	40	15	34	26	4.3	-.441	.059
		M	20	9	17	13	2.1	-.128	-.413
		SK	35	13	29	22	3.6	-.192	.203
		SI	70	39	59	49	4.3	.274	.746
	Experimental (*N* = 31)	PRE	185	101	153	126	10.5	-.301	1.401
		AV	20	9	17	13	1.9	.020	.345
		SP	40	19	33	28	3.2	-.580	.572
		M	20	9	16	13	1.8	-.165	.022
		SK	35	17	28	23	2.6	.063	-.038
		SI	70	36	63	50	6.3	-.515	.585
II	Control (*N* = 33)	POST	185	92	160	125	16.4	-.039	-.581
		AV	20	7	18	13	3.0	.023	-.837
		SP	40	16	36	27	4.6	-.358	.097
		M	20	7	18	13	2.9	-.032	-.631
		SK	35	15	31	23	4.0	.021	-.715
		SI	70	35	63	49	7.8	-.053	-.815
	Experimental (*N* = 31)	POST	185	110	161	143	12.4	-.649	.261
		AV	20	10	19	14	2.0	.121	.266
		SP	40	22	35	29	3.3	-.222	-.596
		M	20	7	19	15	2.9	-.759	.635
		SK	35	19	35	27	3.8	-.144	-.199
		SI	70	45	69	58	5.5	-.527	.066
III	Control (*N* = 33)	DPOST	185	99	151	131	12.6	-.592	.392
		AV	20	10	19	14	3.8	.367	.715
		SP	40	22	35	29	3.4	-.073	-.689
		M	20	10	18	14	2.0	.161	-.462
		SK	35	16	29	24	3.5	-.372	-.464
		SI	70	28	64	50	8.2	-.454	.553
	Experimental (*N* = 31)	DPOST	185	111	163	143	10.5	-.622	1.471
		AV	20	10	19	14	2.4	.288	-.313
		SP	40	23	35	30	2.9	-.745	.382
		M	20	11	20	15	2.2	.-017	-.124
		SK	35	20	31	26	2.8	-.673	.361
		SI	70	46	68	58	5.1	-.134	-.498

I, pretest; II, post-test; III, delayed post-test

scores of the groups were equal for aims and values (AV) and methods and methodological rules (M) categories.

The total post-test scores for students' NOS understanding varied from 92 to 160 for the control group and from 110 to 161 for the experimental group. The mean of total post scores was 125 for the control group and 143 for the experimental group. Mean scores of the experimental group were also higher than that of the control group for all category-based scores.

The total delayed post-test scores for students' NOS understanding varied from 99 to 151 for the control group and from 111 to 163 for the experimental group. The mean of total post scores was 131 for the control group and 143 for the experimental group. Additionally, category-based mean scores of the experimental group were higher than that of the control group in all categories except aims and values of science (AV) for which the averages of the two groups are equal.

4.1.2. Students' NOS understanding before the intervention

This section aims to answer the first sub-question of the first main research question: *RQ1a. How do NOS understandings of the students from the experimental group who were taught with RFN based instruction and the control group who were taught with regular practice compare in pretest?*

As shown in descriptive statistics section (Table 4.1), mean (*M*) scores of the experimental group are equal to or higher than that of the control group for all categories and the total test score (PRE). The significance of the differences in these mean scores is investigated after checking for crucial assumptions of parametric tests in order to decide the appropriate means of statistical analysis.

Normality assumption. The distributions of pretest scores of the two groups can be found in Figure 4.1 indicating an approximately normal distribution for the total pretest scores of both groups. This is also evident in skewness and kurtosis values shared in Table 4.1 above. Tabachnick and Fidell (2013) report that skewness and kurtosis values should be in the range of -1.5 to +1.5 in order to be acceptable and all skewness and kurtosis statistics

are well within this range. Shapiro-Wilk test for normality also suggested that normality was a reasonable assumption for pretests of both control (*SW* = .984, *df*= 33, *p* > .05) and experimental (*SW* = .947, *df*= 31, *p* >.05) groups. Table 4.2 shows the Shapiro-Wilk, degree of freedom and significance values for each RFN category in the pretesting. Accordingly, the score sets for each RFN category for both the control and experimental groups were approximately normally distributed.

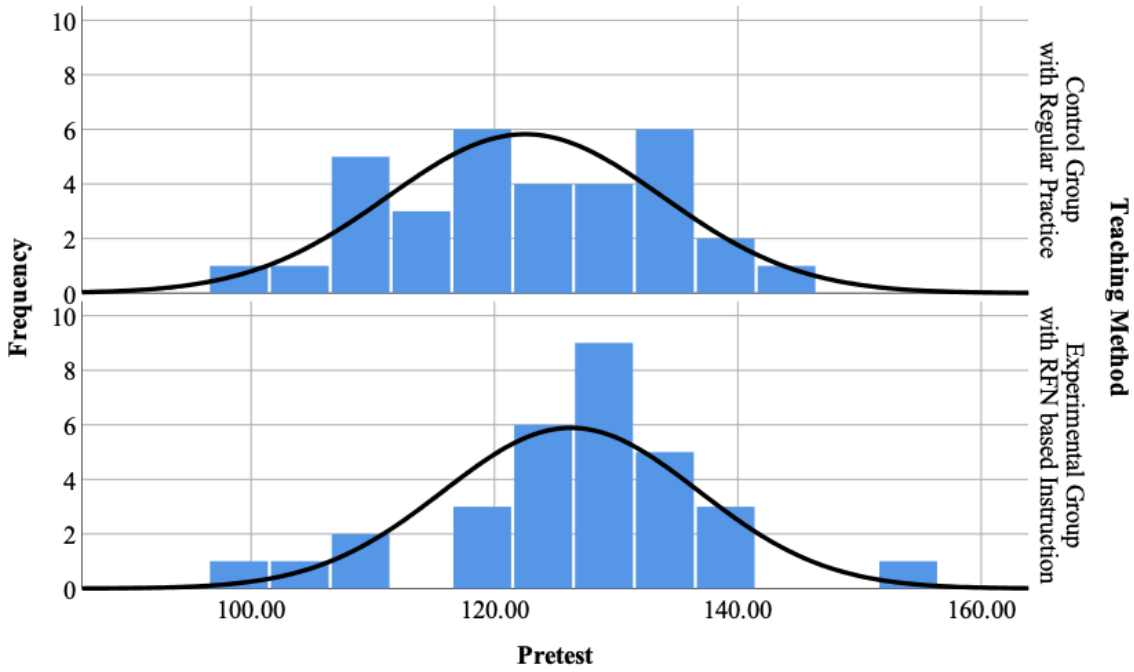


Figure 4.1. Distributions of Pretest Scores for the Control and Experimental Groups.

Table 4.2. Normality values for each category of pretest.

Group		*SW*	*df*	*p*
Control	PRE	.984	33	.889*
	AV	.935	33	.048*
	SP	.975	33	.629*
	M	.962	33	.284*
	SK	.981	33	.828*
	SI	.969	33	.456*
Experimental	PRE	.947	31	.127*
	AV	.957	31	.239*
	SP	.937	31	.070*
	M	.952	31	.172*
	SK	.967	31	.430*
	SI	.941	31	.087*

* Not significant

Homogeneity of variances assumption. Mean based Levene's test was conducted to check for homogeneity of variances of the total and category-based scores of the two groups. As seen in Table 4.3 below, Levene's test indicated that variances of the total pretest scores were equal; F (1, 62) = 1.42, p > .05. The variances were also found to be equal in terms of all RFN categories: aims and values of science, F (1, 62) = 1.79, p > .05; scientific practices, F (1, 62) = 2.22, p > .05; methods and methodological rules of science, F (1, 62) = 0.80, p > .05; scientific knowledge, F (1, 62) = 1.97, p > .05 and social-institutional category, F (1, 62) = 2.17, p > .05.

Since normality and homogeneity of variances assumptions have held, the initial NOS understandings of the experimental and control groups were compared with independent samples t-test. There was no significant difference between the total pretest scores of experimental and control groups; t (62) = 1.38, p >.05. As can be seen in Table 4.3 which presents Levene's test and t-test findings for each category, there was no significant difference between mean scores of the two groups in the pretest for any of the categories. Before the intervention there was no significant difference also between the experimental and control group students' understanding of categories of RFN: aims and values of science, t (62) = .04, p >.05; methods and methodological rules of science, t (62) = .1.13, p >.05; scientific knowledge, t (62) = 1.31, p >.05 and social-institutional category, t (62) = 0.93, p >.05; except scientific practices category, t (62) = .2.15, p < .05.

Table 4.3. Levene's Test and Independent Samples t Test results for pretest.

	Levene's Test for Equality of Variances		t-test for Equality of Means		
	F	*p*	*t*	*df*	*p*
PRE	1.432	.236*	-1.382	62	.171*
AV	1.786	-.186*	-.039	62	.969*
SP	2.219	.141*	-2.154	62	.035**
M	.796	.376*	1.125	62	.265*
SK	1.965	.166*	-1.313	62	.194*
SI	2.170	.146*	-.929	62	.361*

* Not significant

** Significant at the 0.05 level

4.1.3. Comparison of mean changes

This section aims to answer the second sub-question of the first main research question:

RQ1b. How does control and experimental group students' understanding of NOS change from pretest to post-test and to delayed post-test while they learn NOS with regular practice or RFN approach, respectively?

Table 4.4. Descriptive statistics for all three RFN Student Questionnaire administrations.

Group		*N*	*M*	*SD*	Variance	Skewness	Kurtosis
Control	Pretest	33	122.5	11.3	127.8	-.115	-.720
	Posttest	33	124.5	16.4	60.6	-.053	-.815
	Delayed Posttest	33	130.5	12.6	157.8	-.592	.392
Experimental	Pretest	31	126.4	12.4	110.2	-.301	1.401
	Posttest	31	143.4	12.59	152.7	-.649	.261
	Delayed Posttest	31	142.5	10.5	111.1	-.622	1.471

As shared in Table 4.4, descriptive statistics pertaining to students' NOS understanding indicate that after the intervention, mean of RFN Student Questionnaire scores for experimental group students increased from pre-test (M_{e1} = 126.3, *SD* = 10.5) to post-test (M_{e2} = 143.4, *SD* = 12.4). However, mean of delayed post-test scores was slightly decreased in contrast to post-test (M_{e3} = 142.5, *SD* = 10.5). In contrast, control group students received slightly higher grade means for the pretest (M_{c1} = 122.5, *SD* = 11.3) than the post-test (M_{c2} = 122.1, *SD* = 18.3). Then, their mean of post-test scores was raised in the delayed post-test (M_{c3} = 130.5, *SD* = 12.6). The changes in means of NOS understanding scores of the two groups over the three RFN Student Questionnaire implementations is illustrated in Figure 4.2.

Figure 4.2 shows the estimated marginal means of NOS understanding scores. The plot indicates that NOS understanding of the students from both groups enhanced over the course of the study and the NOS understanding scores of the experimental group was steadily higher than the control group at all three examinations. Additionally, it can be inferred that the students in the experimental group were more affected by the instruction they have received since their overall mean change was higher. The significance of the indicated

difference between the mean changes of the two groups was to be investigated with inferential statistics.

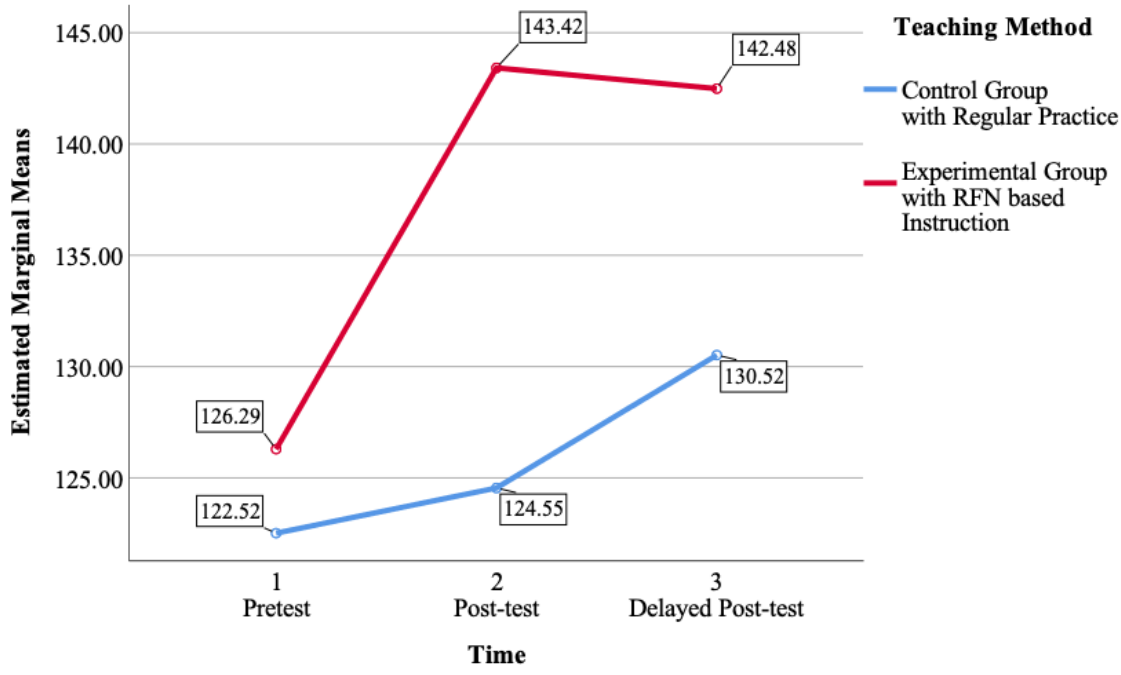


Figure 4.2. Estimated Marginal Means of Three RFN Student Questionnaire Administrations.

As previously shown in Table 4.3, there was no significant difference between initial NOS understandings of the two groups except for the scientific practices category. On the other hand, there were reasons to question the accuracy of this significant difference. First, there were limited numbers of items assigned for each individual category including the scientific practices category while the nature of the scientific practices category is more foliated than others. It includes practices of real world, prediction, explanation, model, data, scientific activities (experimentation, observation and classification), representation, reasoning, discourse and social certification. These are discrete practices meaning that an understanding of one of them does not necessarily indicate an understanding of others. Therefore, more items could have been needed to assess students' understanding of scientific practices. The second reason is that the students' NOS understanding was not significantly different in neither of the other categories and the test as a whole. Lastly, there was no significant difference between the scientific category scores of the two groups at the delayed post-test. These might have had an effect on the assessment of students' initial understanding of NOS. Therefore, when these are considered, mixed model analysis of variance (ANOVA)

was decided to be the appropriate means of investigating the significance of the change in students' NOS understanding for all categories and tests in whole, including the scientific practices category. Mixed model ANOVA or independent multi-factorial ANOVA is a common statistical method for researchers who conduct Likert-scale type questionnaires (Mayers, 2013). Glass, Peckham and Sanders (1972) report that non-normality and heterogenous variances can seriously affect the level of significance and power of the *F* test while conducting ANOVA. In order to eliminate the possibility of false positives or negatives, before conducting the test, these assumptions were checked.

Table 4.5. Normality values for each totality and categories of post and delayed post-tests.

Testing	Group	Score type	*SW*	*df*	*p*
II (Post-test)	Control	POST	.990	33	.987*
		AV	.966	33	.387*
		SP	.978	33	.714*
		M	.960	33	.259*
		SK	.979	33	.758*
		SI	.973	33	.568*
	Experimental	POST	.958	31	.263*
		AV	.967	31	.433*
		SP	.970	31	.527*
		M	.942	31	.092*
		SK	.961	31	.306*
		SI	.955	31	.213*
III (Delayed Post-test)	Control	DPOST	.952	33	.148*
		AV	.964	33	.343*
		SP	.970	33	.469*
		M	.970	33	.482*
		SK	.962	33	.286*
		SI	.966	33	.389*
	Experimental	DPOST	.965	31	.386*
		AV	.952	31	.175*
		SP	.933	31	.053*
		M	.949	31	.151*
		SK	.925	31	.033**
		SI	.980	31	.386*

* Not significant

**Significant at the .05 level

Normality assumption. The dependent variable data should be approximately normally distributed since ANOVA is known to be "robust for modest violations" (Mayers, 2013, p.229). The assumption of normality was tested via examination of the unstandardized residuals. As can be seen in Table 4.5, review of the Shapiro-Wilk test for normality suggested that normality was a reasonable assumption for pretests of both control (*SW* = .984, *df*= 33, *p* > .05) and experimental groups (*SW* = .947, *df*= 31, *p* >.05). This assumption was also held for the post-tests of control (*SW* = .990, *df*= 33, *p* > .05) and experimental (*SW* = .958, *df*= 31, *p* > .05) groups. Lastly, normality assumption was also held for the delayed post-tests of the both control (*SW* = .952, *df*= 33, *p* >.05) and experimental (*SW* = .965, *df*= 31, *p* >.05) groups. As previously discussed, and shown in Tables 4.5 below, normality assumption was held for all categories of the all three testing for both groups except for the scientific knowledge category of the experimental group's delayed post-test, SW = .925, df= 31, p <.05. On the other hand, since ANOVA is known to be "robust for modest violations", it was decided to use mixed model ANOVA for this category as well (Mayers, 2013, p.229).

Homogeneity of variances assumption. Homogeneity of variances assumption was met, as assessed by mean based Levene's test for equality of variances for all levels of the repeated measures: pretest, F (1, 62) = 1.43, p > .05; post-test, F (1, 62) = 3.27, p > .05; and delayed post-test, F (1, 62) = 0.41, p > .05. As seen in Table 4.6 below, this assumption was also held for all categories in all three questionnaire administrations of both groups except, aims and values category in the post-test, F (1, 62) = 5.27, p < .05. Nonetheless, considering the robustness of ANOVA for modest fluctuations, the decision was made to still use ANOVA for assessment of this category as well.

Sphericity assumption. In order to check for sphericity of repeated measures variable Mauchly's sphericity test was conducted. As shown in Table 4.7, the main effect of *time* was found to significantly violate the sphericity assumption for the total score sets, W = .838, χ^2 (2) = 10.75, p < .01 and scientific practices category, W = .851, χ^2 (2) = 9.83, p < .01. Therefore, for these score sets F-values for the main effect of time and its interaction with the between-group variable *teaching method* was corrected for violations of sphericity by adjusting the degrees of freedom using Greenhouse-Geisser estimates of sphericity (ε = 0.86). As can be seen in Table 4.7, the sphericity assumption was sustained for the aims and values of science, methods and methodological rules, scientific knowledge and social-institutional categories.

Table 4.6. Levene's Test and independent samples *t* Test results for all three testing.

Testing	Score type	Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	*p*	*t*	*df*	*p*
I	PRE	1.432	.236*	-1.382	62	.171*
	AV	1.786	-.186*	-.039	62	.969*
	SP	2.219	.141*	-2.154	62	.035**
	M	.796	.376*	1.125	62	.265*
	SK	1.965	.166*	-1.313	62	.194*
	SI	2.170	.146*	-.929	62	.361*
II	POST	3.268	.075*	-5.154	62	.000***
	AV	5.265	.025**	-2.721	56	.009***
	SP	2.539	.116*	-2.244	62	.028**
	M	.103	.750*	-2.714	62	.009***
	SK	.220	.641*	-4.120	62	.000***
	SI	3.966	.051*	-5.246	62	.000***
III	DPOST	.413	.523*	-4.116	62	.000***
	AV	1.412	.239*	.278	62	.782*
	SP	1.074	.304*	-1.860	62	.068*
	M	.020	.889*	-1.885	62	.064*
	SK	1.632	.206*	-2.973	62	.004***
	SI	3.284	.075*	-4.235	62	.000***

* Not significant ** Significant at the 0.5 level *** Significant at the 0.1 level

Table 4.7. Mauchly's Test of Sphericity results.

Score types	Mauchly's *W*	χ^2	*df*	*p*	$\varepsilon^{\dagger}$
Total	.838	10.75	2	.005	0.86
AV	.981	1.16	2	.559	
SP	.851	9.83	2	.007	0.87
M	.915	5.42	2	.066	
SK	.976	1.46	2	.481	
SI	.972	1.71	2	.426	

† Greenhouse-Geisser estimates, only reported when adjustment is needed in the analyses

After the assumptions were checked, mixed model ANOVA was conducted to test the null hypothesis that there is no statistically significant difference between the mean changes of the control and experimental group students' NOS understanding scores from pretest to post-test and to delayed post-test. ANOVA was conducted with time (pretest, post-test and delayed post-test) as the within-subjects factor and teaching method (control and experimental) as the between-subjects factor.

Table 4.8. Summary of the ANOVA statistics for the RFN Student Questionnaire.

Category	Source of variation	SS	*df*	MS	*F*	*p*	η_p^2
TOTAL†	Between groups	6385.18	1	6385.18	21.98	.000	262
	Within groups	5209.58	1.72	3025.73	29.22†	.000	.320
	Interaction	1826.41	1.72	1060.78	10.24†	.000	.142
AV	Between groups	12.84	1	12.84	2.09	.153*	.033
	Within groups	20.44	2	10.22	2.22	.113*	.035
	Interaction	32.77	2	16.38	3.56	.031	.054
SP†	Between groups	177.77	1	177.77	8.96	.004	.126
	Within groups	172.20	1.74	98.92	8.28	.001	.118
	Interaction	5.411	1.74	3.11	0.26	.740*	.004
M	Between groups	31.59	1	31.59	3.98	.050	.060
	Within groups	98.79	2	49.40	11.28	.000	.154
	Interaction	51.67	2	25.83	5.90	.004	.087
SK	Between groups	295.154	1	295.15	15.68	.000	.202
	Within groups	223.94	2	111.97	13.49	.000	.179
	Interaction	72.44	2	36.22	4.36	.015	.066
SI	Between groups	1615.28	1	1615.28	22.99	.000	.271
	Within groups	944.75	2	472.38	18.40	.000	.229
	Interaction	524.38	2	262.19	10.21	.000	.141

SS, sums of squares; MS, mean squares
†Based on Greenhouse-Geisser corrections
*Non-significant

Analysis of variance showed a significant main effect of time on NOS understanding, F (2, 124) = 29.22, $p < .001$, $\eta_p^2 = .320$. Thus, there is significant evidence to reject the null hypothesis and infer that the overtime changes in students' RFN Student Questionnaire scores were significant. Likewise, there was a significant main effect of teaching method, F (1, 62) = 21.98, $p < .001$, $\eta_p^2 = .262$. Hence, when all other factors (i.e time) are ignored, the NOS understanding of the students who were taught with regular practice and RFN based

instruction was significantly different. According to Mayers (2013), when there are two independent groups, mean scores may be used to locate the source of main effects. When the depicted estimated marginal means (Figure 4.2) of students' pretest, post-test and delayed post-test scores are also accounted, it is evident that experimental group students significantly outperformed their peers in the control group. Therefore, based on the analysis of the RFN Student Questionnaire data, RFN based instruction is found to statistically significantly improve NOS understanding in contrast to regular practice. However, there was also a significant interaction between the administration time and teaching method variables indicating that the observed significant differences were dependent on the administration time of the questionnaires, F (2, 124) = 10.24, $p < .001$, $\eta_p^2 = .142$. As can be seen in Table 4.8, when between-group effect sizes of different categories of RFN are compared, the social-institutional categories ($\eta_p^2 = .271$) have the highest partial effect on the students' NOS understanding and it is followed by scientific knowledge category ($\eta_p^2 = .202$). This indicates that the greatest difference between the mean changes of the two groups occurred in these two categories.

Because of the omnibus nature of mixed ANOVA, post hoc analyses using Tukey's HSD are conducted to determine whether the significant difference exists between any one or all 3 of the RFN Student Questionnaire implementations. As can be seen in Table 4.9, pairwise comparisons were corrected using a Bonferroni adjustment for the main effect of time. Results revealed that the mean changes were significant at the 0.001 level from pretest to post-test, and from pre-test to delayed post-test, 95% CIs [-14.43, -4.73] and [-15.93, -8.26] respectively. But the mean changes between the post-test and delayed post-test were non-significant, $p > 0.05$, 95% CI [-6.03, 1.00]. These results indicate that immediate and overall effectiveness of the instruction on students' NOS understanding was significant while the retrogression of students' retention during the two months long delay period was non-significant.

The mean changes in RFN Student Questionnaire scores of control and experimental groups has been also analysed separately for different categories of the RFN framework. Again, mixed model ANOVA was conducted for each category. Accordingly, in terms of the effect of teaching method, mean changes were significant for the following categories of RFN: scientific practices, F (1, 62) = 8.96, $p < .05$, $\eta_p^2 = .126$; methods and methodological

rules of science, F (1, 62) = 3.98, $p < .05$, $\eta_p^2 = .060$; scientific knowledge, F (1, 62) = 15.68, $p < .01$, $\eta_p^2 = .202$; and social-institutional category, F (1, 62) = 22.99, $p < .001$, $\eta_p^2 = .271$.

Table 4.9. Comparison of total and category-based NOS scores in terms of questionnaire administration times.

Category	Time I	Time II	*MD*	*SE*	*p* †	Confidence Interval	
						Lower Bound	Upper Bound
Total	Pretest	Post-test	-9.58	1.97	.000	-14.43	-4.73
	Pretest	Delayed post-test	-12.10	1.56	.000	-15.93	-8.26
	Post-test	Delayed post-test	-2.51	1.43	.251*	-6.04	1.00
AV	Pretest	Post-test	-0.59	0.38	.393*	-1.53	0.36
	Pretest	Delayed post-test	-0.76	0.35	.105*	-1.63	0.11
	Post-test	Delayed post-test	-0.17	0.40	1.000*	-1.16	0.81
SP	Pretest	Post-test	-1.08	0.66	.313*	-2.70	0.53
	Pretest	Delayed post-test	-2.32	0.58	.000	-3.74	-0.90
	Post-test	Delayed post-test	-1.24	0.46	.028	-2.37	-0.10
M	Pretest	Post-test	-1.35	0.41	.004	-2.35	-0.35
	Pretest	Delayed post-test	-1.65	0.31	.000	-2.42	-0.88
	Post-test	Delayed post-test	-0.30	0.39	1.000*	-1.25	0.65
SK	Pretest	Post-test	-2.08	0.55	.001	-3.42	-0.74
	Pretest	Delayed post-test	-2.46	0.48	.000	-3.64	-1.28
	Post-test	Delayed post-test	-0.38	0.50	1.000*	-1.62	0.86
SI	Pretest	Post-test	-4.48	0.94	.000	-6.78	-2.18
	Pretest	Delayed post-test	-4.91	0.93	.000	-7.19	-2.62
	Post-test	Delayed post-test	-0.43	0.82	1.000*	-2.44	1.59

MD, mean difference; *SE*, standard error; *CI*, confidence interval
† Corrected using a Bonferroni adjustment
* Non-significant

As can be seen in Table 4.9, pairwise comparisons further revealed that the mean changes between pretest and post-test were significant for only methods and methodological rules, scientific knowledge and social-institutional categories, 95% CIs [-14.43, -4.73], [-3.42, -3.64] and [-15.93, -8.26] respectively. Mean changes between pretest and delayed post-test were significant for scientific practices, methods and methodological rules of science, scientific knowledge and social-institutional categories. 95% CIs [-3.74, -0.90], [-2.42, -0.88], [-3.64, -1.28], and [-7.19, -2.62], respectively. Lastly, mean changes from post-

test to delayed post-test were significant for only the scientific practices category with a 95% CI [-2.37, -0.10]. For all categories, experimental group students were outperforming their peers in the control group as was seen in Table 4.1. Therefore, the significant mean changes were all in favor of the experimental group.

Overall, analysis of variance indicates that difference between the changes in mean RFN Student Questionnaire scores of control and experimental groups throughout the semester was significant and in all of these experimental group students scored higher than their peers in the control group. When the category-based differences were examined, the mean changes were significant from pretest to posttest for the benefit of the experimental group students for all other categories except, aims and values of science, and scientific practices. After analysis of the data, RFN based instruction is found to statistically significantly improve NOS understanding in contrast to regular practice. It was also found that a 2 months of delay period does not make a statistically significant retrogression in students NOS understanding.

4.2. NOS understanding of the interviewees

The aim of this section is to present NOS understanding scores of the 6 interviewees in order to relate the changes in students' perceptions of NOS with the changes in their understanding of NOS in the following section (4.3). Table 4.10 shows the total and category-based scores of the 6 interview students in pre and post-tests. These two tests were administered at the same weeks of pre and post-interviews, respectively. Thus, only the changes in students' understanding of NOS between these time intervals were found pertinent and their delayed post-test scores were not presented here. According to the preceding section on the results, from pretest to post-test, experimental group students' understanding of NOS had enhanced significantly more than the control group students for the total test scores, methods and methodological rules of science, scientific knowledge, and social-institutional categories.

Table 4.10 shows that the increase in total test scores of the experimental group students with low and medium understanding levels was indeed higher than their counterparts in the control group. In contrast, from the two high-level understanding students, the one in the control group outperformed her counterpart in the experimental

group in terms of the increase in their total RFN Student Questionnaire scores. This does not comply with the trend seen in the overall data. The changes in students' scores for the aims and values and scientific practices categories are irregular as the overall data suggested. For example, in terms of the aims and values category, from the low understanding level students, the control group student increased her score and eventually scored better than the student in the experimental group. But either of the medium understanding level students' understanding of aims and values categories did not improve. When the development in their NOS understanding is considered, experimental group students had significantly outperformed their peers in the last three categories: methods and methodological rules of science, scientific knowledge and social-institutional categories. The interviewees from the experimental group also scored equal or higher than the interviewees from the control group except, again, the high understanding level students. The one in the control group scored one point higher than the experimental group student in terms of the social-institutional category. Therefore, it is concluded that the interviewees with low and medium understanding level were representative of the trend in the overall data which had indicated that the improvement in the NOS understanding of the experimental group students would be better than the control group students. On the other hand, the comparative performances of the interviewees with high-level understanding was an exception to the aforementioned trend.

Table 4.10. Interview students' total and category-based NOS scores in all three tests.

NOS Scores	Categories	Max Score	Experimental			Control		
			LOW S56*	MID S40*	HIGH S38*	LOW S19*	MID S13*	HIGH S33*
Pretest	Total	185	104	129	140	104	128	144
	AV	20	10	13	14	12	13	15
	SP	40	26	30	31	19	25	30
	M	20	11	13	13	11	15	15
	SK	35	21	21	22	17	23	25
	SI	70	36	52	60	45	52	59
Post-test	Total	185	157	161	154	151	133	160
	AV	20	10	13	12	18	13	17
	SP	40	33	32	28	33	30	33
	M	20	18	19	19	17	15	18
	SK	35	27	35	33	27	22	29
	SI	70	69	62	62	56	53	63

*Student identification numbers which were assigned to protect privacy of the participants

4.3. The change in students' NOS perceptions

This section aims to answer the second main research question, "*How does the control and the experimental group students' perceptions of NOS change after learning NOS with regular practice or RFN approach?*". In order to answer this question, interviews were conducted with 6 students before and after the intervention. For this purpose, 3 students were purposefully selected from each class based on their understanding levels as assessed with RFN Student Questionnaire in the pretesting. Transcriptions of pre and post student interviews were qualitatively analyzed to obtain students' perceptions of NOS. In order to investigate how students' perceptions have changed, the codes obtained from the control and experimental group students are compared before and after the intervention. These comparisons are elaborated by sharing related excerpts from the interviews under the following sub-headings of RFN categories. As the study was conducted in Turkey, the language of instruction and data collection including the interviews was Turkish. Therefore, these the quotations were translated from Turkish. The originals can be found in Appendix D. The location of the associated originals is written in parenthesis such as (Appendix D, line 5) after the quotation. The student whose response is being shared and the time of the response can also be identified from square brackets which can be also found at the end of each excerpt. For example, [C-M-POST] would imply that the shared response was given during the post-interview (POST) by the control group student (C) with an initial medium level NOS understanding (M). The following Figure 4.3 explains the meaning and sequence of each notation in the square brackets.

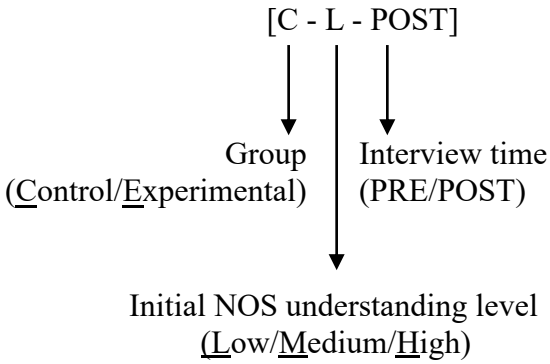


Figure 4.3. Explanation of the notations used in excerpts.

Before making comparisons, all codes that were given to students' explanations are presented in the same table format for each category. Table 4.11 is an example of this format. The table shows the given codes on the leftmost column. The next column proposes an operative definition of this code based on the explanations found in literature or the researcher's own terms. The right side presents which students have mentioned the issues and resultantly received this code for her explanations. As previously explained in the participants heading of methodology section, there were purposefully selected 3 interviewees from each of the control and experimental groups and they had been determined to present an initial low, medium or high-level understanding during the pretest. The interpretation of the example table indicates that during the pre-interviews, the 'exemplary code' in this instance was given only to student with medium-level understanding (M) from the experimental group. This code was also given to the control group students with high- and low-level understanding as respectively represented by H and L on the 5th column. Each of these letters is written on the table to represent a 'novel mention'.

Table 4.11. The frequency of the codes for students' perception of an example category in terms of the groups and interview times.

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Exemplary code*		M (1)	H-M-L (3)	H-L (2)	M-L (2)
…		…	…	…	…
Total mentions of this category		1	3	2	2

For the purposes of this study, a novel mention is operationally defined as 'a code given to each student only once, and on the condition that their answers to the interview questions present proof of attainment of a learning goal or a unique perception on a targeted issue'. Consequently, repetitive mentions of an issue such as empirical adequacy throughout an interview sitting are accounted only once. These novel mentions of unique issues from each student are counted separately for pre and post-interviews of experimental and control groups and displayed on the appropriate columns of the last row. These of the RFN categories. On the other hand, if a student articulates ideas about or shows attainment of learning goals related to objectivity *and* accuracy *in addition to* empirical adequacy, the

student receives separate codes for each of these ideas: objectivity, accuracy, empirical adequacy. Therefore, meaning extracted from segments of students' answers were given codes rather than the vocabulary that they have used. On the occasion that some codes converge in a larger issue, these codes were clustered to form sub-categories under the themes (RFN categories). This was mainly done in order to organize the presentation, interpretation and discussion of these codes in a coherent way. One example of such occasion is the *exploration* sub-category under the aims of science. This sub-category involves the codes of *explanation* and *discovery*. In this case, these codes were separate because the first one refers to a more theoretical exploration while the other refers to a more tangible finding. But, it was determined from the students' references to these, it was determined that the ultimate goal of these is the exploration of the real world.

Additionally, the table sections with (-) show that none of the students who are under the conditions of that section of the table received that particular code. Lastly, the definitions of the codes marked with an asterisk (*) as in the example code were taken from Akgun (2018). She had conducted interviews with university students and evaluated the students' perceptions through the scope of RFN as well. Only when similar codes emerged with the a similar meaning attributed to them, the definitions of Akgun was (2018) used to achieve simplicity in the accumulating literature.

4.2.1. Aims and values of science

In order to get students' perceptions about aims and values of science they were asked the following questions: "Why do the scientists conduct scientific studies?", "What are the aims of conducting scientific studies?", "What are the values that scientists must follow?" and "What are the rules that scientists must abide?". Students' answers to these questions were transcribed and coded. The specific codes related to the aims and values of science and their frequencies are presented in Table 4.12 and Table 4.13 separately. Students' suggestions for aims of science were generally revolving around *exploration*, *social utility*, and *personal and financial motivation*. Therefore, the respective three sub-categories were formed to better represent the data as shown in Table 4.12. Likewise, two sub-categories were formed for the values of science as *cognitive-epistemic and social values of science* and *qualities of a scientist* as shown in Table 4.13.

Table 4.12. The frequency of the codes for students' perception of aims of science in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Exploration					
Explanation	Finding answers for the humans' wondering of the natural phenomena, human nature, and their relationship	H-M (2)	-	-	-
Discovery	Unveiling unknowns about life such as finding new species	-	H-L (2)	-	-
Social utility					
Serving for humanity*	Progression in different fields of life as medicine and technology; meeting the demand	M-L (2)	H-M-L (3)	-	-
Informing the public	Transferring the knowledge accumulation to the public	H-L (2)	M (1)	M (1)	H (1)
Curing illnesses	Finding solutions to diseases	-	H-L (2)	-	M-L (2)
Usefulness	Having a positive effect on practical problems	H-M-L (3)	-	M-H (2)	-
Ease of life	Alleviating life conditions of humans	M (1)	-	H (1)	M (1)
Inventions	Creating or designing things that did not exist before	H-M-L (3)	M (1)	L-H (2)	M (1)
Forecasting	Making predictions in order to take precautions in cases like natural disasters	-	-	H (1)	H (1)
Self-fulfillment					
Curiosity	Conducting science in order to fulfill a strong desire to learn	M-L (2)	-	M (1)	M (1)
Personal pleasure	Conducting science for individual enjoyment	-	-	H (1)	-
Financial motivation	Conducting science to obtain monetary gains	-	M (1)	-	-
Total mention of aims		15	10	9	7

Students' perceptions of the aims of science.

Exploration as an aim of science was only mentioned by the experimental group students. These students suggested that the *explanation* of natural phenomena and *discovery* could be the aims of scientific studies. For example, in the following excerpt, the student suggests that the discovery of new species might be one aim of conducting science.

> Researcher: What could be the aims of scientists to conduct scientific studies?
> Student: There are small, microscopic organisms that we know of. For example, there could be more animals that we cannot see. Scientists could do (studies) about them. [E-H-POST] (Appendix D, line 1)

The student's example of discovering new species is novel and therefore important. Therefore, in order to represent her novel thinking a separate code was attributed: *discovery*. Her choice of example implies that the emphasis on scientific knowledge growth in the case of discovery of the microscopic organisms in the Activity 10 made her think that such revelations are possible, and scientists might be trying to achieve them. Lack of such focus in regular practice used in the control group's instruction might be the reason why none of the control group students asserted exploration as an aim of science.

Social utility was the most prevalently discussed aim of science in both control and experimental groups. Students from both groups suggested various aims of science that ultimately converge in the good of the public such as *serving for humanity*, *informing the public*, *curing illnesses*, *usefulness*, *ease of life*, *inventions* and *forecasting*. Among these serving for humanity was most frequently mentioned as in the following excerpt:

> (Scientists conduct scientific studies) To contribute to humanity. For example, a type of cancer or disease without a cure… They could find a solution for that illness. [E-H-POST] (Appendix D, line 2)

The student's response also touches upon the aim of curing illnesses. This aim was frequently put forth as an example by various students in both groups throughout the term. This collective interest may have been projected onto the interviewees' answers. *Self-fulfillment* of the scientists was not frequently discussed by the students. *Curiosity* of the scientists was suggested as a driving factor by the students from both groups. Additionally, only a total of two students mentioned *personal pleasure* and *financial motivation* as possible aims of conducting science. The student who mentioned financial motivation stated that:

> (Scientists) Try to contribute to society. But some of them do it only for the money and that is bad. [E-M-POST] (Appendix D, line 3)

As can be seen in the excerpt, the student sees doing science for the money as a malicious objective. This might indicate that the student upholds scientists to unrealistically high ethical standards. This is not congruent with a humanistic view of scientists. Considering that also very few students talked about self-fulfillment as an aim of science, it can be concluded that neither the RFN based instructional sequence nor the regular practice was able to promote a realistic view on this issue.

Overall, the total mention of novel codes by the control and experimental groups was not essentially different in pre or post interviews, and there was a reduction in the number of codes obtained from the students' answers in both groups. At the end of the intervention, the students from both groups were still more heavily focusing on social utility as an aim than personal fulfillment and even perceiving the latter to be a malicious goal. Therefore, the results indicate that the effectiveness of the teaching methods used in the two groups was not different in terms of promoting a wider, more humanistic view of science and scientists. But this is not surprising since this issue was not a focus of attention in any of the activities. On the other hand, these results suggest that there is a need to improve students' perception on this aspect. Therefore, if time permits, promoting a more humanistic view of scientists addressed in this instructional unit or the units of the following semester and years.

Students' perceptions of values of science.

Cognitive-epistemic and social values of science were mentioned by the experimental group students through answers which were coded as adequate evidence, precision, and peer relations. As can be seen in Table 4.13, Control group students' answers were related to accuracy, doing no harm, protection of intellectual property and again, peer relations. The total number of novel mentions of these values by different students were 5 for the experimental group and 6 for the control group. Therefore, the initial spread of the codes obtained from the students of the two groups was very close. Later, during the post-interviews, these references increased to 16 for the experimental group and 8 for the control

Table 4.13. The frequency of the codes for students' perception of values of science in terms of the groups and interview times.

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Cognitive-epistemic and social values of science					
Accuracy	Striving for authenticity of scientific findings	-	M-L (2)	M (1)	H-M (2)
Adequate evidence	Sufficiency of obtained proof and its scientific value	M (1)	H-M (2)	-	-
Equality of intellectual authority	Equality of two ideas independent from the hierarchical status of their proponent	-	H (1)	-	-
Explanatoriness	In terms of theories, having a greater coverage in serving to explain the findings of a scientific study	-	H (1)	-	-
Objectivity*	The characteristics of scientific claims which are independent from cultural and religious values	-	L (1)	-	-
Testability	Openness for systematical scientific scrutiny	-	H-L (2)	-	-
Precision	Striving for refined measurement and calculation	M-L (2)	-	-	-
Doing no harm	Animal care, respect for the environment, protection of archeological findings, human subjects protection, consent, non-discrimination and human rights	-	H-M-L (3)	M-L (2)	H-M-L (3)
Protection of intellectual property	Reserving the rights to ownership of ideas	-	H-L (2)	M (1)	M (1)
Transparency	Being upfront about conflicts of interest to uphold trustworthiness and reliability of scientific studies			M (1)	M (1)
Peer relations	Mediation of the communications between scientists in their collaboration and cooperation by being cordial	H-M (2)	M-L (2)	H (1)	H (1)

Table 4.13. The frequency of the codes for students' perception of values of science in terms of the groups and interview times (cont).

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Qualities of a scientist					
Perseverance	Relentless consistency in doing something which may include repetition of scientific studies	M-L (2)	H-M (2)	H-M-L (3)	H-M-L (3)
Enthusiasm	Scientists' passion for their work	H (1)	-	M (1)	-
Benevolence	Having well-meaning and conducting science only for charitable reasons	H (1)	-	-	-
Carefulness	Avoiding potential mistakes by paying attention	H-M-L (2)	-	M (1)	H (1)
Competence	Having professional knowledge of science and successfully conducting scientific studies	-	-	-	H (1)
Total mention of values		11	18	11	13

group. For example, experimental group students' responses during the post-interviews received additional codes which were not mentioned before the intervention. These are accuracy, equality of intellectual authority, objectivity, testability, doing no harm, and protection of intellectual authority. Addition of these codes indicates a broader range of diversification in the experimental group students' perceptions of cognitive-epistemic and social values of science.

During the pre-interviews, *qualities of a scientist* were nearly equally mentioned as the cognitive-epistemic and social values of science by the students from both groups since answers of the experimental group students received 6, and answers of the control groups received 5 novel codes. According to students' answers qualities of a scientist are perseverance, enthusiasm, benevolence, carefulness, and competence. Among these, the most prevalent code was perseverance. As in the following excerpt, nearly all students think that scientists should constantly try in order to achieve:

> First, the project is drawn. Then, you start to do it accordingly. If you can't achieve, you try again and again and ultimately you can succeed. If you can't succeed, you need to persevere. [E-M-PRE] (Appendix D, line 4)

This answer may imply that the student thinks that scientists do not fail as long as they try enough. On the other hand, there are also external factors on achieving a result such as social-institutional constraints. Therefore, the student's answer indicates a naïve view.

> One student from the experimental group mentioned benevolence of the scientists: If they don't want to inform the people, why do they become scientists? If they want the harm of the people, they should not do harm. If so, they should quit the profession. [E-H-PRE) (Appendix D, line 5)

The student's answer demonstrates that the student thinks of benevolence as a prerequisite of being a scientist. This is in line with the students' limited mention of personal fulfillment as an aim of science. After the intervention, the student did not reflect on such a view. Therefore, the RFN based intervention may have had an impact on the student's views on this issue. Similarly, after the intervention, the experimental group students' novel mention of qualities of a scientist was also reduced to 2.

Table 4.14. Change in the number of codes obtained from individual students' answers in terms of aims and values of science.

	Number of codes																	
	Experimental									Control								
	PRE			POST			Change			PRE			POST			Change		
Category	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Aims	4	6	5	3	4	3	-1	-2	-2	5	3	1	1	4	1	-4	1	0
Values	4	5	3	7	5	6	3	0	3	2	7	2	6	5	2	4	-2	0
AV	8	11	8	10	9	9	2	-2	1	7	10	3	7	9	3	0	-1	0

Overall numbers of codes attributed to individual students' answers in terms of aims and values of science are presented in Table 4.14. When the students with the same level of initial NOS understanding are compared, students with low level understanding largely differ. On the other hand, this gap was closed during the post-interviews. Comparison of the number of codes obtained in the pre and post interviews indicate that in terms of the *aims of science*, there is a reduction in the number of codes attributed to experimental group students' answers, while there was no clear pattern for the control group students. In terms of the *values of science*, again, there was no clear pattern in the change in the number of codes of the control group students. But, the number of codes of the experimental group students have increased. When the number of the total codes obtained in terms of the aims and values of science category is examined, two of the experimental group students showed minimal improvement, while two of the control group students remained the same.

When the changes in the number of codes attributed to individual students are closely inspected, it is evident that the RFN based intervention had a positive impact on the students' perceptions of values of science. On the other hand, the change was negative in terms of the aims of science. When all of these codes are accounted, there seems to be minimal improvement. In contrast, there was no improvement in the perception of the control group students. As presented in the previous section, there was no significant difference between the changes in the NOS understanding scores of the control and experimental groups in terms of the aims and values of science category as assessed with RFN Student Questionnaire. Qualitative results suggest that there was a minimal improvement in the experimental group students' perceptions of aims and values of science in contrast to their peers in the control group, but this may not have been big enough to cause a significant difference in the mean changes of their RFN Student Questionnaire scores.

In summary, students from both control and experimental groups, in both of their interviews frequently related the aims of science to social utility. In contrast, personal-fulfilment of the scientists were limitedly mentioned in either of the interviews of the two groups. Therefore, it can be concluded that the students' focus was not changed by the intervention. On the other hand, after the intervention, experimental group students' perceptions of cognitive-epistemic and social values of science was broadened as can be seen in the higher number of novel codes obtained from their answers in the post-interviews. In contrast, their mention of the qualities of a scientist was more limited during the post-interviews. These changes were not observed in the answers of the control group. The changes in the number of codes obtained by individual students also indicate that RFN based intervention caused a minimal improvement in the experimental group students' perceptions of aims and values of science. On the other hand, this difference may not have been large enough to cause a significant difference between the mean changes of the two groups' AV category-based scores in the RFN Student Questionnaire.

4.2.2. Scientific practices

In order to get students' perceptions about scientific practices they were asked the following questions: "What comes to your mind when I say scientific practices?", "Can you give some examples?", "Are there any questions and problems that are related to our lives but would not in the purview of science?", "Have you ever heard about observation? What does it mean? Have you ever done observation in science class?", "Have you ever heard about experimentation? What does it mean? Have you ever conducted experiments in science class?", and "Have you ever heard about classification? What does it mean? Have you ever done classification in science class?". Lastly, the question of "What is the purpose of scientists in using models?" was asked by sharing an example of a pictorial model from the 4th grade science book. The aim of asking more specific questions about observation, experimentation and classification was to learn about participants' prior experiences with these scientific activities. During the post-interviews, these questions also served to investigate the students' ability to link their experiences from the activities in the instructional sequence to the practices of the scientists. All codes obtained from the transcriptions of students' answers are presented in the following Table 4.15. The codes of practical, making practice, and practical solutions represent participants' descriptions of scientific practices. Various activities code was given to the activities that were suggested by

Table 4.15. The frequency of the codes for students' perception of scientific practices in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Experimentation	The process of controlled investigation to determine the effects of one or more variable on others	H-M-L (3)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Observation	Systematical close inspection	M-L (2)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Classification	Grouping things based on a priori reasoning and knowledge from theoretical deduction	H-L (2)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Data	Scientific finding that consist a basis for reasoning and calculation, and their collection and analysis procedures	-	H-M (2)	-	-
Model	Functional representation of objects, structures, organisms or scientific phenomena	-	H-M-L (3)	-	H-M (2)
Explanatory capacity of models	The power of models in explaining the processes that they represent	-	H-M-L (3)	-	-
Predictive capacity of models	The power of models in predicting outcomes of their subject of representation	-	H-M (2)	-	-
Explanation*	A set of statements that used to describe a set of facts by focusing on the causes, context, and consequences of those facts	H (1)	H-M-L (3)	-	-
Prediction	Declarations made in advance of an outcome	H (1)	H-M (2)	-	-
Real world	Investigation of the existing state of things, as opposed to those that is imaginary, simulated or theoretical	M (1)	H-M (2)	H (1)	-
Reasoning	Deliberating about the scientific findings to arrive at conclusions, or the pattern of those deliberations	-	H-M (2)	-	-
Discourse	A collective, on ongoing debate environment around the scientific issues in order to address anomalies	-	H (1)	M (1)	H (1)
Social certification	The processes of verification of scientific findings and their interpretations by other scientists, organizations and public	L (1)	H (1)	M-L (2)	M (1)

Table 4.15. The frequency of the codes for students' perception of scientific practices in terms of the groups and interview times (cont.).

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Various activities	Inspection, questioning, taking notes, software development	M-L (2)	-	H (1)	L (1)
Practical	Students' description of scientific as making things more efficient in terms of time and effort	-	-	H-M (2)	M (1)
Making practice	Students' description of scientific as repetition such as rehearsals	M (1)	-	-	-
Practical solutions	Students' description of scientific practices as hands-on, time efficient means of solving a problem	H (1)	-	-	-
Total mention of scientific practices		15	30	16	15

the students to be examples of scientific practices but were not in the benzene ring heuristic which was put forth as a generative image of science for scientific practices by Erduran and Dagher (2014). This image can be found in Figure 2.4 in the second chapter. Remaining codes are scientific practices that take part in the mentioned benzene ring heuristic.

Experimentation was a familiar term for all students from the beginning. But there were differences between the students' perceptions of experimentation. For example, students with medium and low-level understanding from the experimental group and students with high- and low-level understanding from the control group initially explained it as mixing materials. Below a telling example of such instance is shared:

> Researcher: What does experimentation mean?
> Student: Experiment… There are some jars. When they pour it, it evaporates. I had done it once before. … They had taken us to the Martyrs Park since it was the end of the semester. It happened there. They were making us first watch and then do by ourselves.
> Researcher: Can you give me an example of an experiment? What else we can do could be an experiment?
> Student: For example, a glass… We can fill the glass with a substance. Then, if we pour the other substance into it, another substance might gush out or if we do something wrong the substance might blow up. [E-M-PRE] (Appendix D, line 6)

In her response, the student suggests mixing materials would be an experiment. She doesn't mention any other condition such as controlling the environment to assess the change in the dependent variables. As said before this was common among the students of both groups. But what is significant here is that the student refers to the source of her perception. It is important because the town in which the school is located is small; therefore, it is likely that the other students had also participated in this event. Another contributing factor in this prevalent narrow view could be the name of the instruments which are generally used in this type of chemistry-based activities: *deney tüpü*. It has a similar name in English, and its direct translation is experiment (test) tubes. The frequent use of images of test tubes in the textbooks in order to depict 'experiments', would not have helped to widen students' views. Unfortunately, the precarious experiences these students had with experiments was not resolved with this intervention. Although there were two student-oriented, experimentation activities in the last unit, the same students' answers in the post-interviews suggest that this naïve view of experimentation has persisted since their answers were in similar lines. Additionally, control group students with high and medium-level understanding referred to

experimentation as any activity that is conducted in class. This view has also persisted during the post-interviews:

> Researcher: What does experimentation mean?
> Student: Doing something fun such as projects. Most experiments are fun.
> Researcher: Have you ever done experiments in the classroom?
> Students: Yes, we have looked (at yeast) with a microscope. [C-H-POST] (Appendix D, line 7)

The time of the students' remark is significant. The control group student who had received science instruction based on regular practice refers to experimentation as any fun activity even at the end of the term. Therefore, it can be concluded that the instruction was unable to embark a sophisticated view of experimentation. It was also common for students to confuse experimentation and observation:

> Researcher: Have you ever done experimentation at school?
> Student: We had done it once in school, in the science course. We had looked at the microscopic organisms with a microscope. There was also a wing of a fly. They had made us inspect them. We had viewed the small pieces. Also, mold and bread, we had viewed them too.
> Researcher: What was your goal while doing it?
> Student: To closely see the living things. [E-H-PRE] (Appendix D, line 8)

As shared in the excerpt, the experimental group student with high level understanding refers to observing with a microscope as an experimentation activity. During the post-interviews, she has also given a similar activity as an example. This time she clearly told that Activity 09 (Appendix E) in which they had observed yeast with a microscope was an observation. Therefore, the RFN based instruction she had received was successful in changing her perception in this regard.

There was a similar trend in terms of *observation*. During the pre-interviews, the students explained observation as viewing for some time and reviewing. After the intervention, even the experimental group student with low level understanding had started to describe it as careful inspection of particular characteristics:

> Researcher: What does it mean to make observations?
> Student: Observing… (For instance) I want to investigate a bird. I carefully look at the bird, I investigate it. It is called observation. We carefully investigate.
> Researcher: What do we do by investigating?

> Student: For example, we don't know the characteristics of that bird. We reach some information about it. For example, it can fly, it has short legs, it tweets in a particular way. [E-L-POST] (Appendix D, line 9)

According to her answer, the student perceives observation as carefully investigating with the purpose of learning. This is more in line with a scientific view of observation than viewing for some time without a purpose or reviewing others' work. In contrast, there was no development in the control group students' perceptions. Thus, it can be concluded that RFN based intervention was able to promote a more elaborate view of observation.

In terms of *classification* as a scientific practice, again, nearly all students were familiar with the term except the experimental group student with medium-level understanding. But they were talking about classification as a mere sorting activity. Even after the intervention, none of the students referred to the theoretical background of the classification as a scientific practice. The expectation would be for students to tell that the scientists had determined some common characteristics for groups such as types of celestial bodies or living things since during instruction there was an emphasis on this aspect of classification as a *scientific activity*. Instead, the students' answers were more superficial:

> Researcher: What does classification mean?
> Student: Grouping things. We had done classifications like animals group, plants group, microscopic organisms group, fungi group. In all of them, we had classified them by looking at some common characteristics.
> Researcher: Can you remember any other classification activity?
> Student: It was in the first unit. We had done a classification of planets, stars, and satellites. [E-M-POST] (Appendix D, line 10)

Based on the shared excerpt, it should be acknowledged that the student became able to give examples of classification from scientific contexts and she had a specific language in terms of the characteristics of species to be examined. Nonetheless, there is no reference in students' answer to the predetermined set of rules or theory-ladenness in general.

Among the remaining scientific practices that were listed by Erduran and Dagher (2014) *data*, *model* and *reasoning* were not mentioned by any of the control or experimental group students during the pre-interviews. Later, during the post-interviews, while two students from the experimental group talked about data and reasoning, control group students still did not make any comments about them. During the post-interviews, all students from the experimental group and two students from the control group talked about models. On the

other hand, the two control group students' explanations were limited to the solar system model that was enacted during the Movements of Earth, Sun and Moon activity and they did not make metalevel explanations about the modeling practice of scientists. It should also be noted that there were other activities that involved students in making or benefiting from models (e.g. Activity 9 and Activity 12, shared in appendix E and G, respectively). This meant that the activity had stayed as an isolated event for these students and they could not relate the modeling activity to the scientists' practices related to models. Contrary to their peers in the control group, experimental group students were able to relate preparation and use of models to their use in science, give examples from contexts other than the ones that were referred to throughout the instructional sequence, and even explain the models' *explanatory and predictive capacities*. The following is such an example:

> Researcher: What is the purpose of scientists in using models? For what purpose do the models serve?
> Student: Models help scientists to understand complex things. For example, the law of gravitation would be very complex. By modeling it scientists were able to explain it in simple terms.
> Researcher: What would be another purpose of models?
> Student: They help us test (things) without actually doing them. We model and (think that) if we amalgamate it to that cable it won't work, if we attach it to that cable it might be better. For example, architects draw a building and then construct it. There are oblique buildings just for the sake of design which requires more effort since they have a tendency to collapse. [E-M-POST] (Appendix D, line 11)

In this instance, the student was able to confer about the use of models in science. She gave an example of how models can be used to explain natural phenomena. Additionally, her example of architects' use of models is a good example of using models for making predictions. These all indicate a sophisticated view of models and her perception of models are from a higher vantage point than her peers in the control group. This allows the conclusion that RFN based instruction was more effective in teaching about models as a scientific practice than the regular practice. The increase in experimental group students' novel references to *explanation* and *prediction* as scientific practices was also in line with the increasing depth of their perception of the explanatory and predictive capacity of models. The control group students did not mention about these practices even after the intervention.

One aim of emphasizing nature of science in science teaching is enhancing students' ability to demarcate science from non-science and pseudo-science. In this regard, an understanding of the purview of science as the *real world* is important. Initially, only the

experimental group student with medium-level understanding had some awareness in this regard. She had stated that some things were only left to the control of the god. During the post-interviews her perception had become more sophisticated:

> Researcher: What does science work on?
> Student: The things that can be done in reality. It could be about rain or natural phenomena.
> Researcher: About what could not it be?
> Student: Figments of our imagination. Because we couldn't do them yet. Science isn't concerned about fictional things. [E-M-POST] (Appendix D, line 12)

In her answer, the student is adamant about science's focus. In this answer that was given after the intervention, she is more precise about why some things are not a concern of science beyond an epiphenomenal justification. At the end of the semester, her perception was more sophisticated and grounded. Additionally, her peer with high level understanding was also discussing this issue in similar lines. On the other hand, none of the students from the control group could comment about the science's relationship with real world. Therefore, it can be said that the RFN based instruction that the experimental group students had received was effective in this aspect of their perception of NOS.

No clear pattern could be found in terms of students' perceptions of *social certification*. Initially, experimental group student with low level understanding and control group students with medium and low-level understanding had mentioned about it but later their views did not endure. On the other hand, experimental group student with high level understanding commented about social certification as a scientific practice later in her post-interview. The novel references to *discourse* were also irregular.

When asked about examples of scientific practices during the pre-interviews, a total of three students suggested inspection, questioning, taking notes and software development. These were coded as various activities since they are not mentioned as scientific practices in Erduran and Dagher's (2014) benzene ring heuristic and the data analysis was done from the scope of the RFN framework. During the post-interviews, the two experimental group students had withdrawn from referencing to these various practices as scientific practices. This might be a result of working on the generative image pertaining to scientific practices. This image was adapted for this context from the one developed by Erduran and Dagher (2014). This image is presented below as Figure 4.4. The Turkish version which was used

with the participants of this study was also shared in the Appendix H along with the adapted versions of the rest of the generative images of science.

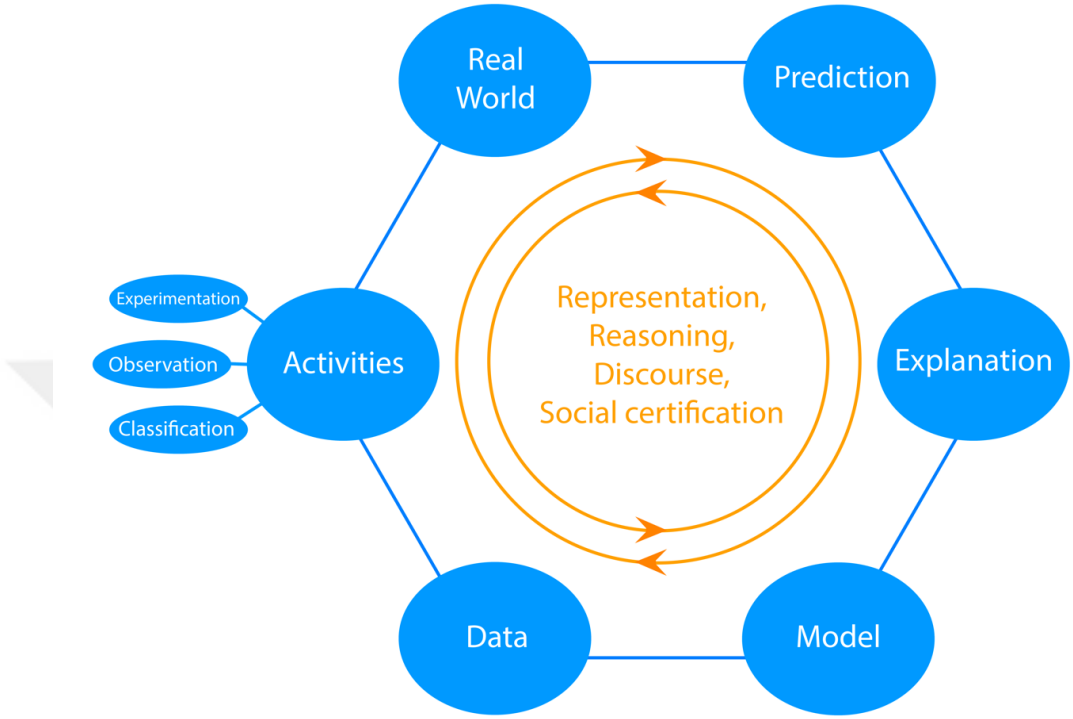


Figure 4.4. Adapted GIS for Scientific Practices category

In the case of scientific practices, adaptation was only made to make the language easier for the students. 5th grade students are not familiar with the benzene ring and therefore the related analogy could not be made. Nonetheless, the orientation of the scientific practices in the image was found memorable by the researcher and the teacher. It should also be noted that the term of *bilimsel pratikler* as an exact translation of scientific practices was not found fruitful for 5th grade students. As shared in the below excerpt, the word of *pratik* (practice) was ambiguous for the students with their tendency to related it to making things in more practical ways or making practice:

> Scientific practices… I can think of making practice like working on it again and again. [E-M-PRE] (Appendix D, line 13)

From her answer, it is clear that the student interprets scientific practices as something closer to rehearsal or repetitive work than the practices of the scientists.

As a last note, as shown in Table 4.16, when the number of novel mentions for issues related to scientific practices is counted, a steep increase from 15 to 30 was found in terms of the experimental group students' novel mentions. The total number of novel mentions of the control group students was decreased by one point. When the previously presented sophistication in the experimental group students' explanations is also accounted, it is clear that RFN based instruction was more effective in broadening and also deepening students' perception of scientific practices. On the other hand, as assessed with the RFN Student Questionnaire in the previous section, there was no statistically significant difference between the mean changes of the experimental and control groups' SP category-based scores from pretest to post-test. Therefore, for the scientific practices category quantitative and qualitative results contradict in terms of the extent of the changes from pretest to post-test. Still, it should be acknowledged that the quantitative results had also indicated that there was a significant difference between the two groups' mean changes from the pretest to delayed post-test.

Table 4.16. Change in the number of codes obtained from individual students' answers in terms of scientific practices.

	Number of codes					
Student	Experimental			Control		
	PRE	POST	Change	PRE	POST	Change
H	5	13	8	6	5	-1
M	5	11	6	6	6	0
L	5	6	1	4	4	0
Total	15	30	+	16	15	-

4.2.3. Methods and methodological rules of science

Students' perceptions of methods and methodological rules of science were probed with the following questions: "What methods do scientists use in order to answer the questions which they have in their minds?", "Do scientists have suppositions in their minds while working on scientific studies?", "Is it possible for scientists to find unexpected results contradicting their prior suppositions?", "What does a variable mean?" and "While working in different subject areas do scientists use the same method?". Students' responses to these questions were transcribed and coded. The novel codes attributed to the students' explanations are presented in Table 4.17.

Table 4.17. The frequency of the codes for students' perception of methods and methodological rules of science in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Hypothesis testing	Falsification or confirmation of hypotheses through designed controlled investigations	-	H-M-L (3)	-	H-M-L (3)
Non-hypothesis testing	Methods of investigation that are not hypothesis-driven	-	H-M-L (3)	-	-
Having presuppositions	Students' idea that scientists have expectations for the process and outcomes of their studies without actually mentioning their testing	H-M-L (3)	-	H (1)	-
Manipulation	Determining, controlling and altering variables in order to test hypotheses	-	H-M-L (3)	-	M (1)
Non-manipulation	Methods of investigation that do not require altering variables	-	H-L (2)	-	-
Various activities	Activities that are mistakenly suggested to be various methods by the students such as archeological excavation, tranquilizing animals, and drawing diagrams	M-L (2)	-	H-M-L (3)	M (1)
Domain specificity of methods	Uniqueness or diversity of methods in terms of different aims and branches of scientific studies	-	H (1)	-	-
Investigating with appropriate tools	Making investigations with microscope, telescopes and computers as different methods of science	H-M-L (3)	-	H-M-L (3)	H-M-L (3)
Total mention of methods		8	12	7	8

As can be seen in Table 4.17, when the mentioned questions were asked during the pre-interview, students' suggestions for methods of science were merely *various activities* of scientists and investigating with appropriate tools. Some of these suggestions were conducting research, trial and error, capturing images, tranquilizing animals, drawing diagrams, making comparisons, finding solutions, and reporting. When specifically asked about having presuppositions during conducting scientific studies, all students from the experimental group and one student from the control group affirmed that scientists could have presuppositions. One student claimed that having these 'presuppositions' was a prerequisite of doing scientific studies:

> (The scientists) ought to have presuppositions. If they do something unknowingly, dangerous things can happen. [C-C-PRE] (Appendix D, line 14)

As evident in the shared excerpt, since students were not familiar with testing of hypotheses, the discussion of these presuppositions was non-specific in nature. For this particular student, presuppositions were some type of expectations that would ensure safety while conducting scientific studies.

After the intervention, students' answers for the same question became more specific. As all students were now familiar with the term of hypothesis, upon hearing presuppositions, they thought about hypotheses and commented about using them in their prior activities in the classroom. But only the experimental group students were able to specify *hypothesis testing*. The following quotation represents the thinking of the control group students:

> Student: … We have also written hypotheses when it's asked in a question. If it is confirmed, we explain why. If it is falsified, we explain why. They (scientists) also have an idea in their minds and after doing it they find the result.
> Researcher: What does hypothesis mean?
> Student: Hypothesis is a proposition. … For example, … with the friction force, it will go a shorter distance on the towel, but it will go a longer distance on the plastic sheet. Its question is also asked.
> Researcher: How do we decide if the hypothesis is confirmed or falsified?
> Student: By conducting research. [C-H-POST] (Appendix D, line 15)

In her explanation, she stated that they write a hypothesis only because it is asked in one of the questions in the activity sheet. She can describe what a hypothesis is and give an example. She is also aware that hypotheses can be confirmed or falsified. On the other hand, while transferring these ideas to science, she says that scientists might also have an *idea*.

Therefore, her perception of hypothesis does not include their testing -or not testing- as a scientific method. Unlike their counterparts in the control group, experimental group students once again were able to give novel examples to explain their ideas, this meant that these students were able to transfer their ideas to unique circumstances. More importantly, they were able to relate their activities in the classroom, their use of the scientific method which is called hypothesis testing to the work of scientists. One student from the experimental group stated that

> For example, in hypothesis testing, we have an idea in our minds. For example, 'all flowers are yellow". We test it. At first glance, there are only yellow flowers around that person so that person would have said this. Then, I can travel to other places, there would be different colors (of flowers). Then, that hypothesis would be falsified. … A hypothesis can be found to be wrong or true. … For the confirmation (of hypothesis) someone predicts that a car goes with a certain speed. Then, they try and see. But not only once, maybe four times thinking that I could have made a mistake. Then, if it is still wrong, they should accept it as wrong. [E-H-POST] (Appendix D, line 16)

As shared in her own words, the student gives an example which was not a part of the instructional sequence. This indicates that the student has a sophisticated view of testing of hypotheses.

Only the students from the experimental group were able to acknowledge that there is a method that does not involve hypothesis testing. They also stated that it is called *non-hypothesis testing*. On the other hand, there are some misunderstandings found in their explanations. One of these students, who is determined to have medium level initial NOS understanding think that falsification of hypothesis is non-hypothesis testing. Another student thinks that none of the activities conducted in the classroom could be an example of non-hypothesis testing while all activities in the classification unit were exemplary cases of this method.

Manipulation of variables was also not mentioned by any of the students during the first interviews. At the end of the semester, all three students from the experimental group and only one student from the control group were able to make comments about determining, controlling or manipulating variables. Just like in the case of hypothesis testing and non-hypothesis testing, the students had a harder time to talk about *non-manipulation*. Again,

while none of the control group students could comment about it, two of the experimental group students could assert their views on this matter.

As mentioned before, students were also asked about the different methods used in different domains of science. Control group students restated some of their prior suggestions such as archeological excavation and inspecting celestial bodies and these were again coded as *various activities*. Among all 6 interviewees, only one student who is the experimental group student with a high level understanding of NOS could show a sophisticated perception about *domain specificity of methods*. The following is the related quotation:

> I think scientific methods are different for different branches (of science). Because, for example about biology, I will pick a flower and do an experiment about it. But since I wouldn't be able to grab the Earth and make experiments on it even if I wanted to do it in space, I think the scientific methods are various. [E-H-POST] (Appendix D, line 17)

The student's reference to the inability of doing experiments on the movements of celestial bodies is significant. This shows that she does not only claim a variety in scientific methods, but she also justifies their existence in her own terms.

Table 4.18. Change in the number of codes obtained from individual students' answers in terms of methods and methodological rules of science.

	Number of codes					
Student	Experimental			Control		
	PRE	POST	Change	PRE	POST	Change
H	2	5	3	3	2	-1
M	3	3	0	2	4	2
L	3	4	1	2	2	0
Total	8	12	+	7	8	~*

* The symbol of ~ indicates that there was no pattern of change in the number of novel codes achieved by the students in that group from pre-interviews to post-interviews: number of codes obtained from one student decreased, the other increased and the last one did not change.

As shown in Table 4.18, in terms of methods and methodological rules of science, while there is an increase in the total number of novel codes attributed to the experimental group students' explanations from 8 to 12, this increase in diversity was smaller in the case

of control group students. To sum up the conclusions reached about students' perceptions of methods and methodological rules of science, the experimental group students' perceptions have become more diverse and elaborated than those of control group students after the intervention. These results are also in congruence with the statistically significant difference between the mean changes of the control and experimental groups students' M category-based scores. Hence, it can be conferred that the RFN based instruction was more effective than the regular practice in this regard.

4.2.4. Scientific knowledge

In order to obtain students' perceptions about scientific knowledge they were asked, "What is scientific knowledge?", "Is it different in any way from knowledge?", "What are the types of scientific knowledge?", "Have you ever heard about theories, laws or models?", "What is the relationship between theories, laws and models?" and "How does scientific knowledge develop?". Students' answers to these questions were transcribed and coded. Obtained codes were organized in three categories which were determined based on the trends seen in the data. These categories are types of scientific knowledge, nature of scientific knowledge and growth of scientific knowledge. The specific codes related to these categories and their frequencies are presented in Table 4.19. In the following, these three trends are discussed.

Firstly, during the pre-interviews, none of the students from either of the groups was able to recall the *types of scientific knowledge*. When each of the three scientific knowledge types was asked, two of the students were able to recognize the concept of theories. The following is one of these instances:

> Student: I know what theories are. They are easy ideas.
> Researcher: What do you mean by easy?
> Student: We had talked about practical information. They are like that.
> [C-M-PRE] (Appendix D, line 18)

As seen in the excerpt, during the first interview, the student who had scored in the medium range in the pretest, and who attends the control group classroom, suggested that theories are somehow easy. While elaborating her first answer, the student refers to her prior

Table 4.19. The frequency of the codes for students' perception of scientific knowledge in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Types of SK					
Theory	Well-substantiated explanations of phenomena at hand	0	H-M-L (3)	0	0
Theory as proposition	Students' view of theories as a statement that expresses just an opinion	0	0	M (1)	M (1)
Law	Explanation of phenomena based on repeated experimental observations	0	H-M-L (3)	0	0
Juridical law	Rules of judicial system that citizens must abide	0	0	M-L (2)	M-H (2)
Model	Explanatory representations of phenomena	0	H-M-L (3)	0	M (1)
TLM complementary	The interdependency and reciprocity of theories, laws and models in forming scientific understanding	0	H-M (2)	0	0
Nature of SK					
Tentative*	Changeability of scientific knowledge in light of new evidence or new interpretation of existing evidence	H-M (2)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Static	Scientific knowledge as a fixed, unchanging, and irrefutable set of information	L (1)	0	0	0
Durable	Existing scientific knowledge's ability to withstand testing without yielding anomalies	0	0	M (1)	0
Testable	Openness of scientific knowledge for further scientific scrutiny	0	H (1)	0	0
Growth of SK					
Cumulative development	Gradual development of scientific understanding with new realizations and discoveries	0	H-M-L (3)	0	H (1)
Paradigm shift	Abrupt changes in scientific knowledge as a result of a telling discovery or fundamental change in approach or underlying assumptions	0	H-L (2)	0	L (1)

Table 4.19. The frequency of the codes for students' perception of scientific knowledge in terms of the groups and interview times (cont.).

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Development by collaboration	The potential of scientific knowledge as a result of collaboration between scientists	M-L (2)	0	H (1)	0
Development with technological advancement	The potential of scientific knowledge as a result of advancements in technology	H (1)	M (1)	M (1)	H (1)
Total mention of scientific knowledge		6	21	9	10

description of scientific practices which was “old and convenient ways of doing investigations” [C-M-PRE] (Appendix D, line 19). Therefore, it can be deduced that the student has previously come across with the concept of theories and she perceives them to be ideas that make doing things more convenient. This explanation could not be further elaborated by the student and it is not relevant to the scientific theories which are conventions that can be falsified by critical testing as described by Popper (2005). Considering the nature of the student’s answer, none of the students had knowledge of scientific theories.

Similarly, while none of the experimental group students recognized the term of laws, two of the control group students could only recall the juridical laws even when explicitly asked about *scientific* laws. While one student from the control group described laws as “I think laws are prohibitions like traffic regulations.” [C-L-PRE] (Appendix D, line 20) another said that:

> I already know what a law is. Law is a regulation put forth by the government. People cannot do whatever they like. [C-M-PRE](Appendix D, line 21)

Additionally, none of the students from either of the groups was familiar with the term of models. All students were asked about what a model is and shown an example from their science textbook from the previous year, and they did not know that it was a model.

After the intervention, all three of the experimental group students had become familiar with the terms of theories, laws and models:

> Researcher: What are the types of scientific knowledge?
> Student: Laws, model and theories. Laws state natural phenomena in the way that they happen. Theories explain what happens. Models depict the natural phenomena with figures. [E-M-POST] (Appendix D, line 22)

Moreover, two students from the experimental group were able to refer also to the complementary nature of the three scientific knowledge types:

> Researcher: What is the relationship between theories, laws and models?
> Student: One of them explains, the other one directly tells, and models depict them in three-dimension. [E-M-POST] (Appendix D, line 23)

For the same question, the answer of the student who had been identified to have a high level of understanding in the RFN Student Questionnaire was more detailed:

> Student: Theory, model and laws complement scientific understanding. None of them is more important than others. All three of them are equally important. If one is missing, it is not complete.
> Researcher: What is not complete?
> Student: For example, if there is no theory, there is no explanation of why and how. [E-H-POST] (Appendix D, line 24)

In contrast, after the intervention, only one and the same student from the control group was able to refer to scientific theories. She stated that "As far as I know, theories are propositions." [C-M-POST] (Appendix D, line 25). According to Popper (2005), basic propositions are protocol-sentences that are to be tested. Wittgenstein asserts that meaningful propositions are reducible to elementary propositions which he describes as pictures of reality (Popper, 2005). Therefore, Wittgenstein per se identifies two distinct kinds of propositions. While two well-known philosophers of science define propositions in two essentially different ways, the student's answer and inability to elaborate is problematic. On the other hand, it should be acknowledged that because of the frequent revisits to the category of scientific knowledge and related ideas, to some extent, experimental group students might have memorized these terms. But in any case, this is seen as an improvement even if the students only acquired a knowledge level understanding.

Secondly, students' perceptions of the *nature of scientific knowledge* were represented with the codes of tentative, static, durable and testable. During the pre-interviews, nearly all students asserted that scientific knowledge could change. The following is one of these instances:

> Researcher: Is it possible for things that we already know to change with a new discovery?
> Student: If our understanding was wrong, of course.
> Researcher: Is it possible for us to be mistaken?
> Student: Yes. Because if we don't know about something before, we will learn when we grow and develop. … If it was an old knowledge, since the technology wasn't developed as much, they could have guessed wrong. All old things may not be true… If it has been the same for a long time and if it hasn't changed until now, it certainly cannot change. It could also be only a supposition. It doesn't always have to be true. [C-M-PRE] (Appendix D, line 26)

It should also be pointed out that this student and only this student also emphasized the durability of longstanding scientific knowledge. There was only one student from the experimental group who contradicted the view that scientific knowledge can change. She had been identified with low level understanding in the first implementation of the RFN Student Questionnaire. During the first interview, she could only assert that scientific knowledge does not change but she could not explain her thinking. The following is an excerpt from her post-interview:

> Researcher: Does scientific knowledge change?
> Student: No.
> Researcher: We have already accumulated some knowledge. Is it possible for these to change?
> Student: No.
> Researcher: Is it possible for them to develop?
> Student: Yes.
> Researcher: How does scientific knowledge develop?
> Student: For example, one scientist invented the microscope. Then the other scientists changed it by adding different materials.
> Researcher: What kind of development is that?
> Student: Cumulative.
> Researcher: How else could scientific knowledge develop?
> Student: By inventing new things.
> Researcher: Is there a name for it too?
> Student: Paradigm shift. [E-L-POST] (Appendix D, line 27)

It is seen in this excerpt that the student thinks that scientific knowledge is tentative, and it can change but only by development. She does not believe scientific knowledge can be falsified. Even though, after the intervention her positivist perception did not change, she became familiar with the growth of scientific knowledge and she was able to suggest examples about the development patterns of scientific knowledge. Consequently, after the intervention, all students from the experimental group became familiar with the tentative nature of science.

Thirdly, in the pre-interviews, while nearly all students asserted that scientific knowledge was tentative in nature, only one student from each group was able to assert ideas about the *growth of scientific knowledge*. According to these students' initial perception, scientific knowledge can develop by technological advancement. The student from the control group who was identified with a medium level understanding of NOS stated the following:

> Researcher: How did our scientific knowledge accumulation increase?
> Student: They… as I said before, as the technology develops, we can learn more. [C-M-PRE] (Appendix D, line 28)

Likewise, the student from the experimental group who was identified with a high level understanding also referred to the development of scientific knowledge with the advancement in technology:

> Before, scientific things were not as much as now. Now, technology is more advanced. They can find knowledge more easily. [E-H-PRE] (Appendix D, line 29)

After the intervention, another student from the control group mentioned the development of scientific knowledge with that of technology, and this was the only reference to the growth of scientific knowledge in the post-interviews from the three control group students:

> Researcher: How did we learn about the things that we know today?
> Student: Since technology has advanced… If technology didn't advance, we couldn't learn more. [C-H-POST] (Appendix D, line 30)

These students' explanations indicate that they recognize the idea of the development of scientific knowledge and they acknowledge the role of technology in the process. But these explanations are not epistemologically grounded. In contrast, after the intervention, experimental group students became able to explain cumulative development and paradigm shift with examples. All three experimental group students were able to describe cumulative development. The following excerpt is from one of these instances:

> Student: For example, Galileo Galilei. The church said something in their books and others knew it that way.
> Researcher: Do you remember what the church said?
> Student: They said the Sun rotates around the Earth. Galileo Galilei said that Earth rotates around the Sun. But nobody accepted it. Galileo wrote a book. They put him in prison. But years later, this scientific knowledge would change. The idea that the Earth rotates around the Sun was proven.
> Researcher: What kind of development is this? How did scientific knowledge develop in this example?
> Student: Over the years, by doing investigations and observations.
> Researcher: How does scientific knowledge develop?
> Student: By adding to it.
> Researcher: Is there a name for it?
> Student: Cumulative development.
> Researcher: Is there any other way that scientific knowledge can develop?

> Student: Paradigm shift.
> Researcher: Do you think the example of Galileo is a cumulative development or a paradigm shift?
> Student: I think it is cumulative. Because Galileo said that Earth turns around the Sun and the church was against it. But as time goes by, adding more and more, since looking at the space became clearer, it was easier to convince others. Then, the Earth's rotation around the Sun can be proved. [E-M-POST] (Appendix D, line 31)

On the other hand, only two students from the experimental group were able to discuss paradigm shift. The student who had been identified with high level of understanding in the pretest gave the same example of Galileo v. Church only by identifying it as a paradigm shift in her own terms.

> Student: For example, before, the church had some knowledge. Galileo was saying the right thing: the Earth rotates around the Sun. But the church would say otherwise.
> Researcher: Do you think it was an example of cumulative development or paradigm shift?
> Student: I think it was paradigm shift. [E-H-POST] (Appendix D, line 32)

These excerpts show that contrary to their peers in the control group, students from the experimental group became able to discuss not only the tentativeness of scientific knowledge but also its growth patterns. While referring to the two ways of development, students referred to the reading texts in Activity 02 and Activity 10. These texts were the same in both groups. Therefore, the way they were delivered with RFN based instruction might be the reason for the observed development in the experimental group students' perceptions. This is a critical outcome since one of the intentions while teaching NOS is to familiarize students with "epistemological features of scientific processes and knowledge" (Erduran & Dagher, 2014, p.6).

As can be seen in Table 4.20, the total number of meaningful codes obtained from the students' answers were initially 6 for the experimental group and 9 for the control group. After the intervention, while there was a steep increase in experimental group students' codes to 21, the number of meaningful codes obtained from the interviews of the control group students barely increased to 10. Therefore, the issues mentioned by the experimental group students became more diversified.

In summary, comparison of the codes of interviewees from the control and experimental groups indicates that RFN based intervention may have improved the students'

perceptions of scientific knowledge more than the regular practice. While control group students did not advance their knowledge about the types and growth of scientific knowledge, experimental group students became able to assert ideas and suggest relevant examples for these topics. An improvement was observed also in terms of the students' perception of the nature of scientific knowledge since it was seen during the post-interviews that the only student who initially thought the scientific knowledge was fixed changed her view. These results are congruent with the relatively higher increase seen in experimental group students' scientific knowledge category scores from pretest to post-test.

Table 4.20. Change in the number of codes obtained from individual students' answers in terms of scientific knowledge.

	Number of codes					
Student	Experimental			Control		
	PRE	POST	Change	PRE	POST	Change
H	2	8	6	2	4	2
M	2	7	5	5	4	-1
L	2	6	4	2	2	0
Total	6	21	+	9	10	~*

* The symbol of ~ indicates that there was no pattern of change in the number of novel codes achieved by the students in that group from pre-interviews to post-interviews: number of codes obtained from one student increased, the other decreased and the last one did not change.

4.2.5. Science as a social-institutional system

In this section, students' perceptions of science as a social institutional system will be discussed. As can be seen in the related generative image of science (Figure 2.7), the social-institutional categories are social certification and dissemination, scientific ethos, social values, professional activities, social organizations and interaction, financial systems, and political power structures. Students' perceptions of these categories will be discussed separately in the following sub-headings which follow the same order. Again, firstly the related interview questions will be listed, then the students' perceptions will be compared in terms of their groups and their prior answers. The overall frequency of codes obtained from

Table 4.21. The frequency of the codes for students' perception of social certification and dissemination of science in terms of the groups and interview times.

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Credibility of research					
Conditionally credible	Changing trust on the outcomes scientific studies based on characteristics of the study instead of blindly accepting to be true	H-M-L (3)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Certification criteria					
Adequate evidence	Sufficiency of obtained proof and its scientific value	M (1)	H (1)	-	-
Repetitive testing	Replicating the same conditions of empirical studies in order to increase credibility of research	-	H-M-L (3)	L (1)	M-L (2)
Verification by trying	Authentication of results and implications of a study	H-M-L (3)	M-L (2)	H-L (2)	M-L (2)
Certification by scientists and public	Authentication by scientists and others for credibility of research	M-L (2)	H (1)	H-M (2)	M (1)
Aims of dissemination					
Informing other scientists and public	Adding to the knowledge of other scientists and public by disseminating the findings of a study	H-L (2)	M (1)	H-M-L (3)	-
Disseminating certified knowledge	Circulating only the findings of verified, peer reviewed, dependable studies	-	L (1)	M (1)	M (1)
Benefitting from works of others	Building on others' studies and their findings as a favorable outcome	H-L (2)	M (1)	H-M-L (3)	H-M-L (3)

Table 4.21. The frequency of the codes for students' perception of social certification and dissemination of science in terms of the groups and interview times (cont.).

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Dissemination pathways					
Direct communication channels	Communicating about scientific findings by telephoning, writing letters or face-to-face	H-L (2)	L (1)	H-L (2)	L (1)
Broadcasting	Communicating scientific findings by airing them on mass communication channels such as television, radio or social media	M (1)	H-M (2)	M (1)	H-M (2)
Publishing	Communicating scientific findings by writing newspapers, articles, and books	-	H-M (2)	-	H (1)
Conferences	Communicating about scientific findings during scientific conventions	H-M (2)	H-M-L (3)	H (1)	H-L (2)
Total mention of SCD		18	21	19	18

the two groups will be compared at the end of this section in accordance with Table 4.28 after all other results are presented under the appropriate headings.

4.2.5.1. Social certification and dissemination. Students' perceptions about social certification and dissemination of science were obtained from their answers to the following questions: "Do you think the information reported by scientists is credible?", "How can we assess the credibility of scientific studies?", "Among two opposing ideas about the same subject or topic how can we understand which idea is scientifically accurate?", "Let's assume that a scientist discovered something important. Do they need to inform other people and scientists?", "How can scientists inform the public and the scientific community?", and "Have you ever heard about conferences or seminars?". Students' answers were transcribed and coded. The specific codes related to social certification and dissemination of science and their frequencies are shared in Table 4.21 under four separate headings. These sub-categories were formed in order to present the students' perceptions in a more meaningful way. In the following, findings are discussed based on these sub-categories.

When asked about the *credibility of research*, students from both groups in both of their pre and post interviews asserted that the credibility of scientific studies was dependent on the context. Students' answers indicated that the students from both groups already had informed views in the pre-interviews:

> "If they have worked hard on it and if it passed through confirmation, it should be true." [C-M-PRE] (Appendix D, line 33)
> "Some of them may not be true. But they do experiments on it. Then, they disseminate it to the world. But some of them may cause diseases." [E-L-PRE] (Appendix D, line 34)

According to these students' responses, the credibility of scientific studies is not indubitable. They are expected to pass through a certification process to be verified and even then, they may have unfavorable consequences. This is an informed view of the certification process. It should be also noted that both of the shared responses are from the pre-interviews.

When asked about how to assess the credibility of scientific studies, students mentioned various *certification criteria*. These are adequate evidence, repetitive testing, verification by trying, and certification by scientists and the public. While repetitive testing

was only mentioned one time during the first interviews, nearly all students suggested it as a certification criterion during the second interviews.

> Student: For example, during the car experiment, in order to confirm the speed of the car we had done it four times.
> Researcher: What do you mean by confirming the speed of the car?
> Student: When we do it for the first time or a second time if we make a mistake, it might be wrong. But in our third and fourth try, it becomes verified. [E-L-POST] (Appendix D, line 35)

The student refers to Activity 12 (Appendix G) in which they had tested the effect of friction forces exerted by different surfaces on the speed or the traveling distance of a free-moving car. In this activity, students were asked to repeat their trials and measurements. As can be seen from the excerpt, the student was able to relate it to the verification practices of scientists. A similar answer was given by a control group student:

> Researcher: Oh, did you do it again and again? What was the importance of it?
> Student: Now, when we throw it again and again… You do something but then you forget. For example, I raised it up here too, but hers dropped sooner. When some time passes, I will say mine dropped sooner. People can sometimes forget. [C-M-POST] (Appendix D, line 36)

The control group student also refers to repeating their experiment during one of the activities. On the other hand, this student perceives the aim of repetition to improve retention. Therefore, she is unable to relate this practice to the conduction of science. Thus, although students from both groups became familiar with repetitive testing after the intervention, control group students were unable to relate it to the self-correcting mechanism of science.

Verification by trying was frequently mentioned by both experimental and control group students. As shared in the following, one student from the experimental group consistently defended trying as a way to get to the truth of claims.

> Student: First, they should really trust the scientist.
> Research: How would you trust a scientist? Is there anything you can control?
> Student: Some people try. Then, they show in the news (and say) that don't use this thing, it causes this and that.
> …
> Researcher: How would you know which idea is scientifically accurate?
> Student: First, (someone) tries what one of them says. If it is wrong, they can try the other one. One by one. [E-L-PRE] (Appendix D, line 37)

This is not a sophisticated view considering that not every idea or product can be tried in practice, and even those that can be tried may not be safe to do so. Still, the students' effort to test reliability should be positively acknowledged. Moreover, the student's reference to the news might indicate one source of generally informed views presented by the students in terms of the necessity for verification of scientific study results.

Another prevalent code frequently seen in student's answers was certification by scientists and the public. Although the number of references to this code was decreased during the post-interviews, the answer of the high-level understanding student from the experimental group was significant in that the student holds scientific organizations responsible in the dissemination of socially certified knowledge.

> Researcher: How can we decide which is true among these two opposing ideas?
> Student: We look at their explanations. We look at their results. If we are not sure, others should evaluate this too. The organizations which help disseminate science should also evaluate. [E-H-POST] (Appendix D, line 38)

It should be also acknowledged that this was the only student who mentioned certification by not only individuals but also groups of individuals. The students' answer indicates that she perceives science to be a collective activity as it was intended with the RFN based instructional sequence.

In terms of the *aims of dissemination*, the students discussed informing other scientists and public, disseminating certified knowledge, and benefiting from works of others. The following is an example of informing others:

> If they don't inform, we wouldn't know what is going to happen. We would have to blame the scientists. Something fell off the Earth, a lot of people died… Scientists, astronauts should let us know so that we can prepare. [C-H-PRE] (Appendix D, line 39)

Accordingly, dissemination is a responsibility of the scientists and the aim of dissemination is informing the public. In the post-interviews, students' answers from both groups were in similar lines. Therefore, no significant change was found as a result of intervention beyond the level of informed perception that they had presented during the pre-interviews.

Table 4.22. The frequency of the codes for students' perception of scientific ethos in terms of the groups and interview times.

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Doing no harm	The umbrella term for the values of animal care, respect for the environment, and human subjects protection	H (1)	H-M-L (3)	M-L (2)	H-M (2)
Respect for the intellectual property	Reserving the rights to ownership of ideas	-	H-L (2)	M (1)	M (1)
Cordiality	Affectionate relationship between scientists during their collaborative activities	H (1)	H-M (2)	-	-
Transparency	Being upfront about conflicts of interest to uphold trustworthiness and reliability of scientific studies	-	-	M (1)	M (1)
Perseverance	Relentless consistency in doing something which may include repetition of scientific studies	M-L (2)	H-M (2)	M-L (2)	H-M-L (3)
Total mention of scientific ethos		4	9	6	7

Dissemination pathways for scientific knowledge were suggested to be direct communication channels such as telephoning, mailing and face-to-face interaction; broadcasting through television, radio and social media; publishing and conferences. Among these, there was an increase in the number of students who mentioned publishing in both groups. This might be a result of students preparing reports throughout the semester. There were no significant changes between the number of meaningful codes in terms of groups or interview times. Still, the improvement in students' perceptions of social certification and dissemination of science was apparent in increasing elaboration of students' answers unlike the frequency of obtained codes.

4.2.5.2. Scientific ethos. To attain students' perceptions about scientific ethos, they were asked: "What are the values that scientists must follow?" and "What are the rules that scientists must abide?". Students' responses were transcribed and coded. The specific codes related to the scientific ethos category and their frequencies are shared in Table 4.22. In the following, these codes are discussed by presenting related quotations.

As can be seen in Table 4.22, the codes of doing no harm, respect for the intellectual property, cordiality, transparency and perseverance were obtained from the transcriptions of students' answers. Among these respect for the intellectual property was not mentioned by any of the experimental group students during the pre-interviews, but later on, during the post-interviews, two students mentioned this issue. Likewise, there was an increase in the number of students who mentioned doing no harm to the study subjects and the environment. In contrast, there was no such change for the control group students. Cordiality between colleagues was only mentioned by the experimental group students. Transparency was mentioned by only one student in both pre and post- interviews and that student was from the control group. Perseverance was frequently brought up by both control and experimental group students as a quality that scientists show in their work. Overall, while there was a steep increase in the number of meaningful codes obtained from the experimental group students, said the increase was minor for the control group students. Moreover, students from the experimental group were more direct and precise in their answers when they were asked about the values related to science during the post-interviews. For example, the low level understanding student from the experimental group stated that

> Student: …based on an agreement they (scientists) jointly conduct experiments. Then, if someone is willing, they try it on that person. If the experiment is successful, they disseminate it as a drug.
> Researcher: What do you mean by 'if someone is willing'?
> Student: We cannot make someone do it forcibly. We should make them sign a petition. They can quit anytime they want. For example, if they say I won't do the scientific experiments, we cannot force them. [E-L-POST] (Appendix D, line 40)

In the shared excerpt, the student talks about the necessity of consent and how it should be obtained via forms. This has been coded with an umbrella term of doing no harm which constitutes respect for the environment, animal care and human subjects protection. At this point, it should be remarked that all students were asked for their own consent in each of these sittings. They were also asked to deliver informed consent forms to their parents and guardians. This procedure was the same for both the control and experimental group students. It is interesting that only one student from the experimental group was able to reflect on this process and mention it as what scientists should do. Her articulation and the increase in the number of codes obtained from the experimental group suggest that these students became accustomed to values related to science as a result of the lessons in which they have been involved. This might indicate that RFN based intervention might have improved experimental group students' perceptions of the scientific ethos.

4.2.5.3. Social values. Students' perception regarding the social values and their effect on science were gathered by their answers to the questions of "What are the values that scientists must follow?", "Can convictions, gender and/or personal ideas of the scientists have an effect on the outcomes of scientific studies?", and lastly, "If so, what kind of effect can it have?". From the coding of the transcriptions, the codes of social utility, respecting the environment, ideological constraints, convictions of scientists and social construction of gender were found to be prevalent. These are presented in Table 4.23.

Social utility was the most frequently mentioned code as all students talked about it in both of their interviews. Respecting the environment was added after the intervention for both groups. It was a learning goal in the teaching and learning materials that were given by the ministry of national education. Therefore, an emphasis on these issues was not missing from either of the groups, unlike many other goals that were targeted during the RFN based instruction but were missing in the regular practice. Finding this code in both groups with the same frequency is consistent with the expected outcome. Ideological

Table 4.23. The frequency of the codes for students' perception of social values in terms of the groups and interview times.

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Social utility	Progression in different fields of life as medicine and technology; meeting the demand	H-M-L (3)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Respecting the environment	Abstaining from activities that could cause unnecessary harm to the environment	-	H-M (2)	-	H-M (2)
Ideological constraints	The society's views on controversial issues may affect the areas of focus of the scientific studies	-	M (1)	-	-
Convictions of scientists	The scientists' previous experiences, personal investment and knowledge about an issue may have an effect on scientific studies	H-M (2)	L (1)	M-L (2)	H-M-L (3)
Social construction of gender	The society's views on gender roles may have an effect on the work lives of the scientists	H-M-L (3)	L (1)	M-L (2)	H-M-L (3)
Total mention of social values		8	8	7	11

constraints were brought up only by one student who received RFN based instruction as in the following excerpt:

> Student: If a malicious government does not like a particular scientist… A well-
> Researcher: Could governments alter the development of scientific studies in a negative way?
> Student: Yes.
> Researcher: How can they affect?
> known person who contributed to the world… Then, the scientist takes it to the government and presents as I have done a good study. If the government rejects and tells that this is a bad study and does not permit it to be conducted, they do great damage to Turkey. [E-M-POST] (Appendix D, line 41)

According to the student, a divergence between a government and an individual scientist could alter the course of that scientist's work so that that study might not even be permitted. In turn, this could have a negative effect on the country as a whole. Convictions of scientists was discussed as a factor by two students from each of the groups during the pre-interviews. But the two students of the experimental group did not comment on this issue during the post-interviews instead, one student who did not mention the effect of conviction of scientists on results of a study or their interpretation has affirmed such connection. Social construction of gender was discussed by all students of the experimental group and two students of the control group. Later, again this was not mentioned by the very two students of the experimental group. This might indicate that the researcher-interviewer did not take the chance to elaborate on these issues. Therefore, it cannot be conferred that there was a retrogression in those students' perceptions of these issues.

There was no difference in the number of novel mentions of issues pertaining to social values of science in terms of the experimental group students. In contrast, there was an increase in the number of codes obtained from the answers of the control group students. This is likely due to lack of comment on the part of the experimental group students in terms of the last two issues during the post-interviews. Therefore, a definitive comparison cannot be made.

4.2.5.4. Professional activities. In order to obtain students' perceptions about professional activities they were asked about "What do scientists do in order to 'conduct science'?" "What do scientists do in order to inform others about their findings?" and "Have you ever heard about conferences or seminars?". Students' answers to these questions were transcribed and

Table 4.24. The frequency of the codes for students' perception of professional activities in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Making inventions	Creating or designing things that did not exist before	H-L (2)	M (1)	L (1)	H-M (2)
Reporting results	Declaring the results of a study in oral or written form	H-L (2)	H-M (2)	H-M (2)	M (1)
Publishing	Communicating scientific findings by writing newspapers, articles, and books	-	H-M (2)	-	H (1)
Seeking funding	Making applications and finding budget for scientific studies	H (1)	H-M-L (3)	M-L (2)	M (1)
Attending conferences	Communicating about scientific findings during scientific conventions	-	M-L (2)	H (1)	H-L (2)
Total mention of professional activities		5	10	6	7

coded. As can be seen in Table 4.24, the codes of making inventions, reporting results, publishing, seeking funding, and attending conferences were obtained.

Making inventions was mentioned frequently as a professional activity of scientists. Students from both groups were already familiar with scientists' responsibility of reporting results during the pre-interviews, therefore there were no increase in the number of times it was brought up during the post-interviews. The changes in the number of novel mentions of the publishing, seeking funding and attending conferences were telling. Publishing had not been mentioned during the pre-interviews and only two students from the experimental group talked about it during the post-interviews. Absence of such change in the control group students' perceptions suggests that this additional code was an effect of the RFN based intervention of the experimental group. There were similar changes in terms of the last two codes, although the changes were not as drastic in comparison to the control group. When the number of mentions of issues related to professional activities is considered, on the whole, a sharp increase was seen in the case of the experimental group, while this inference does not hold for the control group.

4.2.5.5. Social organizations and interactions. In order to get students perceptions about social organizations and interactions they were asked: "In which places or institutions do scientific studies take place?". Students' answers were transcribed and coded. Students acknowledged a broad range of locations which are shared in Table 4.25.

Initially, the student from the control group mentioned a wider selection of places in which science can be conducted. The schools and laboratories were commonly mentioned by the students from both groups. Not all of these students were able to recollect the name of the laboratories, but it was what they were describing as in the following:

> Researcher: In which places do scientific studies take place?
> Student: Scientific studies… like scientific places in which there are experiments…
> Researcher: Do you know if those places have a name?
> Student: …
> Researcher: Where else? Do you know where these places are?
> Student: In some schools.
> Researcher: What kind of schools?
> Student: High schools and middle schools. [C-L-POST] (Appendix D, line 42)

Table 4.25. The frequency of the codes for students' perception of social organizations and interactions in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Scientific institutions	Organizations with a concern of conducting and disseminating science and scientific knowledge	-	M-L (2)	-	-
Research centers	Places in which scientists generally work	-	-	-	H (1)
Universities	Places in which scientists conduct scientific studies and teach	-	H (1)	-	H (1)
Hospitals	Places in which scientists from medicine are may work	-	L (1)	H (1)	-
Schools	Schools that is a part of K-12 education years	L (1)	M-L (2)	H (1)	L (1)
Laboratories/experiment rooms	Places to conduct some of controlled experiments	H-M-L (3)	M-L (2)	H-M-L (3)	H-M-L (3)
Scientific companies	Private organizations science is commercialized	H (1)	-	-	-
Observatories	Places in which some of astrological studies are conducted	-	H (1)	-	
Space station	The international base in which astronauts conduct investigations	-	-	M (1)	M (1)
Excavation sites	Places in which some of archeological work is done	-	-	M (1)	-
Informal science settings	Places such as museum, and botanical gardens	-	M (1)	H-M-L (3)	-
Conference rooms	Places in which scientists convene	-	M-L (2)	-	-
Total mention of social organizations and interactions		5	12	10	7

In this excerpt the student's inability to remember the term of laboratories is not as telling as the student's thinking that laboratories are located solely in K-12 schools, especially considering that the excerpt is from a post-interview. This indicates that the regular practice was unable to introduce an informed view of laboratories and their function.

An important point about the change in students' perceptions of social organizations is the increase in experimental group students' reference to conference rooms as a place to conduct science. This might be caused by having discussions about conferences as a part of their RFN based intervention. When the number of students' references to social organizations is considered, there was a noticeable increase in that of experimental group students from 5 to 12. In contrast, control group students' mention of diverse locations decreased by 1 point. It should also be acknowledged that although the category put forth by Erduran and Dagher (2014) contain the interactions between the organizations, there was no indication of this in students' answers. One reason for this shortcoming might be the word choice in the adaptation of the category name to the Turkish. The name used during the lessons to refer to this aspect of science was *bilimsel kurumlar* whose exact translation is scientific institutions and the interactions part of the category name was omitted. This was seen as a need for enhancing students' perception of the relationship of these places to science. On the other hand, this might have resulted in a loss of emphasis on the social relations in and between these institutions.

4.2.5.6. Financial systems. Students' perceptions about financial systems of science were obtained from their answers to the questions of "Is there a need for money to conduct science?" and, if the students' answers are affirmative, "Where do the scientists obtain the money that they need?". Students' responses were transcribed and coded. The obtained codes are shared in Table 4.26.

When asked about the necessity of money to conduct science, all students acknowledged that there was a need for money to buy the necessary equipment. A majority of the students referred to government as a source of funding. One student from the control group even identified the taxpayers as the ultimate source of this capital:

> In general, this is a responsibility of the government. They (scientists) generally take it (money) from the government. Besides, the government gets it from the bazaars and market, mostly from the tax. [C-M-PRE] (Appendix D, line 43)

Table 4.26. The frequency of the codes for students' perception of financial systems in terms of the groups and interview times.

Code	Explanation of the code	Frequency of the code			
		Experimental		Control	
		PRE	POST	PRE	POST
Need for money	The view that conducting scientific studies requires money at various levels	H-M-L (3)	H-M-L (3)	H-M-L (3)	H-M-L (3)
Government funding	The view which addresses governments' contribution to science through taxpayer's money	H-M-L (3)	H-M-L (3)	H-M (2)	H-M-L (3)
Self-funding	The view that scientists or obliged to work and earn money to spend it on scientific studies	L (1)	-	H (1)	-
Commercialization of science	Monetizing the products of science such as inventions, and newly cultivated knowledge	M (1)	M-L (2)	-	-
Getting loan	The view that scientists need to borrow money in order to by equipment	H (1)	-	-	-
Benefaction/ donation	The view that the public can aid science through donations	H (1)	H (1)	-	-
Fundraising among scientists	The view that scientists can obtain grass-roots money from the public	-	M (1)	M-L (2)	M (1)
Total mention of financial systems		10	10	8	7

As presented in the excerpt, even the initial perception of this particular student was advanced, and her answers after receiving regular practice over a term were not changed. The only exception to the admission of government's role in the financial system of science was the control group student with low level understanding, and she has also clearly recognized the relationship of the government with the financial systems of science during the post-interviews as shared in the following:

> Researcher: Where should they (scientists) find the necessary money?
> Student: From the government.
> Researcher: In what capacity should the government give this money?
> Student: Government should give the money so that they (scientists) can conduct science. [C-L-POST] (Appendix D, line 44)

During the pre-interviews two students, as in one student from each group, stated that scientists should fund their own studies with the money gained by the merits of other work. This was one of those instances:

> Researcher: You said scientists need money. How can they find it?
> Student: They can earn by working.
> Researcher: Is there anything else they can do?
> Student: The money doesn't fell from the sky. It doesn't grow on trees. [E-L-PRE] (Appendix D, line 45)

Later, after the intervention her perception of earning money from other sources had become more elaborated:

> Researcher: Then where can they (scientists) find the money?
> Student: The municipality gives them money for them to buy instruments.
> Researcher: Okay, municipality. Where else?
> Student: For example, they can have some instruments at hand. They can combine those and make some medicine. Then, if they (the medicine) are found to be proper and useful by testing, they (scientists) can present it to the world. It could get sold in the pharmacies. Then, they (scientists) can get half of that earnings. [E-L-POST] (Appendix D, line 46)

What the student refers to is known as commercialization of science which in this instance is in turn used for the betterment of the science. Even though the student has a naïve view of government as the municipality, she presents a sophisticated view of funding of scientific studies, and later on, this view can feed in to better understanding of motivations and need for transparency in scientific reports through the revisits to the topic in systematical articulation of NOS in science content. In contrast, the perception of the control group

Table 4.27. The frequency of the codes for students' perception of political power structures in terms of the groups and interview times.

		Frequency of the code			
Code	Explanation of the code	Experimental		Control	
		PRE	POST	PRE	POST
Government funding	Governments' monetary contribution to science as a tool to guide the topic of studies	-	H-M-L (3)	-	-
Government inspection	The view that verification systems of government may pose a threat	M (1)	H-M (2)	M-L (2)	-
Permission from the government	The view that citizens need to obtain permission from the government	-	H-M-L (3)	L (1)	M-L (2)
Free of government interference	The view that governments cannot affect science	L (1)	-	H (1)	-
Total mention of political power structures		2	8	4	2

student who proposed self-funding did not take a turn towards such an elaborate scheme of funding as commercialization of science. Therefore, it can be deduced that the change in the experimental group student's perception can be a consequence of RFN based intervention. The experimental group student with high level understanding proposed getting loans and receiving donations as sources of funding. Although her view of donations persisted, she did not mention getting loans during the post-interviews.

As a last remark, the number of meaningful codes obtained from the experimental group students' answers remained the same. But there was a qualitative improvement in terms of the depth of the students' answers and unlike them the number of codes obtained from the control group students which have decreased by one point.

4.2.5.6. Political power structures. To attain students' perceptions about scientific ethos, they were asked: Could governments have an effect on the scientific studies?", and if the answer is affirmative as a follow-up, "For example, how could the governments support or hinder science from different areas of science?". Students' answers were transcribed and coded. The codes pertaining to this category of RFN are presented in Table 4.27.

There was both commonalities and divergences between the control and experimental group students' initial perception of political power structures. For example, they have commonly mentioned government inspection, one student from each group had stated the science to be free of government interference, and none of the students from either of the groups recognized funding as a controlling tool for the government. But, permission of the government was only mentioned by the control group students. Considering the few numbers of codes that could be obtained, control group students seemed to outdo their counterparts in the experimental group. After the intervention, this difference was overturned.

After the intervention, government inspection was suggested by students from both groups as a tool for governments to control science. Additionally, during the post-interviews, all students from the experimental group acknowledged government funding as a potential tool for development and monetization of science. The following is one of these instances:

> Researcher: Can governments affect the development of scientific knowledge?
> Student: Yes, they can.

Researcher: How?
Student: When scientists don't have money, the government gives them a sum of money. Government helps them to buy rockets and suits to go to space. When they go to space and take something, they can put it in or sell it to some museums. It can be sold abroad. When a sum of money is received, the government's money is paid back, and the rest can be taken. [E-M-POST] (Appendix D, line 47)

The student's answer implies an advanced perception of the relationship between political power structures and financial systems. Her suggestion of products of science to be included in international trade in order to bring money to the local government is especially worth an emphasis. These issues were addressed in Activity 5 and Activity 9 of the instructional sequence. Lack of mention of government funding as a tool in political power structures by the control group students suggests that the improvement in this experimental group student's perception was to some extent caused by of RFN based instruction. This is also supported by the steep increase seen in the number of meaningful mentions seen in the experimental group students' explanations.

Table 4.28. Change in the number of codes obtained from individual students' answers in terms of social-institutional categories.

	Number of codes																	
	Experimental									Control								
	PRE			POST			Change			PRE			POST			Change		
Category	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
SCD	6	6	6	7	8	6	1	2	0	7	6	6	5	7	6	-2	1	0
SE	2	1	1	4	3	2	2	2	1	0	4	2	2	4	1	2	0	-1
SV	3	3	2	2	3	3	-1	0	1	1	3	3	4	4	3	3	1	0
PA	3	0	2	3	5	2	0	5	0	2	2	2	3	3	1	1	1	-1
SOI	2	1	2	2	5	5	0	4	3	4	4	2	3	2	2	-1	-2	0
FS	4	3	3	3	4	3	-1	1	0	3	3	2	2	3	2	-1	0	0
PPS	0	1	1	3	3	2	3	2	1	1	1	2	0	1	1	-1	0	-1
SI	20	15	17	24	31	23	4	16	6	19	23	19	19	24	16	0	1	-3

As can be seen in Table 4.28, there was an increase in the number of codes received by the experimental group students in all social-institutional categories except the financial systems and social values categories. In contrast changes in the control group students' perceptions were mostly inconclusive since there was no clear pattern of development for the categories of social certification and dissemination, and scientific ethos. Moreover, there were no changes for the social organizations and interactions, and financial systems

categories. The experimental group student with an initial medium understanding level has gained more codes than any of her peers while she was the student with the least number of codes at the beginning. This might indicate that the student was not previously exposed to these ideas but took an interest during the course. Therefore, it can be concluded that RFN based instruction was more effective in broadening and deepening the students' perceptions of social-institutional categories of science. But individual differences were also a factor in the extent of these changes.

In summary, as the quantitative results had also suggested, experimental group students outperformed their peers in the control group also in terms of the development in their perceptions of social-institutional aspects of science. On the other hand, there were some issues that should be considered in the design of instruction for these aspects. They are discussed in the following chapter, along with the conclusions for other categories.

4.4. Summary of the results

Effectiveness of RFN based instruction on 5th grade students' understanding, and perceptions of NOS was investigated by administrating the RFN Student Questionnaire and conducting individual student interviews. The results obtained from the analysis of quantitative and qualitative data indicate that RFN based instruction may be more effective than regular practice in terms of improving students' understanding and perceptions of NOS. According to the analysis of students' pretest scores with t-test, before the intervention, there were no significant differences between the control and experimental group students' total or category-based scores except for the scientific practices category. Considering the limited number of questions assigned to each category, and students' equivalence in all other categories and test as a whole, it was decided that the control and groups were not different in terms of their understanding of scientific practices.

After the 13 weeks of intervention, the scores of the students from the two groups significantly differed in their total and category-based scores of methods and methodological rules of science, scientific knowledge and social-institutional categories. Pairwise comparisons were also conducted in order to determine if the significant differences exist between any two of the three questionnaire administrations. Accordingly, the changes from the pretest to post-test were significant for the total test scores and category scores of

methods and methodological rules of science, scientific knowledge and social-institutional categories. From post-test to delayed post-test, the changes were not significant except for the scientific practices category. From pretest to delayed post-test, all changes were significant except for the aims and values of science. The mean scores of the students from the two groups showed that students from the experimental group were scoring higher than the control group in all categories. Therefore, the significant changes were in favor of the experimental group students. Considering the pairwise comparisons, it was also concluded that RFN based instruction significantly enhanced experimental group students' NOS understanding and students' retention did not significantly deteriorate in the two months followed after the intervention. These results suggest that among the two teaching methods, regular practice and RFN based instruction, the latter may have a more positive impact on students' understanding of NOS.

The differences seen in the students' RFN Student Questionnaire scores were also reflected in their perceptions of NOS. Students' answers to interview questions were coded and thematically analyzed from the scope of the RFN framework by using open coding and constant comparison of the obtained codes. Control and experimental group students' novel mention of issues related to NOS were compared in terms of their breadth and depth. As a result, it was found that during the pre-interviews, the numbers of codes attributed to control and experimental group students' answers were similar in all categories except for minor discrepancies. To illustrate a minor discrepancy in this context, control group student with medium understanding level obtained 5 codes for her answers related to scientific knowledge unlike all other of her peers who received only 2 codes. Likewise, the depth of control and experimental group students' answers were similar during the pre-interviews.

After the intervention, experimental group students received more codes in terms of 4 categories of RFN: scientific practices, methods and methodological rules of science, scientific knowledge and social-institutional categories. In fact, there were also increases in the number of codes they have received for each social-institutional category except social values, professional activities, and financial systems. In contrast, there were no clear patterns of change in the number of codes received by the control group students for methods and methodological rules of science and scientific knowledge. A lack of clear pattern means that while codes of one student from that group increased in number, another decreased and the last one did not change. In terms of aims and values of science, the number of codes obtained

by control group students did not change. The only increase was seen in the social-institutional categories and that was only minimal in comparison to the experimental group students. Among the 7 social institutional categories, in two categories they showed improvement, in two categories they did not show any changes, in two categories there were no clear patterns, in one category the number of codes they have received was decreased. Therefore, it can be concluded that the development in the breadth of codes obtained by the experimental group was better than the control group. As discussed throughout the previous sub-sections for each category, the deepening of the experimental group students' answers was more apparent in contrast to that of their peers in the control group. This was more prominent in the methods and methodological rules of science, scientific knowledge and social-institutional categories.

In conclusion, while the NOS understanding and perceptions of control and experimental groups were similar in the beginning, after the intervention experimental group students outperformed their peers in terms of their NOS understanding, and depth and breadth of their perceptions and for the most part the quantitative and qualitative results were in congruence except for the scientific practices category.

5. DISCUSSION

This chapter presents the summary of the study, discussion of the effectiveness of RFN based instruction on students' NOS knowledge based on quantitative and qualitative results, implications of the study, limitations of the study, and suggestions for further research. In the first section, the purpose, theoretical background and methodology of the study are summarized. In the second section, the quantitative and qualitative results and their alignment are discussed in light of the previous studies and integration of family resemblance approach to science education. In the last sections, implications and limitations of the study are examined and recommendations for future directions are made.

5.1. Summary of the study

There are various accounts in describing, teaching and learning of nature of science (NOS). One line of these accounts depends on family resemblance concept of Wittgenstein to describe nature of science with its domain-specific and general aspects. Erduran and Dagher (2014) have reconceptualized Irzik and Nola's (2011; 2014) family resemblance approach by broadening its categories, proposing theoretical justification of inclusion of these categories in education, making suggestions on their integration to the classroom, and developing generative images of science that could be used in practice. Later, Kaya and Erduran (2016) have coined the term of Reconceptualized Family Resemblance Approach to Nature of Science (RFN) in order to underscore the significance of these contributions.

The current study investigates the effectiveness of integrating RFN categories throughout a semester of 5th grade science content on the students' understanding and perceptions of nature of science. For this purpose, an instructional sequence was developed to teach three units of the 5th grade science curriculum: Sun, Earth, Moon and Their Movements; Classification of Living Things; and Measuring Force and Friction. The study followed a quasi-experimental, convergent parallel mixed method study design. Participants of the study were the science teacher and 64 of her 5th grade students. While there were 31 students in the experimental group, 33 students in the control group. Since the school was gender segregated, all of the participants were female. During the 13 weeks of intervention

process, this instructional sequence was implemented with RFN based instruction and regular practice to experimental and control groups, respectively.

Throughout the study, RFN Student Questionnaire was implemented at three times: before, right after and two months after the intervention. Semi-structured interviews were also conducted before and after the intervention with 6 students who were purposefully selected based on their initial NOS understanding levels. These interview students were taken in equal numbers from the two groups, 3 students from each group. RFN Student Questionnaire was adapted from the RFN Questionnaire developed by Kaya, Erduran, Aksoz and Akgun (2018) for use with lower secondary school students. The RFN Student Questionnaire has 37 Likert-scale items targeting all categories of RFN framework. Interview questions were also aimed to address all RFN categories. Total and category-based RFN Student Questionnaire scores of the students were assessed with both descriptive and inferential statistics.

Firstly, an independent samples t-test was conducted and determined that there were no significant differences between the groups' initial NOS understandings except for the scientific practices category. After obtaining this result and checking for parametric test assumptions, mixed model ANOVA was determined to be the appropriate test of statistical analysis. Consequently, mean changes of the two groups from pretest to delayed post-test were found to be significantly different in terms of the total scores and category scores for scientific practices, methods and methodological rules of science, scientific knowledge and social-institutional. During the two months delay period students' NOS perceptions did not change significantly except for the scientific practices category as assessed by the mean changes between post-test and delayed post-test. Mean changes between pretest and post-test scores of the two groups were significantly different for the methods and methodological rules of science, scientific knowledge and social-institutional categories along with total test scores. All in all, the only category without a significant difference between the mean changes of the two groups was the aims and values of science.

For qualitative analysis, RFN categories were used as the themes of the coding framework. Then, participants' answers were constantly compared in terms of groups and interview times to obtain sub-categories and codes for the RFN themes. 'Novel mentions' were defined as the unit of analysis to determine the differences between the breadth of

control and experimental group students' perceptions, and to track the changes in individual students' perceptions. Frequency of the codes was tabulated and discussed in terms of understanding levels of the interviewees and the instruction they have received. Excerpts from the interviews were also shared in order to compare the depth of students' perceptions with their peers and their prior answers. As a result of these analyses, it was found that the quantitative and qualitative data support the effectiveness of RFN based instruction in unison. For example, the codes obtained from experimental group students were enhanced both in terms of breadth and depth for the categories of methods and methodological rules of science, scientific knowledge and social-institutional categories. Results revealed that although there was no clear pattern in the changes of the control group students' perceptions of aims of science, there was a minimal decrease in the experimental group students' perceptions of aims of science. On the other hand, there was an increase in the number of codes attributed to the experimental group students' answers about cognitive-epistemic and social values of science from pre to post-interviews. Still, this improvement may not be large enough to be present at quantitative results as a significant difference. There was only one discrepancy in the comparison between the quantitative and qualitative results, and that was in terms of scientific practices category. The difference between the mean changes of control and experimental group students' scientific practices scores from pretest to post-test were not found to be significantly different. On the other hand, codes obtained from the two groups indicated that while there was no change in the number of codes obtained from the control group students' answers from pre-interview to post-interview, there was a noticeable increase in that of the experimental group. Therefore, it was concluded that RFN based instruction was more effective than regular practice also in terms of the scientific practices category.

When the students' understanding levels are considered, it was seen that all three of the experimental group students initially started off with similar numbers of codes in all categories except for aims and values of science and social-institutional categories. Nonetheless, the possible effect of memorization through frequent revisits to these categories should also be considered while reviewing these highly positive results, especially in terms of scientific knowledge category. As assessed with the numbers of codes obtained in their pre-interviews, control group students' perceptions of all categories were also similar to each other. On the other hand, generally, there were no change, minimal development, or inconclusive patterns of change in students' perceptions of different categories.

All in all, all of these outcomes support the conclusion that RFN based instruction might be more effective than regular practice on the students' understanding and perceptions of NOS, but the level of its effectiveness might depend on students' initial understanding and perceptions of NOS. As has been done in this study, RFN categories can be incorporated into science content and the results of this study suggest that these enrichment efforts would be fruitful in terms of the development of students' understanding and perceptions of NOS. Therefore, the materials developed in this study has a potential to be used in lower secondary classrooms with a goal of improving students' understanding and perceptions of NOS with evidence-based practice. The study also contributes to the amassing literature in terms of assessing students' understanding and perceptions of NOS with the adaptation of the questionnaire, and the resultant coding framework.

5.2. Effectiveness of RFN based instruction on students' NOS knowledge

The outcomes of the study indicated that RFN based instruction can enhance the students' understanding and perceptions of NOS. More specifically, the RFN based instruction is more effective than the regular practice on students' overall understanding of NOS along with their understanding of scientific practices, methods and methodological rules of science, scientific knowledge, and social-institutional aspects of science. It was also found that in comparison to regular practice, RFN based instruction is better in deepening and widening students' perceptions of these categories. It is not surprising that the experimental group students who received RFN based instruction performed better on nearly all categories of RFN. According to Kaya and Erduran (2016), the regular practice guided by the textbook and learning goals put forth by Ministry of National Education (MoNE) addresses only a part of cognitive-epistemic aspects of science and generally focuses on the transfer of science content. Turkish science education curriculum has seen minor revisions since then, but these changes did not improve on the issue of lack of connections to NOS. On the other hand, for the RFN based instruction, the science content was enriched by systematically integrating the RFN categories suggested by Erduran and Dagher (2014).

Maybe a more important conclusion that can be derived from these results is that the 5th grade students were *able to learn* these NOS aspects. Leden and Hansson (2017) identified two different patterns in selecting age-appropriate NOS issues. These were put

forth by Abd-El-Khalick (2012) and Erduran and Dagher (2014). The first approach chooses an additive scheme in the selection of the issues to be introduced, while the latter supported an enrichment scheme with early introduction and later enrichment as the issues emerge in the content. Since the aim of the study was to investigate the effectiveness of suggestions made in the RFN framework and address various RFN categories, an effort was made to integrate all possible categories to the science content as the opportunities aroused. As Bell (2006) suggested various educational approaches were used to make these issues meaningful for the students instead of rigidly declining these connections from a start based on assumptions on students' readiness. Some of these approaches were adjusting the scaffolding by the teacher, using advance organizers and visual aids, and instructional techniques such as think-pair-share. As a result, all cognitive-epistemic and social-institutional categories of RFN were addressed as shared in the horizontal articulation table (see Table 3.2 in the methodology chapter). The affirmative results in terms of improvement in experimental group students' understanding and perceptions of nearly all RFN categories indicate that these categories can be effectively addressed at least in the lower secondary level.

For the *aims and values of science*, the mean changes in the control and experimental groups were not significantly different. One possible reason for this outcome may be that the students already had broad views about the aims and values of science. As a result, students' understanding could have improved but not enough to cause significant changes. Another reason could be the limited duration of the study. With the systematical enrichment scheme suggested by Erduran and Dagher (2014), these issues would be repetitively addressed in the upcoming years. While analyzing the codes obtained from the students' answers, these codes were separated as aims of science and values of science. This closer inspection revealed that actually, experimental group students' perceptions of cognitive-epistemic and social values of science improved. On the other hand, some of the values suggested by the students were directly concerned about qualities of scientists such as perseverance and enthusiasm. The frequency of the students' novel mentions of perseverance and their descriptions indicated a problem in terms of students' views of science and scientists suggesting that students believe that if scientists persevered enough, they could solve any problem. This is in line with the findings of Griethuijsen, van Eijck, Haste, Brok, Skinner, Mansour, Gencer and BouJaoude (2015) which suggested that students from outside western Europe including Turkey tend to believe that scientists can solve most problems they face. A lack of acknowledgement for external factors such as ideological constraints or political agenda in these students' views

is concerning. There was a decrease in the number of references to codes of perseverance, enthusiasm and aims of science in general. Ultimately, it was concluded that there was no observable pattern of change in students' perceptions of aims and values of science. Ultimately, the qualitative results supported the quantitative results while also showing some development that could not be detected by the questionnaire. Qualitative results have also revealed another issue. Qualities of a scientist was not a concern of this instructional sequence, but it could be since students are clearly invested in this issue. It would be a fruitful discussion since the students seem to hold unrealistic views of scientists to be relentlessly enthusiastic and determined. A suggestion for science teachers would be to address these issues in the 5th grade or preceding years in order to depict a more humanistic and approachable image for scientists.

For the *scientific practices*, unlike the last three categories, from the pretest to post-test the mean changes of the two groups were not significantly different. However, analysis of interviews indicated otherwise. There was a noticeable increase in the number of novel mentions of scientific practices by the experimental group students. Interestingly, this increase was proportionate to the students' understanding levels. On the other hand, the number of codes obtained from the control group students decreased or did not change. Therefore, it was concluded that the experimental group students' perceptions of scientific practices were enhanced more so than their peers in the control group. One possible reason for this discrepancy between the quantitative and qualitative results may be about the nature and the limited number of the questionnaire items. It should also be noted that during the interviews some resilient misconceptions were detected in students' perceptions of experimentation and observation. While some students thought that experimentation was any fun activity conducted in the classroom, another thought that experimentation was just trying. Moreover, students generally confused experimentation with observation. Activities centering around experimentation and observation had been conducted, but neither of the two teaching methods seemed to have a positive effect on this regard. Therefore, this is an issue to be carefully considered in the design of related instructional materials. Again, this issue can be sorted out by revisiting these issues with a systematical vertical articulation. Karabas (2017) had conducted a quasi-experimental study in which scientific practices-based instruction (SPBI) was implemented in the experimental group while teaching 56 7th grade students about electric circuits over a 4 weeks period. As a result of this study, it was found that experimental group students who received SPBI outperformed their peers in the

control group who received traditional science instruction in terms of their perceptions of scientific practices. On the other hand, this improvement in students' perceptions was not supported by a statistical significance. Karabas (2017) suggested that to increase the effectiveness of SPBI, an intervention of longer duration may be needed. During this study, scientific practices were addressed in 9 separate occasions over a span of 12 weeks. This longer duration might be the reason why teaching about scientific practices caused significant differences from pre-test to delayed post-test. Therefore, the current study's outcomes are in line with and improve upon the findings of Karabas (2017).

For the *methods and methodological rules of science*, there was a significant difference between the mean changes of the two groups. Investigation of the number of codes obtained from the two groups in pre and post-interviews also supported this conclusion. The most apparent difference between the control and experimental group students' answers was the lack of the control group's references to *non*-hypothesis testing and *non*-manipulation. Both of the groups have determined and manipulated variables and determined and tested hypotheses on two separate occasions. The students also made inferences on scientific findings which were found without testing a hypothesis and read a passage in which a non-manipulative observation was conducted by an astrophysicist. On the other hand, only the experimental students who had a chance to reflect on these issues with targeted class discussions were able to mention non-hypothesis testing and non-manipulation. Still, experimental group students' explanations were not to be accepted without a grain of salt. While one of these students confused falsification of hypothesis with non-hypothesis testing, another student could not give examples for non-hypothesis testing from the activities conducted in the classroom. Therefore, non-hypothesis testing and non-manipulation as scientific methods might have been beyond the readiness levels of at least some of the students. Nonetheless, there might have been a need to better articulate these issues in the lesson plans or in their enactment. On the other hand, in contrast to Çelikdemir's (2006) study with 6th and 8th graders, it was determined that none of the interviewees held the belief that scientific studies follow a step-wise methodology even before the intervention. The participants of the current study were 5th grade students and therefore they had not received any instruction regarding science. It might be the regular instruction conducted in middle schools imposing the empirical views found to be held by the students. Still, another reason could be that image of science presented in elementary schools in Turkey have improved since 2006.

For *scientific knowledge*, there was a significant difference between the mean changes of the control and experimental group students. Experimental group students' relatively better improvement was also apparent in the comparison of the number of codes obtained from these students in pre and post-interviews. Additionally, once again, there was no clear pattern of change in the control group students' perceptions. Especially, the experimental group students' explanations of the growth of scientific knowledge through scientific terms such as paradigm shift and cumulative development was an interesting result. These ideas could easily be deemed too complex for 5th grade students, but students were even able to talk about the complementary nature of theories, laws and models. This point illustrates the fruitfulness of Bell's (2006) suggestion to make use of different teaching strategies before omitting any NOS related issues from the curricula. Still, it should be acknowledged that students from either of the groups did not mention the theory-ladennes of scientific practices such as classification even though that was emphasized during the lessons. This might indicate a shortcoming on the part of the students' perceptions of scientific knowledge or the designed activities that were aimed to improve students' perceptions of theory-laden nature of science.

For the *social-institutional categories*, there was again a significant difference between the mean changes of the control and experimental groups. Moreover, the highest effect size was obtained for the social-institutional categories. One reason for this might be the higher number of items allocated for social-institutional categories in comparison to the remaining four. On the other hand, another reason could be that indeed students showed the greatest improvement in this category. Such a conclusion would be in line with the literature which indicates that social-institutional aspects of science are often ignored from curricula as stated by Akerson, Buck, Donelly, Nargund-joshi, and Weiland (2011). When the numbers of codes obtained by the two groups are compared it is seen that the increase in the number of codes obtained from the experimental group was higher than that of the control group. Therefore, the quantitative and qualitative results support the effectiveness of the RFN approach in unison in comparison to the shallow coverage of the regular practice. When each of the seven social-institutional categories is assessed separately, it was seen that in five of these categories an improvement was observed for the experimental group students, while the number of codes obtained for these categories from control group students decreased, did not change or did not reveal a clear pattern of change. Among the remaining two categories, the number of experimental group students' codes attributed to social values and

financial systems of science did not indicate a clear pattern of change. When students' answers to related questions are examined, it was seen that their perception of financial systems was already sophisticated during the pre-interviews. On the other hand, it was still seen in the shared excerpts that students' perceptions of science had become more elaborated during the post-interviews. It should also be noted that although there was a development in students' perceptions of social organizations and interactions, students did not discuss the interaction between the organizations or scientists when it comes to conducting science. One reason for this may be a faulty translation of the title of this category into Turkish. The translation was made as *bilimsel kurumlar* whose direct translation is scientific institutions. Therefore, the emphasis on the interactions of these may not have been done frequently enough for students to pick up the importance of social interactions. The word social was exchanged with scientific in order to prevent a possible confusion for the students. The concern was that social organizations could also include organizations such as UNICEF, Red Cross, and WWF while these were not actually in focus. Still, the addition of *sosyal ilişkiler/etkileşimler* (social interactions) could be better to be added by other researchers and teachers. Then, the one suggested name of the category would be *bilimsel kurumlar ve sosyal etkileşimleri* (scientific organizations and social interactions). This emphasis on the name is made since it can have an effect on the focus of the teacher as well as the students. Another issue to be addressed is the ideas students associated with the political power structures. The codes attributed to students' answers are all in relation to governments. This might indicate that the students associate politics only with governments but not interpersonal relationships or their effect on issues such as gender although they were also discussed during the lessons. One reason for this might be that in Turkish language and culture, *politika* (politics) is indeed generally used in relation to government policies. Another reason could be the lack of students' experience with this second use of the word. Overall, the experimental group students' perceptions of social-institutional categories were enhanced more than that of control group students as evidenced by the increase in their number of novel mentions and elaborateness of their explanations of diverse issues. Alayoglu (2018) conducted a quasi-experimental study on the effect of teaching science as a social-institutional system on forty-two 5th grade students' understanding of social-institutional dimension of science and their attitudes towards science. Accordingly, the experimental group students were instructed with RFN perspective, and the control group students were taught with traditionally designed science instruction. The results of the study showed a statistically significant improvement in the experimental group students' understanding in comparison to their counterparts in the

control group. These results are in line with the findings of the current study. Therefore, the two studies support the view that students from as early as 5th grade can learn about the social-institutional aspects of science when they are effectively emphasized during the instruction. As a last remark, it should also be pointed out that social-institutional categories may be the most critical category in terms of depicting the students' ability to learn about broad aspects of science. As can be seen in Figure 2.1, when the scope of RFN is compared to other accounts of NOS, it covers a broader ground than others. The one aspect of RFN that is not shared by any of the other accounts is the institutional factors. The reason for the omission of this aspect may be a distrust in terms of students' ability to learn about these issues (Akerson *et al.*, 2011). Therefore, finding of affirmative results in this study in teaching social organizations and interactions, and political power structures is significant.

In summary, the outcomes of this study and studies presented from the literature bear the conclusion that integration of RFN categories into science content -as students can learn about them- can improve their understanding and perceptions of these categories. Moreover, systematically articulating these categories over an extended time frame can improve the effectiveness of the RFN based interventions.

5.3. Implications of the study

Results of this study indicate that experimental group students significantly improved their understanding and perceptions of NOS when it was taught to them with a holistic approach. As a consequence, RFN is found as an effective way of teaching NOS. Likewise, this study contributes to the literature in that with some effort students can learn about aims and values of science, scientific practices, methods and methodological rules of science, scientific knowledge and social-institutional aspects of science as long as they are systematically incorporated into the current science curriculum content. This is an important outcome of this study because as Erduran and Dagher (2014) intended in the reconceptualization of science, science teaching should be able to depict holistic nature of science.

The lack of emphasis on NOS in curricula documents and textbooks that are currently in use requires the development of teaching materials. This study has contributed to this need, by developing materials such as reading texts, lesson plans, activity sheets and rubrics that

could be used in practice. It should also be pointed out that these materials have been empirically tested and found effective.

Other contributions of this study to NOS teaching in secondary schools is the adaptation of the RFN Questionnaire and the generative images of science. Visuals were an important part of this intervention and they have likely played an important role in the development in the students' perceptions of science. Moreover, the questionnaire adapted in this study can be used in getting timely quantitative descriptions of students' understanding of NOS.

5.4. Limitations of the study

There are some limitations of the current study to be considered while interpreting the results and conducting future studies. First limitation is the duration of the intervention. The intervention spanned 13 weeks and covered only 3 units of science content. Therefore, the aim of addressing all RFN categories might have put a strain on the extent of discussions that could take place in the classroom. On the other hand, it should be emphasized that Erduran and Dagher (2014) advises flexibility in making connections to NOS as opportunities emerge. Hence, this would not be a problem for real-life implementations of the framework.

Another limitation of the study is that all participants were female. Therefore, should there be gender-based differences in students' learning, they could not be assessed. Consequently, this study assumes that this has not been a critical issue for the data intervention process.

Lastly, the researcher was in the classroom throughout the semester to conduct classroom observation. This might have posed a threat to the students' engagement with the lessons. Likewise, for the same reason, the teacher's instruction may not represent her usual practice. Again, it was assumed that this does not constitute a critical issue on the outcomes of this study.

5.5. Suggestions for further research

There are suggestions to be made for further research based on the findings and implications of the current study. Firstly, analysis of curricula and the difference between the control and experimental group students' instruction indicate that there is a need for instructional change. In this study, the teacher was already familiar with the RFN approach and NOS teaching in general. She was also supplied with the teaching materials and guided by the researcher. If the goal is to scale up this intervention, the science teachers need the same if not more support to be able to conduct this type of instruction. Therefore, teaching NOS holistically needs to be emphasized in prospective and in-service science teacher education. Therefore, there is a need for studies that develops effective teacher education interventions like that of Kaya *et al.* (2018). Another support could come from the development of educative curriculum materials for the teachers. In this sense, there is also a need for more material development with broader coverage in terms of science content and grade levels for the systematical articulation of RFN categories. A starting point for material development could be mapping the curriculum for NOS learning opportunities that could be presented to the teachers. Only then the teacher, interventions and educative curriculum materials would come into play. An implication of this study was that children as young as fifth grade students could learn about diverse issues related to NOS. Other studies could work with even younger students and again address issues targeting all categories of RFN so that a pattern could emerge for the selection of fruitful NOS learning opportunities based on the students' developmental readiness. Therefore, there is a need for longitudinal studies that track the development of students for the systematical horizontal and vertical articulation of family categories.

REFERENCES

AAAS. (1989). *Science for all Americans*. Washington, DC: American Association for the Advancement of Science.

Abd-El-Khalick, F. (2012). Examining the sources for our understandings about science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education*, *34*(3), 353-374.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Akerson, V. L., Buck, G. A., Donnelly, L. A., Nargund-Joshi, V., & Weiland, I. S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology, 20*(5), 537–549.

Akerson, V. L., Carter, I., Pongsanon, K., & Nargund-Joshi, V. (2019). Teaching and Learning Nature of Science in Elementary Classrooms. *Science & Education*, doi:10.1007/s11191-019-00045-1.

Akerson, V., Pongsanon, K., Park Rogers, M., Carter, I., & Galindo, E. (2015). Exploring the use of lesson study to develop elementary preservice teachers' pedagogical content knowledge for teaching nature of science. *International Journal of Science and Mathematics Education, 15*(2), 293-312. doi: 10.1007/s10763-015-9690-x

Akgun, S., Kaya, E., Erduran, S., & Aksoz, B. (2017, April). *Pre-service science teachers' perceptions of scientific knowledge*. Paper presented at NARST Annual Conference, San Antonio, TX.

Aksoz, B., Erduran, S., Kaya, E., & Akgun, S. (2018, March). *Investigating pre-service science teachers' understanding about cognitive-epistemic systems of science*. Paper presented at NARST Annual Conference, Atlanta, GA.

Alayoglu, M. (2018). *Fifth grade students' attitudes towards science and their understanding of its social-institutional aspects*. (Unpublished master's thesis). Boğaziçi University, Istanbul, Turkey.

Allchin, D. (1999). Values in science: An educational perspective. *Science & Education, 8*(1), 1–12.

Allchin, D. (2011). Evaluating knowledge of (whole) science. *Science Education, 95*(3), 518- 542.

Allchin, D., Andersen, H. M., & Nielsen, K. (2014). Complementary approaches to teaching nature of science: Integrating student inquiry, historical cases, and contemporary cases in classroom practice. *Science Education, 98*(3), 461-486. doi: 10.1002/sce.21111

Alters, B. J. (1997). Whose nature of science?. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *34*(1), 39-55.

Arriola, G. A., An examination of the relationship between professional development providers' epistemological and nature of science beliefs and their professional development programs (Doctoral dissertation). Portland State University, Portland, OR, USA. doi: 10.15760/etd.5520

Bağcı Kılıç, G., Metin, D., Yardımcı, E., & Berkyürek, İ. (2007). Doğada bilim eğitimi. *I. İlköğretim Kongresi*.

Bell, R. L. (2006). Perusing Pandora's box: exploring the what, when, and how of nature of science instruction. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and nature of science* (pp. 427–446). Dordrecht: Springer.

Biological Sciences Curriculum Study. (1990). *Science and technology: Investigating human dimensions.* Colorado Springs, CO: Author.

BouJaoude, S., Dagher, Z.R. & Refai, S. (2018). The portrayal of nature of science in lebanese ninth grade science textbooks. In C.V. McDonald and F. Abd-El-Khalick (Ed.) *Representations of Nature of Science in School Science Textbooks* (pp.79-98). New York: Routledge.

Boz, Y., Aydemir, M., & Aydemir, N. (2011). Türkiye'deki 4, 6 ve 8. sınıf ilköğretim öğrencilerinin epistemolojik inançları. *İlköğretim Online*, *10*(3), 1191-1201.

Brandon, R. N. (1994). Theory and experiment in evolutionary biology. *Synthese*, *99*(1), 59-73.

Bülbül, K., & Küçük, M. (2007). İlköğretim birinci kademe öğrencilerinin bilimsel bilgiye bakış açılarının incelenmesi. *1. Ulusal İlköğretim Kongresi*, 15-17.

Carey, S., Evans, R., Honda, M., Jay, E. and Unger, C. (1989). 'An experiment is when you try it and see if it works': a study of junior high school students' understanding of the construction of scientific knowledge. *International Journal of Science Education, 11*(5), 514-529.

Chinn, C., & Malhotra, B. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*(2), 175–218.

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary educational psychology*, *29*(2), 186-204.

Çelikdemir, M. (2006). *Examining middle school students' understanding of the nature of science*. (Master's thesis). Middle East Technical University, Ankara, Turkey.

Cilekrenkli, A., Kaya, E., Erduran, S., Akgun, S., & Aksoz, B. (2019, April). *Perceptions of nature of science: A comparative study on pre-service teachers from England and Turkey*. Paper presented at 92nd Annual International Conference of National Association of Research in Science Teaching (NARST), Baltimore, MD, USA.

Creswell, J. W. (2012). *Research Design: Planning, Conducting, and Evaluating Quantitative and Qualitative Research.* Boston, Massachusetts: Pearson

Cullinane, A. & Erduran, S. (2015, July). *Incorporating nature of science in science teacher education: a proposed Irish example.* Paper presented at IHPST thirteenth biennial international conference, Rio de Janeiro, Brazil.

Dagher, Z. R., & Erduran, S. (2017). Abandoning patchwork approaches to nature of science in science education. *Canadian Journal of Science, Mathematics and Technology Education*, *17*(1), 46-52.

Deng, F., Chen, D. T., Tsai, C. C., & Chai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education*, *95*(6), 961-999.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Bristol: Open University Press.

Durant, J., Evans, G. & Thomas, G. (1989). The public understanding of science. *Nature, 340*(6228), 11-14.

Duschl, R., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of Research in Science Teaching*, *26*(6), 467-501. doi: 10.1002/tea.3660260602

Eflin, J. T., Glennan, S., & Reisch, G. (1999). The nature of science: A perspective from the philosophy of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *36*(1), 107-116.

Erduran, S. & Dagher, Z. (2014). *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories*. Dordrecht: Springer.

Erduran, S., & Dagher, Z. R. (2014b). Regaining focus in Irish junior cycle science: Potential new directions for curriculum and assessment on Nature of Science. *Irish Educational Studies*, *33*(4), 335-350.

Glaser, BG. & Strauss, AL. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research.* New York: Aldine De Gruyter, 28-52.

Glass, G. V., Peckham, P. D., & Sanders, J. R. (1972). Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance. *Review of educational research*, *42*(3), 237-288.

Greene, J. C. & Caracelli, V. J. (1997). Defining and describing the paradigm issue in mixed-method evaluation. *New Directions for Evaluation*, 74, 5-17. doi:10.1002/ev.1068

Hacking, I. (1996). The Disunities of the Sciences. In: P. Galison & D. Stump (eds.) *The Disunity of Science* (pp.37-74). Stanford: Stanford University Press.

Hodson, D. (2009). *Teaching and learning about science: Language, theories, methods, history, traditions and values*. Rotterdam, The Netherlands: Sense.

Hodson, D., & Wong, S. L. (2017). Going beyond the consensus view: Broadening and enriching the scope of NOS-oriented curricula. *Canadian Journal of Science, Mathematics and Technology Education*, *17*(1), 3–17.

Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science. *Science & Education, 20*, 591–607.

Irzik, G., & Nola, R. (2014). New directions for nature of science research. In M. Matthews (Ed.), *International handbook of research in history, philosophy and science teaching* (pp. 999– 1021). Dordrecht, The Netherlands: Springer.

Karabaş, N. (2017). *The Effect of Scientific Practice-Based Instruction on Seventh Graders' Perceptions of Scientific Practices* (Unpublished master's thesis). Boğaziçi University, İstanbul, Turkey.

Kaya, E., Erduran, S. (2016). From FRA to RFN or how the family resemblance approach can be transformed for science curriculum analysis on nature of science. *Science & Education, 25*(10), 1115–1133.

Kaya, E., Erduran, S., Akgün, S., & Aksöz, B. (2017). Öğretmen Eğitiminde Bilimin Doğası: Bütünsel Bir Yaklaşım. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 11*(2), 464-501.

Kaya, E., Erduran, S., Aksoz, B., & Akgun, S. (2019). Reconceptualised family resemblance approach to nature of science in pre-service science teacher education. *International Journal of Science Education*, *41*(1), 21-47. *doi: 10.1080/09500693.2018.1529447*

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *39*(7), 551-578.

Kwasnik, B. H. (1999). The role of classification in knowledge representation and discovery. *Library Trends, 48*(1), 22–47.

Leach, J., Driver, R., Millar, R. & Scott, P. (1997) A study of progression in learning about 'the nature of science': issues of conceptualisation and methodology, *International Journal of Science Education, 19(*2), 147-166, doi: 10.1080/0950069970190202

Leden, L. & Hansson, L. (2017). Nature of science progression in school year 1–9: A case study of teachers' suggestions and rationales. *Research in Science Education.* doi: 10.1007/s11165-017-9628-0

Lederman, N. G., Abd-El- Khalick, F., Bell, R. L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497-521.

Lederman, N. G., Schwartz, R., Abd-El-Khalick, F., & Bell, R. (2001). Pre-service teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics and Technology Education*, *1*(2), 135-160. doi: 10.1080/14926150109556458

Lederman, J. S., & Khishfe, R. (2002). Views of nature of science, Form D. *Unpublished paper. Illinois Institute of Technology, Chicago, IL.*

Lee, I. (1947). Why discussions go astray. *ETC: A Review of General Semantics, 4*(2), 81-88. http://www.jstor.org/stable/42582126.

Longino, H. E. (1990). *Science as social knowledge: Values and objectivity in scientific inquiry*. Princeton, NJ: Princeton University Press.

Longino, H. E. (1993). Essential tensions—Phase two: Feminist, philosophical, and social studies of science. In L. M. Antony & C. Witt (Eds.), *A mind of one's own. Feminist essays on reason and objectivity* (pp. 257–272). Boulder, CO: Westview Press.

Longino, H. E. (1995). Gender, politics and the theoretical virtues. *Synthese, 104*(3), 383–397.

Longino, H. E. (2002). *The fate of knowledge*. Princeton, NJ: Princeton University Press.

Mackay, L.D. (1971). Development of understanding about the nature of science. *Journal of Research in Science Teaching*, *8*(1), 57-66.

Matthews, M. R. (1998). In defense of modest goals when teaching about the nature of science. *Journal of Research in Science Teaching, 35*(2), 161-174.

Matthews, M. R. (2012). Changing the focus: From nature of science (NOS) to features of science (FOS). In M. S. Khine (Ed.), *Advances in nature of science research* (pp. 3–26). Dordrecht, The Netherlands: Springer.

McComas, W. F., Clough, M. P., Almazroa, H. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies* (pp 3-39). Dordrecht: Kluwer Academic.

McComas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 41–52). Dordrecht: Kluwer.

McDonald, C. V. (2017). Exploring representations of nature of science in Australian junior secondary school science textbooks: A case study of genetics. In *Representations of Nature of Science in School Science Textbooks* (pp. 110-129). Routledge.

Metz, K. E. (1995). Reassessment of developmental constraints on children's science instruction. *Review of Educational Research, 65*(2), 93–127.

Milli Egitim Bakanligi (2006). *İlkogretim Fen ve Teknoloji Dersi (6., 7. ve 8. Siniflar) Ogretim Programi*. Ankara.

Milli Egitim Bakanligi (2013). *İlkogretim Fen Bilimleri Dersi (3., 4., 5., 6., 7. ve 8. Siniflar) Ogretim Programi*. Ankara.

Milli Egitim Bakanligi. (2018a). *Fen bilimleri dersi öğretim programı*. Ankara.

Milli Egitim Bakanligi. (2018b). *Ortaokul fen bilimleri ders kitabı 5.* Ankara: Özgün Matbaacılık

Milli Egitim Bakanligi. (2018c). *İmam Hatip Ortaokulu Haftalık Ders Çizelgesi*.

Meichtry, Y.J. (1992). Influencing student understanding of the nature of science: data from a case of curriculum development. *Journal of Research in Science Teaching, 29*(4), 389-407.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscut- ting concepts, and core ideas*. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next generation science standards: For states, by states.* Appendix H. Retrieved from http://www.nextgenscience.org/next-generation-science-standards, accessed at April 2018.

Özbay, H. E., & Köksal, M. S. (2015). Relationship between middle school students' frequency of participation in lab activities and scientific epistemological beliefs: Turkish case. *International Journal of Modern Education & Computer Science*, *7*(12).

Özer, F., Doğan, N., Yalaki, Y., Irez, S., & Çakmakci, G. (2019). The ultimate beneficiaries of continuing professional development programs: Middle school students' nature of science views. *Research in Science Education*, 1-26.

Popper, K. R. (1957). Science: Conjectures and refutations. In *Conjectures and refutations. The growth of scientific knowledge* (pp. 43–78). London: Routledge, 1963, 2002.

Popper, K. (2005). *The logic of scientific discovery*. Routledge. Chicago

Radder, H. (2009). The philosophy of scientific experimentation: A review. *Automated Experimentation, 1*(2), 1–8. doi:10.1186/1759-4499-1-2

Sadıç, A., Çam, A., & Topçu, M. S. (2012, June). Investigation of epistemological beliefs of primary school students according to gender and class level. In *X. National Science and Mathematics Education Congress* (pp. 27-30)*, Niğde, Turkey*.

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, *89*(4), 634-656.

Saribas, D. & Ceyhan, G.D. (2015). Learning to teach scientific practices: Pedagogical decisions and reflections during a course for pre-service science teachers. *International Journal of STEM Education, 2*(1), 7.

Schwartz, R., & Lederman, N. (2002). It's the nature of the beast: The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching*, *39*(3), 205-236. doi: 10.1002/tea.10021

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics*. Upper Saddle River.

van Driel, J. H., Meirink, J. A., van Veen, K., & Zwart, R. C. (2012). Current trends and missing links in studies on teacher professional development in science education: a review of design features and quality of research. *Studies in science education*, *48*(2), 129-160.

van Griethuijsen, R. A., van Eijck, M. W., Haste, H., den Brok, P. J., Skinner, N. C., Mansour, N., Savran Gencer, A., & BouJaoude, S. (2015). Global patterns in students' views of science and interest in science. *Research in science education*, *45*(4), 581-603.

Wittgenstein, L. (1958). *Philosophical investigations*. Oxford: Blackwell

Yacoubian, H. A. (2012). *Towards a philosophically and a pedagogically reasonable nature of science curriculum* (Doctoral dissertation). University of Alberta, Edmonton, AB, Canada.

APPENDIX A: RFN STUDENT QUESTIONNAIRE

BİLİMİN DOĞASI ANKETİ

Her bir maddeyi dikkatli bir şekilde okumanızı ve cevabınızı **uygun olan yere (X) işaretini koyarak** ifade etmenizi rica ederiz. Eğer tam olarak anlayamadığınız bir ifade olursa yanına belirtiniz. **Tüm soruları mutlaka cevaplamanız gerekmektedir.** Emin olmadığınız veya anlayamadığınız sorularda **Kararsızım (3)** seçeneğini seçmeniz çalışmanın sonuçlarının daha güvenilir olmasını sağlayacaktır.

	Kesinlikle Katılmıyorum (1)	**Katılmıyorum (2)**	**Kararsızım (3)**	**Katılıyorum (4)**	**Kesinlikle Katılıyorum (5)**
1. Bilimsel bilgi değişmez.					
2. Bilim insanları birbirlerinin çalışmalarını inceler ve değerlendirir.					
3. Deneyler bilim insanları tarafından çokça test edildiği için güvenilirdir.					
4. Bilim, üniversiteler ve araştırma merkezleri gibi kurumlarda gerçekleşir.					
5. Fizik, kimya ve biyoloji gibi bütün bilim dallarında (örneğin mikroskobik canlılar, hayvanlar, maddenin yapısı ve kuvvet gibi farklı konularda çalışırken) aynı bilimsel yöntem kullanılır.					
6. Bilim insanlar arasındaki sosyal ilişkilerden ve toplumdan etkilenir.					
7. Bilimde ilerleme, bilim insanlarının bilimsel bilgiyi gözden geçirmesiyle ve değerlendirmesiyle gerçekleşir.					
8. Bilim insanları doğaya saygı göstermelidir.					
9. Bilimsel verilerin (araştırma sonuçlarının) incelenmesi ve yorumlanması bilimsel pratiklerden (uygulamalardan) bazılarıdır.					
10. Teoriler ve yasalar bilimsel bilgi türleridir; ancak modeller (örneğin şekil, sembol ya da resim) bir bilimsel bilgi türü değildir.					
11. Bilim insanları araştırmalarını toplumla paylaşmak zorunda değildir.					
12. Bilimsel modeller (örneğin şekil, sembol ya da resim) karmaşık bilimsel fikirleri anlamamızı kolaylaştırır.					
13.Gözlem tüm bilim dallarında kullanılır.					
14. Bilim insanları, problemleri çözerken yeterli miktarda kanıt bulabilmek için farklı yöntemler kullanmak zorundadır.					
15. Bilim insanları araştırma yapmak için paraya ihtiyaç duyarlar.					
16. Sınıflandırma yapmak (örneğin canlıların sınıflandırılması) bilim insanlarının olayları açıklamasına ve tahmin etmesine yardımcı olur.					
17. (Klonlama gibi) Bilimin ürettiği yeni yöntem ve teknolojiler toplumlarda yeni değer yargıları oluşturabilir.					
18. Bilim insanlarının cinsiyetleri onların bilimi nasıl yaptıklarını etkiler.					

	Kesinlikle Katılmıyorum (1)	Katılmıyorum (2)	Kararsızım (3)	Katılıyorum (4)	Kesinlikle Katılıyorum (5)
19. Eğer bilim insanları düşüncelerini deney ve gözlem gibi bilimsel yöntemlerle ispat edemezlerse düşüncelerini değiştirmeleri gerekir.					
20. Devletlerin aldıkları kararlar bilimsel bilginin gelişimini etkiler.					
21. Bilimsel modeller (örneğin güneş sistemi modeli gibi) gerçek dünyadaki olayları, varlıkları ve durumları temsil eden araçlardır.					
22. Bazı bilim insanlarının diğerlerinden daha fazla para kazanması bilim insanları arasında gerginliğe yol açar.					
23. Bilimsel bilgi bilim insanlarının şahsi fikirlerinden etkilenmez.					
24. Bilim insanlarının ırkları ve milliyetleri bilimi etkilemez.					
25. Teoriler, yasalar ve modeller birlikte çalışarak bilimsel bilgiyi oluşturur.					
26. Bilim insanları fizik, biyoloji ve kimya gibi farklı bilim dallarında (mikroskobik canlılar, hayvanlar, maddenin yapısı ve kuvvet gibi farklı konularda) çalışırken aynı bilimsel pratikleri (deney, gözlem, veri toplama ve model gibi uygulamaları) kullanırlar.					
27. Bilim insanları akademik dergilerde bilimsel yazılar yazarlar.					
28. Teorilerin bazıları kabul edilmiştir, bazıları ise hala tartışılmaktadır.					
29. Bilimsel bilginin oluşum süreci nesnellik ve bilim insanlarının maddi beklentileri gibi değerlerden etkilenmez.					
30. Bilim insanları, araştırmalarını diğer bilim insanlarıyla paylaşmak için konferanslara katılırlar.					
31. Bir çalışmanın bilimsel sayılabilmesi için çalışmaya başlarken bilim insanlarının sonuca dair varsayımları (beklentileri) olmalıdır.					
32. Bilimsel çalışmaların güvenirliği nesnellik ve yeterli kanıt sunma gibi bazı standartlara göre değerlendirilir.					
33. Teori, kanun ve modeller bilim insanlarının olayları açıklamalarına ve tahmin etmelerine yardımcı olur.					
34. Yasalar teorilere göre daha doğrulanabilir bilimsel bilgilerdir.					
35. Bilim insanları araştırdıkları soruya göre deney ve gözlem gibi farklı yöntemler kullanır.					
36. Bilim insanları araştırma yaparken diğer bilim insanlarıyla iletişim kurarlar.					
37. Bilimsel çalışmalar sadece değişkenler değiştirilerek yapılabilir.					

APPENDIX B: INTERVIEW PROTOCOL FOR STUDENTS

1. Bilim deyince aklına ne geliyor?

2. Kimler bilim yapar?

3. Bilim insanları ‘bilim yapmak’ için neler yaparlar? Bilimsel araştırmalarını nasıl yaparlar?

4. Bilim insanları hangi amaçlarla bilimsel çalışmalar yaparlar? Sen bilimsel bir çalışma yürütecek olsan amacın neler olabilirdi?

5. Bilimin amaçlarından biri de çevremizde olan olayları anlamlandırabilmektir. Mesela her zıplayışımızda Dünya’ya düşeriz değil mi? Einstein bunun sebebini araştırmıştır. Peki, bilim insanlarının hakkında çalışmadığı, bilimsel olarak yanıtlanamayacak sorular var mıdır? (EVET ise Bilimin konusu dahilinde olmayan ne gibi sorular olabilir?)

6. Bir bilim insanının aklındaki bir soruyu yanıtlamak için çalıştığını düşünelim. Mesela kuvvetin cisimler üzerindeki etkisini ya da uzaydaki gök cisimlerini inceliyor olsun. Bu bilim insanı bu soruları yanıtlamak için neler yapabilir? Hangi yöntemleri kullanabilir?

7. Peki bu bilim insanı bilimsel çalışmasını yaparken sonucun ne olacağına dair bir beklentisi var mıdır? (EVET ise Çalışmanın sonucu onun beklediğinden farklı olabilir mi? Mesela hareket eden bir cisme kuvvet uyguladığında durduracağını düşünürken çalışmasının sonucunda o kadar kuvvetle durduramadığını öğrenebilir mi?

8. Bilimsel pratikler deyince aklına ne geliyor?

9. (Daha önce bahsetmediyse) Gözlem yapmak diye bir şey duydun mu? Gözlem yapmak ne demektir? Daha önce fen dersinde gözlem yaptınız mı? (EVET ise neler yapmıştınız?)

10. (Daha önce bahsetmediyse) Peki, deney yapmak diye bir şey duydun mu? Deney yapmak ne demektir? Daha önce fen dersinde deney yaptınız mı? (EVET ise neler yapmıştınız?)

11. Sana göre deney ve gözlem arasında bir fark var mı?

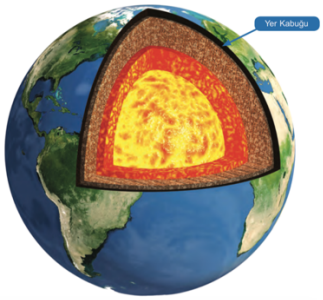
12. (Daha önce bahsetmediyse) Sınıflandırma yapmak diye bir şey duydun mu? Sınıflandırma yapmak ne demektir? Daha önce fen dersinde sınıflandırma yaptınız mı? (EVET ise neler yapmıştınız?)

13. Bilim dalları deyince aklına ne geliyor? Daha önce derslerinizde bu kavramı kullandınız mı? (HAYIR ise açıklama yapılabilir. Önce örnek ver bilimin fizik, kimya biyoloji gibi farklı alanları var. Bu farklı alanlarda bilim insanları farklı konularda çalışırlar. Örneğin kimya maddenin doğrudan göremediğimiz tanecik halini çalışıyor, biyoloji ise canlıları onların davranışlarını ya da organları ve vücut yapıları gibi konuları)

14. Böyle farklı alanlarda çalışırken bilim insanlarının kullandıkları yöntemler aynı mıdır? (Örneğin gözlem demiştin bunu hayvanların doğal yaşam alanlarını incelerken ve ısının suya etkisini incelerken aynı şekilde mi kullanırlar?)

15. Bilimsel bilgi türleri nelerdir?

16. Bazı bilimsel çalışmalarda bilimsel model denilen şekiller, semboller veya üç boyutlu cisimler kullanılır. Mesela belki hatırlarsın geçen sene yer kabuğunun yapısını öğrenirken farklı katmanlarını göstermek için ders kitabında bu görsel kullanılmıştı. Peki, sence bilim insanları bu tarz gösterimleri neden kullanırlar? Siz daha önce hiç model yaptınız mı? (+düz yazı kullanmamla model kullanmam arasında bir fark var mı?)



17. Bugün Dünya ve doğa olayları hakkında yüzyıllar önce yaşamış birinden daha çok şey biliyoruz değil mi? Mesela biz yağmur neden yağıyor biliyoruz. Bu konuma nasıl geldik? Bilimsel bilgi birikimimiz nasıl gelişti? Peki bugüne kadar bildiğimizi düşündüğümüz her şeyin yeni bir keşifle tamamen değişmesi mümkün mü?

18. Bilim insanları birbirlerinin çalışmalarından yararlanabilir mi?

19. Bilim insanlarının inançları, cinsiyetleri ve kişisel düşünceleri bilimsel çalışmaların sonucunu etkileyebilir mi? Nasıl, ne yönden etkileyebilir?

20. Bilim insanlarının ortaya çıkardığı bilgiler güvenilir midir? Bilimsel bir çalışmanın güvenilir olup olmadığını nasıl anlarız? (BAZEN ise neye bağlı, nasıl karar verebiliriz? Güvenilirliğini kontrol etmek için yapabileceğimiz bir şey var mıdır?)

21. Aynı konu/durum hakkındaki iki farklı fikirden hangisinin bilimsel olarak doğru olduğunu nasıl anlayabiliriz?

22. Bilim insanlarının sahip olması gereken değerler/takip etmesi gereken kurallar nelerdir? (EVET ise Bunlar neler olabilir?)

23. Bilimsel bir çalışma yürütmek için paraya ihtiyaç var mıdır? (EVET ise bilim insanları gerekli olan bu parayı nereden bulurlar?)

24. Devletler yapılacak olan bilimsel çalışmaları etkileyebilirler mi? Örneğin farklı alanlardaki çalışmalara destek veya engel olabilirler mi?

25. Bir bilim insanı olduğunu ve önemli bir şey keşfettiğini düşünelim. Diğer bilim insanlarını ve halkı bundan haberdar etmen gerekir mi? Neden? (EVET ise diğerlerini bilgilendirmek için neler yapabilirsin? Çalışma sonuçlarını yayınlamanın yararı ne olabilir?)

26. Peki, bilim insanları araştırmalarının sonuçları hakkında toplumu ve diğer bilim insanlarını bilgilendirmek için neler yaparlar? Daha önce konferans, seminer gibi kelimeler duydun mu?

27. Bilimsel çalışmalar hangi ortamlarda/kurumlarda gerçekleştirilir? (LAB ise bu laboratuvarlar nerelerde bulunabilir?

APPENDIX C: CONSENT FORMS

VELİ BİLGİ VE ONAM FORMU

Araştırmayı Destekleyen Kurum: Boğaziçi Üniversitesi
Araştırmanın Adı: Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımına Dayalı Bilimin Doğasının Ortaokul Sınıflarında Öğretilmesi

Proje Yürütücüsünün
Adı: Doç. Dr. Ebru Kaya
E-mail Adresi: ebru.kaya@boun.edu.tr
Telefonu: 0212 359 69 14

Araştırmacının Adı: Ayşegül Çilekrenkli
Telefonu: 0537 336 25 74
E-mail Adresi:
aysegul.cilekrenkli@boun.edu.tr

Sayın veli,

Boğaziçi Üniversitesi Eğitim Fakültesi Matematik ve Fen Bilimleri Eğitimi Bölümü'nde öğretim üyesi olarak çalışmaktayım. Yüksek lisans öğrencim Ayşegül Çilekrenkli ile birlikte bilimin doğası ile ilgili deneysel bir araştırma yürütmekteyim. Araştırmanın katılımcıları olarak çocuğunuzun öğrenim gördüğü sınıf seçildi. Okul müdürünüz ve MEB araştırmamı gerçekleştirmem için izin verdi. Siz de çocuğunuzun araştırmaya katılmasına onay verirseniz araştırmaya katkı sağlayacaksınız. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyorum. Bu bilgileri okuduktan sonra çocuğunuzun bu araştırmaya katılmasını isterseniz lütfen bu formu imzalayıp kapalı bir zarf içinde fen bilimleri öğretmenlerine ulaştırınız. Sizin onay vermeniz halinde çocuğunuzdan da sözlü olarak katılma onayı alınacaktır.

Çocuğunuzun bu araştırmaya katılmasını kabul ettiğiniz taktirde, dönem boyunca çocuğunuzun sınıfında fen bilimleri dersi kendi fen bilimleri öğretmenleri tarafından bilimin doğasıyla (bilimin amaçları, yöntemleri, uygulamaları vb) ilgili bir yaklaşım göz önünde bulundurularak işlenecektir. Bu yaklaşım bilimin farklı alanlarının öğrenciler tarafından daha iyi anlaşılmasını sağlamaktadır. Böylece öğrencilerin fen bilimleri dersinde daha başarılı olmaları hedeflenmektedir. Bu süreçte öğrenciler yeni geliştirilen müfredata uygun bir eğitim alacaklardır. Araştırma boyunca bu öğretim yaklaşımının etkinliğini incelemek amacıyla sınıftaki bütün öğrencilere 37 soruluk bir anket birinci dönem başında, birinci dönem sonunda ve ikinci dönem başında olmak üzere toplam 3 kez öğretmenleri tarafından uygulanacaktır. Bu anketlerin sonucundan yola çıkarak dönem boyunca bilimin farklı alanlarını anlayışlarındaki gelişmeye göre yaklaşık olarak 5 öğrenciyi seçip kısa süreli bir görüşme yapacağım. Bu görüşme esnasında sizin izniniz doğrultusunda benim not almamı kolaylaştırmak açısından ses kaydı alınabilir. Bu görüşmeler araştırmacı öğrencim tarafından seçilen öğrencilerle bireysel olarak ve okul içinde okul yönetiminin uygun göreceği bir mekânda gerçekleştirilecektir. Görüşmelerin yaklaşık bir saat sürmesi beklenmektedir.

Çocuğunuzun bu araştırmaya katılımı kendileri açısından herhangi bir risk içermemektedir. Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Araştırmaya katılım durumu çocuğunuzun ders notunu kesinlikle etkilemeyecektir. Eğer öğrenciniz dönem sonu görüşmesi için seçilirse ve ses kaydı alınmasına izin vermişseniz alınan ses kayıtları araştırma süresince taşınabilir usb bellekte muhafaza edilip araştırma sona erdiğinde silinecektir. Öğrencilerin kimliklerinin gizliliğini sağlamak adına araştırma belgelerinde isimleri yerine rastgele atanan sayılar kullanılacaktır. Bunun yanında öğrencilerin anketlere ve görüşme esnasında verdikleri cevaplar çocukların kimliği gizli tutularak bilimsel nitelikte sunumlarda gösterdikleri gelişimi yansıtmak amacıyla kullanılabilir.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Çocuğunuz araştırmaya katıldığı takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden çekilme hakkına sahiptir. Ayrıca bu araştırma hakkında ek bilgi almak istediğiniz takdirde lütfen proje yürütücüsü olan Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü Öğretim Üyesi Doç. Dr. Ebru Kaya ile temasa geçiniz (e-mail: ebru.kaya@boun.edu.tr).

Eğer çocuğunuzun bu araştırmaya katılmasını kabul ediyorsanız, lütfen bu formu imzalayıp kapalı bir zarf içerisinde fen bilimleri öğretmenlerine iletin.

Ben, (öğrenci velisinin adı) ....., yukarıdaki metni okudum ve çocuğumun katılması istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında soru sorma imkânı buldum. Bu çalışmayı çocuğumun istediği zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğini ve bıraktığı takdirde herhangi bir olumsuzluk ile karşılaşmayacağını anladım.

Bu koşullarda söz konusu araştırmaya hiçbir baskı ve zorlama olmaksızın çocuğumun katılmasını kabul ediyorum.
Formun bir örneğini aldım / almak istemiyorum.

Öğrencinin Adı- Soyadı:
Veli Adı-Soyadı:
İmzası:
Adresi:
Telefon:
Tarih (gün/ay/yıl):...../...../.....

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

ÖĞRETMEN BİLGİ VE ONAM FORMU

Araştırmayı Destekleyen Kurum: Boğaziçi Üniversitesi
Araştırmanın Adı: Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımına Dayalı Bilimin Doğasının Ortaokul Sınıflarında Öğretilmesi

Proje Yürütücüsünün
Adı: Doç. Dr. Ebru Kaya
E-mail Adresi: ebru.kaya@boun.edu.tr
Telefonu: 0212 359 69 14

Araştırmacının
Adı: Ayşegül Çilekrenkli
Telefonu: 0537 336 25 74
E-mail Adresi:
aysegul.cilekrenkli@boun.edu.tr

Sayın öğretmen,

Boğaziçi Üniversitesi Eğitim Fakültesi Matematik ve Fen Bilimleri Eğitimi Bölümü'nde öğretim üyesi olarak çalışmaktayım. Yüksek lisans öğrencim Ayşegül Çilekrenkli ile birlikte bilimin doğası ile ilgili deneysel bir araştırma yürütmekteyim. Okul müdürünüz ve MEB araştırmamı gerçekleştirmem için izin verdi. Siz de araştırmaya katılmayı kabul ederseniz araştırmaya katkı sağlayacaksınız. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyorum. Bu bilgileri okuduktan sonra bu araştırmaya katılmayı isterseniz lütfen bu formu imzalayıp araştırmacı öğrencime teslim ediniz.

Araştırmaya katılmayı kabul ettiğiniz takdirde, bir sınıfınızda bilimin doğasına ilişkin normalde kullandığınızdan farklı öğretim yöntemi kullanacaksınız. Bu yöntem Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımına Dayalı Bilimin Doğası olarak adlandırılmaktadır. Buna göre bilimin epistemik-bilişsel ve sosyal-kurumsal yönleri öğretim sürecinde açıkça vurgulanmaktadır. Sınıfta kullanacağınız aktiviteler bu yaklaşımla yeniden değerlendirilip revize edilecek ve sizin tarafınızdan sınıfınızda uygulanacaktır. Aktivitelerin işleyişini ve öğrencilerin aktivitelere katılımını değerlendirmek amacıyla sınıfınızda ses kaydı alınacaktır. Ekstra olarak sizden bir anketi öğrencilerinize dönem boyunca üç kez uygulamanızı isteyeceğiz. Bu sürece yönelik görüşleriniz önemli olduğundan sizinle haftalık görüşmeler yapılıp bu yaklaşımın sınıfınıza uygunluğunu tartışmanız istenecektir. Bu görüşmeler esnasında sizin izniniz doğrultusunda benim not almamı kolaylaştırmak açısından ses kaydı alınabilir.

Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Ses kaydı alınmasına izin vermişseniz alınan ses kayıtları araştırma süresince taşınabilir USB bellekte muhafaza edilip araştırma sona erdiğinde silinecektir. Görüşmeler esnasında verdiğiniz cevaplar ve sınıfta alınan ses kayıtlarınız kimliğiniz gizli tutularak bilimsel nitelikte sunumlarda ve yayınlarda kullanılabilir. Kimliğinizin gizliliğini sağlamak adına çalışmaya yönelik olarak hazırlanan yayınlarda isminiz yerine bir takma ad kullanılacaktır.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Araştırmaya katıldığınız takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden çekilme hakkına sahipsiniz. Ayrıca bu araştırma hakkında ek bilgi almak istediğiniz takdirde lütfen proje yürütücüsü olan Boğaziçi Üniversitesi Matematik ve Fen Bilimleri Eğitimi Bölümü Öğretim Üyesi Doç. Dr. Ebru Kaya ile temasa geçiniz (e-mail: ebru.kaya@boun.edu.tr).

Eğer araştırmaya katılmayı kabul ediyorsanız lütfen aşağıda işaretlenen yeri imzalayınız.

Ben, ..., yukarıdaki metni okudum ve katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında soru sorma imkânı buldum. Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir olumsuzluk ile karşılaşmayacağını anladım.

Bu koşullarda söz konusu araştırmaya hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.
Formun bir örneğini aldım / almak istemiyorum.

Öğretmen Adı-Soyadı:
İmzası:
Adresi:
Telefon:
Tarih (gün/ay/yıl):...../...../.....

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

APPENDIX D: TURKISH VERSIONS OF INTERVIEW QUOTATIONS AND EXCERPTS

1. Araştırmacı: Bilim insanları bilimsel çalışmalar yaparken başka ne amaçları olabilir?
   Öğrenci: Bizim bildiğimiz en küçük mikroskobik canlılar var. Mesela onlardan farklı bizim göremediğimiz başka hayvanlar da vardır. Onlar hakkında yapabilirler. [E-H-POST]
2. Öğrenci: İnsanlara katkıda bulunmak için. Mesela bir kanser ya da hiçbir çözümü olmayan (bir hastalık). O hastalığa bir çare bulabilirler. [E-H-POST]
3. Öğrenci: Bize tüm topluma katkıda bulunmaya çalışıyorlar, ama bazıları ise sırf para için yapıyorlar. O tarafı kötü oluyor. [E-M-POST]
4. Öğrenci: İlk önce projesini çizersin. Sonra ona göre de yapmaya başlarsın. Olmazsa sonra tekrar tekrar deneyip en sonunda başarırsın. Başaramazsan da devam etmen çabalaman lazım. [E-M-PRE]
5. Öğrenci: İnsanlara bilgi vermek istemiyorsa neden bilim insanı oluyor? İnsanların zararını istiyorsa insanlara zarar vermemeli o zaman mesleğini bırakmalı. [E-H-PRE]
6. Araştırmacı: Deney yapmak ne demektir?
   Öğrenci: Deney... böyle kavanozlar oluyor. Sıvı maddeler oluyor. Böyle döktükleri zaman böyle uçuyor, ama ben bir keresinde yapmıştım. Eski eve gidiyorduk. 15 Temmuz Şehitler Parkı'na götürmüşlerdi sene sonu diye. Orada vardı. Orada bize de yaptırıyorlar izletiyorlardı, ilk önce sonra yaptırıyorlardı.
   Araştırmacı: Peki başka aklına gelen deney örnekleri var mı? Mesela ne yapsak başka deney olabilir?
   Öğrenci: Başka mesela böyle bir tane bardak. Bardağa bir tane madde doldurabiliriz. Sonra öbür maddeyi boşaltırsak böyle bir tane madde fışkırabilir ya da yanlış bir şey yaparsak o madde patlayabilir. [E-M-PRE]
7. Araştırmacı: Deney yapmak ne demektir?
   Öğrenci: Proje gibi eğlenceli şeyler yapmaktır. Çoğu deney zaten eğlenceli olur. Eğlenceli şeyler.
   Araştırmacı: Sınıfta hiç deney yaptınız mı?
   Öğrenci: Evet, mikroskopla baktık. [C-H-POST]
8. Araştırmacı: Okulda hiç deney yaptınız mı?
   Öğrenci: Okulda deney yapmıştık bir kere, fende. Mikroskopla mikroskobik canlılara bakmıştık. Bir de sivrisinek kanadı vardı. İnceltmişlerdi onları. Ufak parçalarını izlemiştik. Bir de küfle ekmek, onları da izlemiştik.
   Araştırmacı: Peki, bunu yaparken amacınız neydi?
   Öğrenci: Canlıları daha yakından görmek. [E-H-PRE]
9. Araştırmacı: Gözlem yapmak ne demektir?
   Öğrenci: Gözlem yapmak... Ben bir kuşu incelemek istiyorum. Onu kuşa iyice bakarım, incelerim, ona gözlem denir. İyice inceleriz.
   Araştırmacı: İnceleyip ne yaparız?
   Öğrenci: Mesela kuşun özelliklerini bilmiyoruz. Sonra o kuşu gözlemleriz, bilgilerine ulaşırız. Mesela kuş uçabilir, kısa bacakları vardır, cik cik cik diye ses çıkartır. [E-L-POST]

10. Araştırmacı: Sınıflandırma yapmak ne demektir?
    Öğrenci: Bir şeyi gruplar haline getirmek. Hayvanlar grubu, bitkiler grubu, mikroskobik canlılar grubu, mantarlar grubu diye sınıflandırma yapmıştık. Hepsinde de belirli özelliklere bakarak sınıflandırma yapmıştık.
    Araştırmacı: Başka sınıflandırma aktivitesi hatırlıyor musun?
    Öğrenci: İlk ünitedeydi. Gezegenler, yıldızlar, bir de uydu gibi sınıflandırma yapmıştık. [E-M-POST]
11. Araştırmacı: Bilim insanlarının modeller kullanmasının amacı nedir? Modeller ne işe yarar?
    Öğrenci: Modeller (bilim insanlarının) karışık şeyleri daha iyi anlamalarını sağlar. Mesela yer çekimi kanunu çok karışıktı. Modelleyerek onları çok basit bir şekilde anlatmayı başardılar.
    Araştırmacı: Başka ne işlevi olabilir modellerin?
    Öğrenci: Yapmadan test etmemize işe yarar. Çizerek modelleriz sonra ona bakarak şunu şu kabloyla birleştirsek olmaz, şunu şu kabloyla birleştirsek daha iyi olur diye modeller olur. Mesela mimarlar ilk önce çiziyorlar binanın resmini sonra yapmaya başlıyorlar, ama eğik binalar oluyor şekil olsun diye ama onlar için mimarların daha fazla uğraşmaları gerekiyor çünkü düşme ihtimalleri daha fazla olabiliyor.
    [E-M-POST]
12. Öğrenci: Gerçekte yapılan şeyler. Yağmurla ilgili olabiliyor, doğa olayları ile ilgili şeyler olabiliyor.
    Araştırmacı: Ne olamaz peki?
    Öğrenci: Hayalimizdeki şeyler olamaz, çünkü gerçek dünyada yapmadık onları daha. Bilim hayali ürünlerle ilgilenmiyor. [E-M-POST]
13. Öğrenci: Bilimsel pratikler pratik yapmak. Yani tekrar tekrar çalışmak geliyor. [E-M-PRE]
14. Öğrenci: Bence olması gerekir. Bir şeyi bilmeden yaparsa tehlikeli şeyler olabilir. [C-H-PRE]
15. Öğrenci: Biz de hipotez yaptığımızda bir soruda soruyor doğrulandı mı, doğrulandıysa neden doğrulandı açıklamasını yapıyoruz. Yanlışlandıysa neden yanlışlandı açıklamasını yapıyoruz. Onlar da (bilim insanları) aklında bir düşünce olur yaptıktan sonra da sonucunu bulur.
    Araştırmacı: Hipotez ne demektir?
    Öğrenci: Hipotez bir yargı. Mesela sürtünme kuvveti hangi cisimlerin üzerinde... Yani mesela hipotezinizi kurunca mesela sürtünme kuvveti havlunun üzerinde daha az gidecek ama plastik örtünün üzerinde fazla gidecek gibi. Onun sorusu da geliyor zaten hipoteziniz doğrulandı mı diye biz de ona göre cevaplıyoruz.
    Araştırmacı: Hipotezin doğrulanıp doğrulanmadığına nasıl karar veriyoruz?
    Öğrenci: Araştırma yaparak. (ACT12) [C-H-POST]
16. Araştırmacı: Hipotez test etme nasıl oluyor?
    Öğrenci: Hipotez test etmede mesela kafanızda bir düşünceniz var. Mesela "bütün çiçekler sarıdır". Biz bunu test ediyoruz. Baktım, o kişinin etrafında hep sarı çiçek vardır, o öyle demiştir. Sonra başka yerleri de gezerim, farklı renkler de vardır. O zaman da hipotez yanlışlanmış olur.
    ...
    Öğrenci: Hipotezi yanlış da çıkabilir doğru da çıkabilir.
    …

Öğrenci: Doğrulanması da mesela araba şu hızla gider diye tahmin ediyor, sonra bakıyor deniyor. Ama bir kere değil de böyle dört kere falan tekrar ediyor. Ufak hata yapmışımdır diye. Sonra yanlış çıkıyorsa yanlış olarak kabul etmeli bunu. [E-H-POST]

17. Öğrenci: Bilimsel yöntemler her (bilimsel) dala göre bence farklı. Çünkü mesela biyoloji ile ilgili oradaki çiçeği alacağım ve bir deney yapacağım. Ama bunu mesela uzayda uygulasam Dünya'yı alıp bir deney yapamayacağıma göre bence yöntemleri farklı farklı. [E-H-POST]
18. Öğrenci: Teorileri de biliyorum. Kolay olan böyle fikirler.
    Araştırmacı: Kolaylığından kastettiğin nedir?
    Öğrenci: Yani pratik bilgi diye konuşmuştuk. Onun gibi. [C-M-PRE]
19. Araştırmacı: Bilimsel pratikler deyince aklına ne geliyor?
    Öğrenci: İşte ona göre resimlerini alır. Eskiden kalmış o bilimsel pratik olan kolay olan yollar kullanır. Birleştirir hemen kolay küçük bir inceleme ama çok merak edilen bir şey olur. [C-M-PRE]
20. Öğrenci: Yasa trafik kurallarında veya başka şeylerde yasak olan şeylerdir bence. [C-L-PRE]
21. Öğrenci: Yasayı biliyorum zaten. Yasa devletin koyduğu kanundur, herkes kafasına göre şey yapamaz. [C-M-PRE]
22. Araştırmacı: Bilimsel bilgi türleri nelerdir?
    Öğrenci: Yasalar, modeller, teoriler. Yasalar doğada olan olayları olduğu gibi anlatır. Teoriler doğada olan olayları açıklar. Modeller ise bir olayı şekiller ile anlatır. [E-M-POST]
23. Araştırmacı: Teori, model ve yasa arasındaki ilişki nedir?
    Öğrenci: Biri açıklıyor, biri direkt söylüyor model ise onu resme dökerek üç boyutlu bir şekilde yapıyor. [E-M-POST]
24. Araştırmacı: Teori, yasa ve model arasındaki ilişki nedir?
    Öğrenci: Teori, model ve yasalar bilimsel anlayışı tamamlıyorlar. Hiçbiri bir diğerinde önemli değil. Üçü de aynı önemde. Biri olmazsa olmuyor.
    Araştırmacı: Ne olmuyor?
    Öğrenci: Mesela teori olmasa neden ve nasıl sorularını yanıtlayamaz. [E-H-POST]
25. Bildiğim kadarıyla teoriler önerilerdir. [C-M-POST]
26. Araştırmacı: Bugüne kadar bildiklerimiz şeylerin yeni bir keşifle değişmesi mümkün müdür? Şu ana kadar keşfettiğimiz şeylerin?
    Öğrenci: Eğer yanlış biliyorsak tabi ki de.
    Araştırmacı: Yanlış biliyor olma ihtimalimiz var mı?
    Öğrenci: Evet var, çünkü eskiden bilmiyorsak geliştikçe büyüdükçe öğreneceğiz.
    …
    Öğrenci: Eğer bu eskiden kalma bilgiyse eskiden daha az teknoloji olduğu için yanlış bilmiş olabilir. Eskiden her şey doğru olmayabilir.
    …
    Öğrenci: Bu eğer eskiden kalmışsa ve şu ana kadar artık değişmemişse kesinlikle bu değişmez. Bir de bu şey var. Onun üstüne bu bir varsayım olabilir. Genellikle bu hep gerçek olması gerekmiyor. [C-M-PRE]

27. Araştırmacı: Bilimsel bilgi değişir mi?
Öğrenci: Değişmez.
Araştırmacı: Bugüne kadar belli bir bilgi birikimimiz var. Bunlardan bazılarının ilerde değişmesi mümkün müdür?
Öğrenci: Hayır.
Araştırmacı: Gelişmesi mümkün müdür?
Öğrenci: Evet.
Araştırmacı: Nasıl gelişir bilimsel bilgi?
Öğrenci: Bir bilim insanı mikroskopu bulmuş. Başka bilim insanları da üzerine malzemeler ekleye ekleye daha çok değiştirmişler.
Araştırmacı: Bu nasıl bir gelişim?
Öğrenci: Birikimsel.
Araştırmacı: Başka nasıl gelişebilir bilimsel bilgi?
Öğrenci: Yeni yeni şeyler icat ederek.
Araştırmacı: Bunun bir adı var mı?
Öğrenci: Devrimsel ilerleme. [E-L-POST]

28. Araştırmacı: Bilimsel bilgi birikimimiz peki? Öğrendiklerimiz nasıl arttı?
Öğrenci: Öğrendiklerimiz...
Araştırmacı: Bildiklerimiz.
Öğrenci: Onlar daha demin dediğim gibi teknoloji ilerledikçe daha çok bilgi edinebiliyoruz. [C-M-PRE]

29. Öğrenci: Eskiden bu kadar bilimsel şeyler yoktu. Şimdi teknoloji daha çok gelişti. Bilgileri daha kolay bulabiliyorlar. [E-H-PRE]

30. Araştırmacı: Bugüne kadar bildiğimiz şeyleri biz nasıl öğrendik?
Öğrenci: Teknoloji geliştiği için bu kadar...teknoloji gelişmeseydi biz daha fazla öğrenemezdik.
Araştırmacı: Teknoloji nasıl gelişti?
Öğrenci: Bilim insanları interneti falan buldu. Uzaydan uydu olduğu zaman... [C-H-POST]

31. Öğrenci: Galileo Galilei örneği olabilir. Kilise kendi kitaplarında böyle diyordu, herkes de öyle biliyordu.
Araştırmacı: Ne diyordu kilise hatırlıyor musun?
Öğrenci: Güneş dünyanın etrafında dönüyor diyordu. Galileo Galilei de dünya güneşin etrafında dönüyor diyordu. Sonra kimse onu kabul etmiyordu. Kitap yazıyordu Galileo. Onu hapse atıyorlardı. Ama yıllar sonra bu bilimsel bilgi değişiyordu. Dünyanın güneşin etrafında döndüğü ispatlanıyordu.
Araştırmacı: Peki bu nasıl bir gelişme oldu? Bilimsel bilgi nasıl gelişmiştir?
Öğrenci: Zaman geçtikçe incelenerek gözlemler yapılarak.
Araştırmacı: Bilimsel bilgi nasıl gelişir?
Öğrenci: Üstüne kattıkça.
Araştırmacı: Bunun bir adı var mı?
Öğrenci: Birikimsel ilerleme.
Araştırmacı: Başka bir yolu daha vardı sanki?
Öğrenci: Devrimsel ilerleme.
Araştırmacı: Galileo örneği sence birikimsel mi devrimsel mi?
Öğrenci: Birikimsel, çünkü Galileo diyordu ki dünya güneşin etrafında dönüyor. Ama kilise buna hayır diyordu. Ama günler geçtikçe zaman ilerledikçe üstüne kata kata uzaya bakmaları daha net olduğu için herkesi ikna etmek daha kolay oluyor. Sonra dünyanın güneşin etrafında döndüğü ispatlanabiliyor. [E-M-POST]

32. Öğrenci: Mesela önceden kilisenin bilgileri vardı. Galileo doğrusunu diyordu dünya güneşin etrafında dolanır. Kilise de zıttını diyordu.
    Araştırmacı: Bu birikimsel bir gelime miydi yoksa devrimsel bir gelişme mi olmuştu?
    Öğrenci: Bence devrimseldi. [E-H-POST]
33. Öğrenci: Eğer bunun üzerinde çok çalışmışsa ve bu onaylamalardan geçmişse eğer doğrudur. [E-M-PRE]
34. Öğrenci: Bazıları güvenilir olmayabilir, ama bir şeyin üzerinde deney yapıyorlar. Ondan sonra dünyaya yayıyorlar ama bazıları hastalık falan yapabiliyor. [E-L-PRE]
35. Öğrenci: Mesela oyuncak araba deneyinde oyuncak arabanın hızını doğrulamak için dört kez yapmıştık. (ACT12)
    Araştırmacı: Oyuncak arabanın hızını doğrulamaktan kastın ne?
    Öğrenci: Yani hocam onu ilk yaptığımızda ikinci yaptığımızda yanlış yaptığımızda yanlış olabilir ama üçüncü dördüncü denememizde daha doğrulanır. [E-L-POST]
36. Araştırmacı: Tekrar tekrar mı yaptınız? Bunun önemi neydi?
    Öğrenci: Şimdi tekrar tekrar atınca... Bir şeyi yaparsın ama unutursun. Mesela diyelim ben buraya kadar getirdim ama onunki erken düştü ya, birazcık zaman geçse hemen diyeceğim hemen benim ki erken düştür. İnsan unutabiliyor bazen. [C-M-POST]
37. Öğrenci: Önce o bilim insanına iyice inanmamız lazım.
    Araştırmacı: Neye göre inanacaksın, nasıl inanacaksın. Kontrol edebileceğin bir şey var mı?
    Öğrenci: Gidiyor bazı insanlar deniyor. Sonra haberlerde gösteriyorlar şu şeyi kullanmayın böyle şeyler yapıyor diye.
    …
    Araştırmacı: [ortaya atılan iki fikirden] bilimsel olarak hangisinin doğru olduğuna nasıl karar veririz?
    Öğrenci: Önce bir tanesinin dediğini uygularlar. Yanlış çıkarsa diğerininkini uygularlar. Sıra sıra. [E-L-PRE]
38. Araştırmacı: Bu ikisinden hangisinin doğru olduğuna nasıl karar verebiliriz?
    Öğrenci: İkisinin açıklamasına bakarız. İkisinin sonuçlarına bakarız. Emin değilsek de başka kişiler de bunu değerlendirmeli. Bilimin yaygınlaşmasına yardımcı olan kurumlar da onu değerlendirmeli. [E-H-POST]
39. Öğrenci: Bilgilendirmezlerse ne olacağını bilemeyiz ve o an bir şey oldu... Mesela bilim insanını suçlamamız gerekir. Dünya'dan bir şey düştü falan onca insan öldü. Bilim insanları, astronotlar bunu haber vermeli ki biz de ona göre hazırlanalım. Mesela adını unuttum... Onları bulan... [C-H-PRE]
40. Araştırmacı: Bilim insanları bilimsel çalışmalarını nasıl yaparlar?
    Öğrenci: Hocam laboratuvarlarda konferanslarda falan konuşurlar, anlaşırlar. Ondan sonra anlaşma sonucunda ortaklaşa deney yaparlar. Ondan sonra da bir kişi isterse onun üzerinde denerler. Deney başarılı geçerse de dünyaya sunarlar ilaç olarak.
    Araştırmacı: Peki orada isterseden kastın neydi?
    Öğrenci: Yani zorla yaptıramayız bu kişiye. Bir tane dilekçe imzalatmalıyız. İstediği zaman bırakabilir yani. Mesela ben bilimdeki deneyleri yapamam derse zorlamamamız lazım onu. [E-L-POST]
41. Araştırmacı: Devletler olumsuz yönde etkileyebilir mi bilimsel çalışmaların gelişimini?
    Öğrenci: Evet.
    Araştırmacı: Nasıl etkileyebilir?

Öğrenci: Kötü bir devlet eğer bir bilim insanını sevmiyorsa... Çok iyi dünya bir katkı sağlamıştır o kadar iyi bir şey yapmış olur. Sonra onu götürür der bu güzel bir çalışma kabul edin diye. Devlet de hayır bu çalışma kötü derse yapmasına izin vermezse Türkiye'ye çok kötü bir zarar vermiş olur. [E-M-POST]

42. Araştırmacı: Bilimsel çalışmalar hangi ortamlarda gerçekleştirilir?
Öğrenci: Bilimsel çalışmalar böyle deneylerin olduğu bilim yerlerinde olur.
Araştırmacı: Bunların bir adı var mı aklına geliyor mu?
Öğrenci: ...
Araştırmacı: Başka nerelerde olabilir? Yada bunlar neredelerde bulunur?
Öğrenci: Bazı okullarda bulunabilir.
Araştırmacı: Nasıl okullarda?
Öğrenci: Liselerde mesela. Lise ve ortaokullarda. [C-L-POST]
43. Öğrenci: Bu iş bir devlet işlerindendir genellikle. Çoğunlukla devletten alırlar. Devlet de bunu zaten pazardan, marketlerden çoğunlukla vergilerden alıp verirler. [C-M-PRE]
44. Araştırmacı: Bu ihtiyaç duydukları parayı nereden bulmalılar?
Öğrenci: Devletten.
Araştırmacı: Devlet ne anlamda bu parayı vermeli?
Öğrenci: Devlet onların deneyleri yapabilmesi için para vermelidir. [C-L-POST]
45. Araştırmacı: Paraya ihtiyacı var dedin. O para nereden bulsun?
Öğrenci: Çalışarak kazanabilir.
Araştırmacı: Başka yapabileceği bir şey var mı?
Öğrenci: Yani gökten yağmıyor para. Ağaçlarda yetişmiyor. [E-L-PRE]
46. Araştırmacı: Peki bu parayı nereden bulmalı bilim insanları?
Öğrenci: Belediye onlara malzeme almaları için para verir.
Araştırmacı: Belediyeden olabilir. Başka nerelerden olabilir?
Öğrenci: Mesela ellerinde malzemeler vardır. Onları birleştirip bir ilaç yapabilirler. Sonra test edip doğruysa faydalıysa dünyaya sunulur. Eczanelerde satılır. Ondan sonra da eczanelerde satılan paranın yarısını onlar alır. [E-L-POST]
47. Araştırmacı: Devletler bilimsel bilginin gelişimini etkileyebilir mi?
Öğrenci: Etkileyebilir.
Araştırmacı: Nasıl etkileyebilir.
Öğrenci: Bilim insanlarının paraları olmadığında devlet de ona bir miktar para verir. Uzaya gitmeleri için roket almalarına kıyafet almalarına yardımcı olur. Uzaya gidip bir şeyler aldıklarında müzelere koyabilirler yada satılabilir bazı müzelere. Yurtdışına satılabilir. Oradan da bir miktar para aldığımızda devletin parasını veririz, kendi miktar paramızı da kendimize alabiliriz. [E-M-POST]

APPENDIX E: ACTIVITY 09

Öğrenci Numarası: Masa numarası:

Lesson Plan 9: Classification of Fungi

Grade Level: 5
Unit: F.5.2. Classification of Living Things
Curriculum. Goal(s):
F.5.2.1.1. Students will be able to classify living things based on their similarities and differences by giving examples (MEB, 2018a).
RFN learning goals:

- Students will be able to link their activities in the classroom to some of the scientific practices (Scientific Practices)
- Students will be able to make observations from the microscope. (Scientific Practices)
- Students will be able to make assert a link between discovery of penicillin and aims and values of science. (Aims and Values of Science)
- Students will be able to pose ideas about commercialization of science. (SI-Financial Systems)

Lesson Design: **Part 1:** Engagement (10 minutes) **Part 2:** Observing yeast under microscope (30 minutes) **Part 3:** Discovery of penicillin (20 minutes) **Part 4:** Revisiting FRA Wheel (20 minutes)	**Instructional Techniques:** Microscobic observation Drawing diagrams Think-pair-share Whole group discussion **Prerequisite:** None **Lesson Duration:** 80 minutes

Part 1: Engagement (10 minutes)
To engage students in the teacher will ask the students whether they like pastries and which ones are their favorite. She will then ask if they know how they are made and bring the detail that fungi known as yeast is used in the process.

Part 2: Observing yeast under microscope (30 minutes)
She tells the students that they are very small, but they will have a chance to see them. She will ask if they are so small that they cannot see with naked eye what they can do (observe them with microscope). Then she tells that they have only one microscope while they are so many people, so she needs their cooperation.

She gives out the worksheets and reading sheet. She goes through the worksheet with the students and explain that in the first questions they will need to draw what they see; therefore, they need to carefully observe the image. She asks them to work in pairs while waiting their turn at the microscope.

She shows the yeast-sugar-water mixture and shows the regular yeast. Then she puts a drop of mixture on to the slide. She calls 4 students at a time, gives them a chance to observe the yeast under the microscope and asks them questions such as “What do you see? What are we doing now? Are there other scientific practices that could help us learn more about yeast? Do we obtain any data? Did we make any predictions about the nature of yeast?”. These questions will be asked in order to explicitly tie the *observation* students conduct to observation as a scientific practice and other related scientific practices.

Öğrenci Numarası: Masa numarası:

In the meantime, other students work on the reading sheet and the question number 2 of the working sheet. The students who made observations draw what they have seen in the appropriate place given at question number 1.

When all students get a chance to make observations and discuss with their teacher, the teacher calls their attention to a laboratory video in which another teacher is making the same observation and showing the image. The students compare their drawings to this image. Then the teacher asks "What purpose did drawing this image serve for us? Can you relate this to any of the scientific practices?" in order to discuss about *models* (SP).

Part 3: Discovery of penicillin (20 minutes)
The teacher shows another short video about the discovery of penicillin. In this video the story of how Alexander Fleming has found penicillin is told. After the video she asks "What do you think about the video? Do you know what penicillin is used for? Can we relate this to aims and values that we had previously discussed about? What do you think aim of conducting science was in this story?" in order to discuss aims and values of science (AV). Then she asks "What do you think buying medicine from the pharmacy? Some of the medicine are very expensive. Penicillin can be a lifesaving drug, but you need money to reach it. Do you think it should have been free because it is a scientific discovery that helps us all? If these should not cost money to people how are scientists are supposed to make money for living and for further studies?" in order to redirect the discussion to commercialization of science. (SI-FS)

Part 3: Revisiting FRA Wheel (20 minutes)
At the end of this discussion the teacher asks students to write their ideas about aims and values of science and commercialization of science in the last two questions of the worksheet. Afterwards some students present their answers. The teacher writes some of the keywords on the boards and then asks the students to where does the keywords belong in the RFN Wheel. She goes through each category and asks students if they can see any other connections to what they have done and discussed today. She frequently asks students to elaborate their ideas instead of just suggesting a match and leaving it at that. At the end of this lesson, students should be able to pose ideas about observation, data, discussion and real world as scientific practices, aims and values of science and financial systems.

You may find activity sheet 9: Classification of fungi

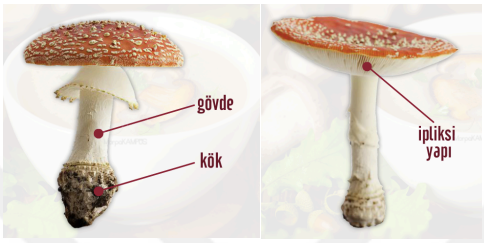
Rubric 9

Score / Evaluation Criteria	None (0 Pts)	Partial (2 Pts)	Complete (4 Pts)
Student was able to suggest links to at least two scientific practices between the activities they have conducted and explain this link.			
Student was able to assert a relationship between discovery of penicillin and aims and values of science.			
Student was able to show understanding of commercialization of science.			
TOTAL SCORE			

Öğrenci Numarası: Masa numarası:

MANTARLAR

Mantarlar bitkiye benzeyen ancak kendi besinini üretemediği için bitki grubunda yer almayan canlılardır. Besinlerini hazır olarak alırlar. Salgıladıkları enzimler sayesinde hayvan ve bitkilerin yapısında bulunan besin maddelerini kullanırlar. Genellikle ormanlarda, nemli yerlerde, bitkilerin üzerinde yaşarlar.



Şapkalı mantarlar:
Besin olarak tükettiğimiz mantarlar şapkalı mantarlardır. Bazı türleri zehirlidir. Bu nedenle insanlar tarafından kontrollü olarak üretilen *kültür mantarları*nı besin olarak tüketmemiz gerekir. Aşağıdaki görseldeki gibi *kök* ve *gövde*den oluşurlar. Şapkanın altında bulunan *ipliksi yapı*lar sayesinde çoğalırlar. Besinlerini kendileri yapamadıkları için sap kısımlarıyla dışarıdan beslenirler.

Küf mantarları:
Besinlerin üzerinde yaşarlar. Açıkta bırakılan yiyeceklerin üstünde oluşan gri-mavi-yeşil renklerindeki tabaka küf mantarlarıdır. Özellikle açıkta bırakılan yiyecekler, nemli ortamda kalan yiyecekler küf mantarlarının yaşam alanıdır. Küf mantarları antibiyotik yapımında kullanılır. Antibiyotik ilk kez peynir küfünden elde edilmiştir.





Maya mantarları:
Gözle göremeyeceğimiz kadar küçük canlılardır. Yaşamsal faaliyetlerinin oluşabilmesi için uygun sıcaklık, besin ve su gerekir. Bu şartlar sağlandığında çoğalır. Ekmeğin mayalanması ve peynir yapımı için maya mantarları kullanılır.

Parazit mantarlar:
İnsan, hayvan ve bitkilerin üzerine tutunarak yaşayan ve üzerinde yaşadığı canlılarda birtakım hastalıklara sebep olan mantarlardır. Pamukçuk, saçkıran gibi hastalıkların nedeni bu mantarlardır. Mantarların neden olduğu hastalıklardan korunmak için temizliğimize dikkat etmeli ve başkalarının eşyalarını kullanmamalıyız.



Öğrenci Numarası: Masa numarası:

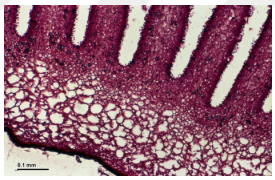
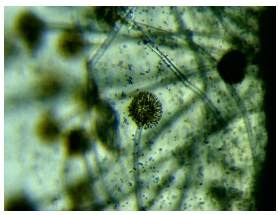
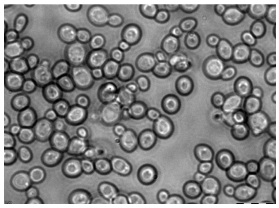
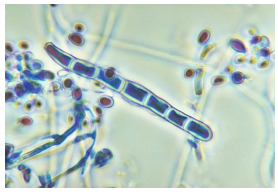
Mantarlar

A. Aşağıdaki soruları yanıtlayınız.

1. Mikroskopta gördüğünüz görüntüyü aşağıdaki kutunun içine çiziniz. İncelediğiniz örneğin hangi mantar grubuna ait olduğunu ve neden böyle düşündüğünüzü belirtiniz.

Mikroskopta incelediğimiz örnek .....
grubuna aittir. Çünkü .....
.....
.....
.....
.....
.....

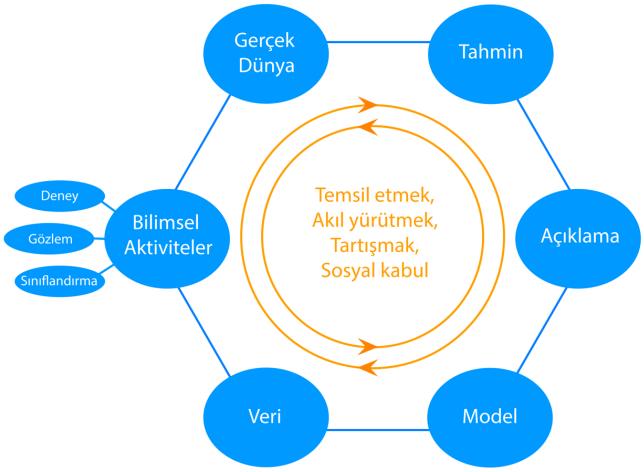
2. Aşağıda mikroskop altındaki ve çıplak gözle görülen görüntüleri verilen mantarları türleri ile oklar çizerek eşleştiriniz.

Çıplak gözle görüntüsü	**Mikroskop altındaki görüntüsü**	
		Maya mantarı
		Saçkırana sebep olan parazit mantar
		Şapkalı mantar
		Küf mantarı

Öğrenci Numarası: Masa numarası:

B. Aşağıdaki soruları yanıtlayınız.

1. Aşağıda bilimsel pratikleri gösteren bir görsel verilmiştir. Bugünkü aktivitede kullanılan bilimsel pratikleri bu görsel üzerinde işaretleyiniz. Daha sonra bu pratikleri aktivite boyunca nasıl kullandığınızı açıklayınız.



2. Penisilinin keşfinin bilimin amaç ve değerleri ile nasıl bir ilişkisi olduğunu düşünüyorsunuz?

3. Alexander Fleming'in bulduğu penisilinin ilaç haline gelip satılması hakkında ne düşünüyorsunuz? Bilimsel buluşlar ticari olarak alınıp satılabilmeli midir yoksa halka ücretsiz olarak dağıtılmalı mıdır? NEDEN?

APPENDIX F: ACTIVITY 11

Öğrenci Numarası: Masa numarası:

Lesson Plan 11: Force

Grade Level: 5
Unit: F.5.3. Measuring Force and Force of Friction
Curriculum Goal(s):
F.5.3.1.1. Students will be able to measure the magnitude of force with dynamometer.
F.5.3.1.2. Students will be able to prepare a model of dynamometer. (MEB, 2018a).
RFN learning goals:

- Students will be able to explain theory, law and models as types of scientific knowledge. (Scientific Knowledge)
- Students will be able to explain that theory, law and models work together to make up our scientific knowledge body. (Scientific Knowledge)
- Students will be able to explain their understanding by reviewing models. (Scientific Knowledge)
- Students will be able to make use of prior models to explain current situation. (Scientific Knowledge)
- Students will be able to draw models to present their explanations and predicitions for future use.(Scientific Knowledge)

Lesson Design: **Part 1:** Retention (10 minutes) **Part 2:** Action-at-a-distance forces (30 minutes) **Part 3:** T, L, M (30 minutes) **Part 4:** TLM (10 minutes)	**Instructional Techniques:** Whole group discussion Answering questions Writing **Prerequisite:** None **Lesson Duration:** 80 minutes

Part 1: Retention (10 minutes)
The teacher starts the lesson by reminding that last year they had learnt that by exerting a direct force, namely, by pulling and pushing they could change *direction*, *speed* or *shape* of objects. She asks the students about examples of these cases. For example, she asks how could force change the direction of an object. As students give examples she lists some of them on the board. During this discussion she emphasizes that to change speed or direction of an object what is important is the *net force* acting on the object.

Part 2: Action-at-a-distance forces (15+15 minutes)
When she feels that the board is saturated with examples, the teacher points out that in each of their examples the force needs to be in direct contact with the object. Then she asks, "Is it possible to exert force on objects from a distance?". As the students pose ideas she divides the board into two and writes these new examples on the empty side. She guides the discussion and tells about gravitational force, magnetic force and static electricity even if students cannot think of them. As these examples arise she demonstrates them by dropping an object, statically charging a balloon and bringing two magnets together.

At the end when both sides of the table have examples, she labels these sections as *contact forces* and *action-at-a-distance forces*.

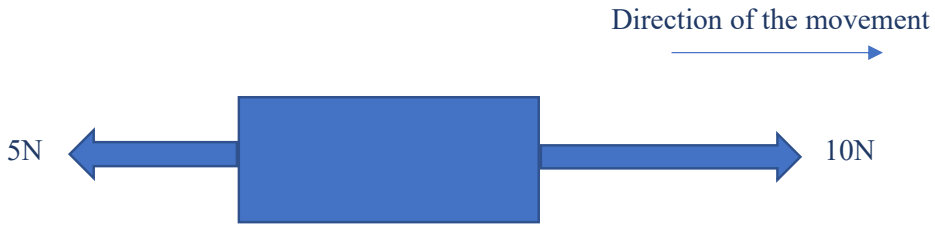
Then the teacher spreads the activity sheets and asks the students to answer the questions on section A.

Öğrenci Numarası: Masa numarası:

Part 3: T, L, M (15 +15 minutes)
The teacher asks, “What are types of scientific knowledge?”. After getting some answers she then asks the students if they have previously heard about these terms: *theory*, *law* and *model*. She divides the board into three sections and labels them with these terms. After getting students’ comments as to the meanings of these terms, she explains:

> Laws tell us *what* happens, theories explain *how* and *why* something happens. Do you know for sure, through observation, that while we are on Earth if I let an object free, it will drop to the Earth? We do, right? So, saying that “There is an attraction force between any two object.” (which are in this case the pen and the Earth) is a law, to be specific it is law of gravitation. She writes it on the appropriate section. But if I say “there are tiny particles in these objects and they attract each other so an invisible force called gravitational force brings them together” it is a theory because I am trying to explain how the two objects attract each other, by using my reasoning, by making inference. Now this is called theory of gravitation. She writes a short version of theory of gravitation on the appropriate section.
>
> Now, about *model*s. We have already done some of them during the term. Which ones do you remember? What was the purpose of using models? (they generally say to explain) There is another purpose of models which is to predict what is going to happen. Let me explain.

The teacher draws a rectangular object on the model side of the board. Then she shows a familiar object like a pencil case. She picks a student and they exert a force on the object with differing amounts of force, so the object moves around. She asks, “Who used more force?” for each case. She shows an approximation of the forces on the board with lines:



She explains draws the direction of the object when these forces are applied. This try and draw a model process goes on. She says “As you said our models explain to others what we have done. Now what about prediction?” She writes a question on the board: “Forces are applied to a still object. Ece pulls the object to the right with force of 8N, while Begüm pulls to the left with a force of 3N. Which direction does the object move?” She wants them to use the other models they had drawn on the board to predict what will happen. She gets answers from the students with explanation. At the end, she repeats, “So this way we can use models to predict what could happen in similar circumstances.”. She also points out one more time, “The 3 types of scientific knowledge are theory, laws and models.”

Students answer questions in the section B of the activity sheet.

Part 4: TLM (10 minutes)
The teacher shows the TLM GIS for students (on the smart board). Then she asks, “What does this image tell you?”. After getting some answers, she explains the analogy of the image. “This is a whole brick wall. When the small bricks come together, they make up a huge wall. Just like

Öğrenci Numarası: Masa numarası:

this, each theory, law and model that the scientists come up with is just one piece of our scientific knowledge accumulation. Therefore, theories laws and models work together to explain natural phenomena.”.

The students answer the questions on the section C of the activity sheet.

You may find activity sheet 11: Force

Rubric 11

Score / Evaluation Criteria	None (0 Pts)	Partial (2 Pts)	Complete (4 Pts)
Student was able to present basic understanding of theory, law and models. C			
Student was able to write explanation of given models. B1			
Student was able to draw a model to explain a given situation. B2			
The student attempted to use prior models to explain current situation. B2			
Student was able to explain that theory, laws and models work together and make up scientific knowledge body. D			
TOTAL SCORE			

Sources: MONE textbook

Öğrenci Numarası: Masa numarası:

KUVVET

A. Aşağıdaki soruları yanıtlayınız.

1. Aşağıdaki cümlelerin başındaki noktalı yerlere cümlelerin ifade ettiği bilgi doğru ise "D" yanlış ise "Y" harfi yazınız.

(....) Kuvvet hareketli cisimlerin yönünü değiştirebilir.
(....) Cisimlere uzaktan etki edebilen görünmez kuvvetler vardır.
(....) Kuvvetin birimi kısaltması N olan Newark'tır.
(....) Kuvvet bir durgun bir cismin yönünü, hızını ve şeklini değiştirebilir.

2. Aşağıdaki bilgilerden hangisi kuvvetin özellikleri arasında yer **almaz**?
A) Dinamometre ile ölçülür.
B) Kuvvetin belli bir büyüklüğü vardır.
C) Birimi metredir.
D) Duran cisimleri harekete geçirir.

3. Aşağıdaki kuvvet örneklerini uygun kutuya yerleştiriniz.

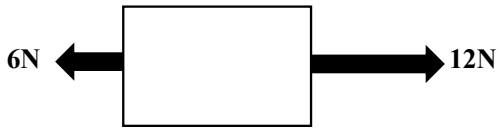
İtme Elektrik Manyetik Kaldırma Çekme Yer çekimi

Uzaktan etki eden kuvvetler	**Fiziksel temas ile** etki eden kuvvetler

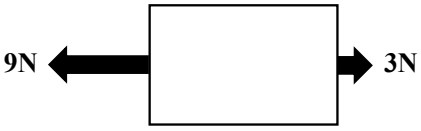
B. Aşağıdaki soruları yanıtlayınız.

1. Aşağıdaki kuvvet-hareket modellerini açıklayınız.

Cisim **sağa** doğru hareket eder



Cisim **sola** doğru hareket eder.



Cisim hareket etmez.



Öğrenci Numarası: Masa numarası:

2. Aşağıdaki soruyu anlatan kuvvet-hareket modelini çiziniz. Sorunun yanıtını yukarıdaki modellerle açıklayarak belirtiniz.

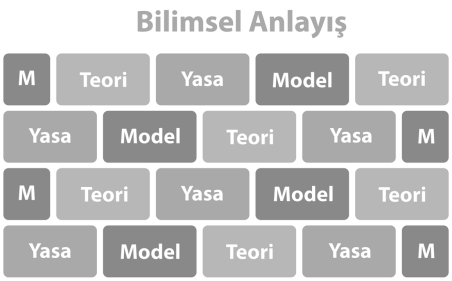
"Durgun bir cisme saga doğru 7 N sola doğru 1 N büyüklüğünde kuvvet uygulanmaktadır. Cisim hangi yöne doğru hareket eder?"

C. Aşağıdaki cümlelerin noktalı yerlerine verilen sözcük veya sözcük gruplarından uygun olanı yazarak cümleyi tamamlayınız. Her sözcük veya sözcük grubu yalnızca bir kez kullanılmalıdır.

Bilimsel bilgi birimi	Teoriler	Yasalar
Modeller	Bilimsel bilgi türleri	

- ……. doğada olan olayları olduğu gibi anlatır.
- ……. doğada olan olayların neden ve nasıl olduğunu açıklar.
- Teori, yasa ve modeller ……. olarak bilinir.
- Teori, yasa ve modeller birlikte …….ni oluşturur.
- ……. benzer olayların sonuçlarını tahmin etmekte kullanılır.

D. Aşağıdaki görsel bilimsel bilgi hakkında ne anlatmaktadır?



APPENDIX G: ACTIVITY 12

Öğrenci Numarası: Masa numarası:

Lesson Plan 12: Friction Force

Grade Level: 5
Unit: F.5.3. Measuring Force and Force of Friction
Curriculum Goal(s):
F.5.3.1.1. Students will be able to give daily life examples related to friction force.
F.5.3.1.2. Students will discover the effect of friction force by testing with different materials. (MEB, 2018a).

RFN learning goals:

- Students will be able to construct a testable hypothesis. (Methods and Methodological Rules)
- Students will be able to determine and manipulate variables. (Methods and Methodological Rules)
- Students will be able to test hypothesis based on obtained data. (Methods and Methodological Rules)
- Students will be able to use reasoning in order to explain the results. (Scientific Practices)
- Students will be able to determine the scientific methods used by reviewing their activities. (Methods and Methodological Rules)
- Students will be able to explain two scientific methods. (Methods and Methodological Rules)
- Students will be able to depict where their activities stand in the scientific methods spectrum. (Methods and Methodological Rules)

Lesson Design: **Part 1:** Determining focus (10 minutes) **Part 2:** Experimentation (30 minutes) **Part 3:** Presenting experiment reports (30 minutes) **Part 4:** Trustworthiness (10 minutes)	**Instructional Techniques:** Whole group discussion Collaborative learning Experimentation Answering questions Reporting **Prerequisite:** None **Lesson Duration:** 120 minutes

Part 1: Determining focus (15 minutes)
The teacher starts the lesson by asking "what were the different types of forces we had mentioned last week?" and brings the discussion to an example which was previously suggested by the students: friction force. She asks what they already know about friction force such as whether it is a contact force or an action-at-a-distance force and where and how can it be observed. Then she declares that today they will investigate friction forces and asks students what they would like to know about it. Even if it is not suggested she poses the question of whether the magnitude of the friction force depends on the surface on which the object is moving. Then she says that we need to make it an appropriate and understandable question before being able to work on it. After some discussion with the students she writes the *research question* they will all investigate on the board:

> Does the magnitude of the friction force acting on a moving object depend on the surface on which the object is moving?

Öğrenci Numarası: Masa numarası:

The teacher introduces the activity sheet and asks students to carefully listen while she gives directions in order to be able to work independently. As they had done before students will work as scientific teams. She reminds that sometimes scientists use hypothesis testing as a method in their studies. In this study they need to use hypothesis testing; therefore, as a team they need to transform the research question into a testable hypothesis. So, the students first write the research question on their sheets and work on it with their team members.

After each team is finished with writing their hypothesis, the teacher explains different kinds of variables with examples. She asks the class what the hypothesis could be according to their research question. Then, students determine their variables according to the research question and hypothesis.

Part 2: Experimentation (25+20 minutes)
With the guidance of the teacher the students set up their inclined planes and conduct their experimentation with different cloths by laying under the inclined plane and measuring the distance the car can travel with each of them. While doing so in order to record the data they have gathered, the students answer questions 1 and 2 of the section B.

The teacher asks what happened to their cars when they have set them free from above the inclined plane. They discuss as a whole class what could be the forces acting upon their cars. Afterwards students discuss with their team and model the forces acting upon their car on the question B3.

The teacher asks random groups what their initial hypothesis was and whether the data they have gathered supported it. Afterwards the students answer questions B4 and B5.

Part 3: Presenting experiment reports (20 minutes)
Each group selects a presenter and then each group present what they have done what was their hypothesis, their results, and whether their hypothesis was supported with evidence. As students present their numbers the teacher graphs them on the board. This way each result presented becomes a data point to eventually see if there is a pattern. If some numbers don't make sense, the teacher asks students what could have been gone wrong so that this false result was obtained. She emphasizes that there is always a possibility of error while having measurements and conducting experiments. Therefore, the scientists should always point out the problems they realize and reflect on the criticism they receive (aims and values of science).

Part 4: Methodology
The teacher starts the day by introducing the scientific methods matrix. She gives positive and negative examples for each testing hypothesis and manipulating variables. Based on the previous days' discussions and activities students determine what scientific methods they have used and answer the questions C1, C2 and C3.

Part 5: Trustworthiness
The teacher creates a conflict by asking "Are all scientific studies reliable?". Then she guides the discussion towards there must be some criteria on which we evaluate the trustworthiness of scientific studies.

You may find activity sheet 12: Friction Force

Öğrenci Numarası: Masa numarası:

Rubric 12

Score / Evaluation Criteria	None (0 Pts)	Partial (2 Pts)	Complete (4 Pts)
Student was able to construct testable hypothesis.			
Student was able to determine the variables which they used in their experiment.			
Student was able to test their hypothesis based with the data they have gathered.			
Student was able to use reasoning in order to explain the results.			
Student was able to determine the scientific methods which they used during the activity.			
Student was able to explain the scientific methods which they used during the activity.			
Student was able to place the activity in the scientific methods matrix in terms of the methods they have used.			
Student was able to give examples of measures taken by scientists to sustain reliability of scientific studies.			
TOTAL SCORE			

Sources: MONE textbook

Activity Sheet for the Experimental Group

Öğrenci Numarası: Masa numarası:

SÜRTÜNME KUVVETİ

A. Günün konusuna göre aşağıdaki soruları yanıtlayınız.

1. Araştırma sorusu
Sınıf tartışması sonucunda ulaşılan ortak araştırma sorusunu aşağıya yazınız.

2. Hipotez
Yazdığınız araştırma sorusuna uygun olarak bu aktivitede test edeceğiniz hipotezi aşağıya yazınız.

3. Kullanılacak olan değişkenler
Kurduğunuz hipotezi test edebilmek için hangi değişkenleri değiştirmeniz gerekiyor?
Bağımlı değişkenler:

Bağımsız değişkenler:

Kontrol edilen değişkenler:

B. Mukavva kıvırarak düzeneğinizi aşağıdaki görseldeki gibi kurunuz. Aracı eğik düzlemin üzerinden serbest bırakınız. Aracın ulaştığı mesafeyi cetvel ile ölçerek tabloya not ediniz. 3 farklı zemin materyali için de aktiviteyi tekrarlayınız.



1. Veri toplama
Arabanın ağırlığını ve farklı yüzeylerde ulaştığı mesafeyi cetvel ile ölçerek aşağıya not ediniz.

Arabanın ağırlığı (N):

	Zımpara Kağıdı	**Havlu**	**Plastik Örtü**
Arabanın aldığı yol (cm)			

Öğrenci Numarası: Masa numarası:

2. Veri inceleme
Araba en uzun yolu hangi zemin üzerinde almıştır?

3. Model
Kurduğunuz düzenekte arabanın üzerine etki eden kuvvetleri aşağıdaki kutucuk üzerinde modelleyiniz.



4. Açıklama
Çalışmanın başında kurduğunuz hipotez doğrulandı mı yanlışlandı mı? Neden?

5. Akıl yürütme
Aracınızın farklı yüzeylerde farklı mesafelere ulaşabilmesinin nedeni nedir?

Arabaya etki eden kuvvetler nelerdir?

Kuvvetlerin araba üzerindeki etkisi nedir?

C. Bilimsel yöntemler
1. Bugünkü aktivitede kullandığınız bilimsel yöntemler aşağıdakilerden hangileridir?

- Hipotez test etme
- Hipotez test etmeden inceleme
- Değişken değiştirme
- Değişken değiştirmeden inceleme

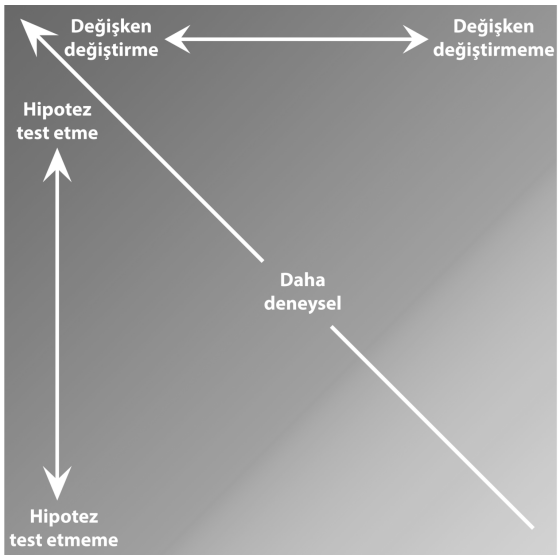
Öğrenci Numarası: Masa numarası:

2. Kullanılan yöntemleri açıklayınız.

-

-

3.Aşağıdaki bilimsel yöntemler görselinde aktivitenin yer alması gereken yeri X ile işaretleyiniz.



D. Bilimin amaç ve değerleri

1. Bilimsel bir deneyin güvenilir olmasını sağlamak için nelere dikkat edilmelidir? <u>En az iki örnek</u> vererek açıklayınız.

Activity Sheet of the Control Group

Öğrenci Numarası: Masa numarası:

SÜRTÜNME KUVVETİ

A. Günün konusuna göre aşağıdaki soruları yanıtlayınız.

1. Araştırma sorusu
Sınıf tartışması sonucunda ulaşılan ortak araştırma sorusunu aşağıya yazınız.

2. Hipotez
Yazdığınız araştırma sorusuna uygun olarak bu aktivitede test edeceğiniz hipotezi aşağıya yazınız.

3. Kullanılacak olan değişkenler
Çalışmada hangi değişkenleri değiştirmeniz gerekiyor?
Bağımlı değişkenler:

Bağımsız değişkenler:

Kontrol edilen değişkenler:

B. Mukavva kıvırarak düzeneğinizi aşağıdaki görseldeki gibi kurunuz. Aracı eğik düzlemin üzerinden serbest bırakınız. Aracın ulaştığı mesafeyi cetvel ile ölçerek tabloya not ediniz. 3 farklı zemin materyali için de aktiviteyi tekrarlayınız.



1. Arabanın ağırlığını ve farklı yüzeylerde ulaştığı mesafeyi cetvel ile ölçerek aşağıya not ediniz.

Arabanın ağırlığı (N):

	Zımpara Kağıdı	**Havlu**	**Plastik Örtü**
Arabanın aldığı yol (cm)			

2.Araba en uzun yolu hangi zemin üzerinde almıştır?

Öğrenci Numarası: Masa numarası:

3. Kurduğunuz düzenekte arabanın üzerine etki eden kuvvetleri aşağıdaki kutucuk üzerinde gösteriniz.



4. Çalışmanın başında kurduğunuz hipotez doğrulandı mı yanlışlandı mı? Neden?

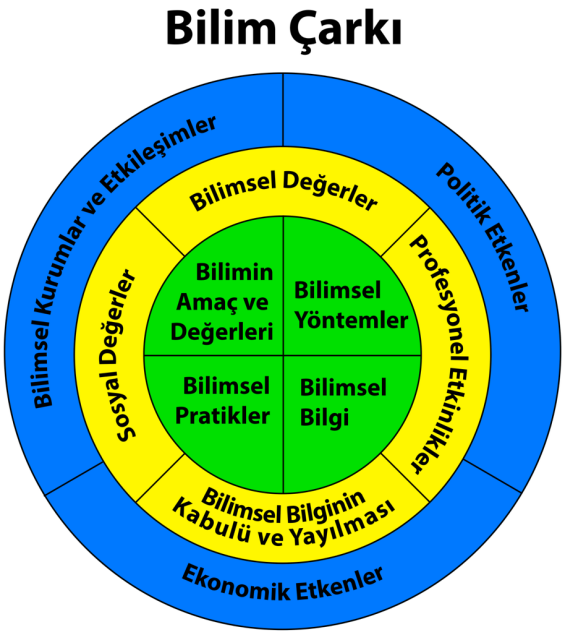
5. Aracınızın farklı yüzeylerde farklı mesafelere ulaşabilmesinin nedeni nedir?

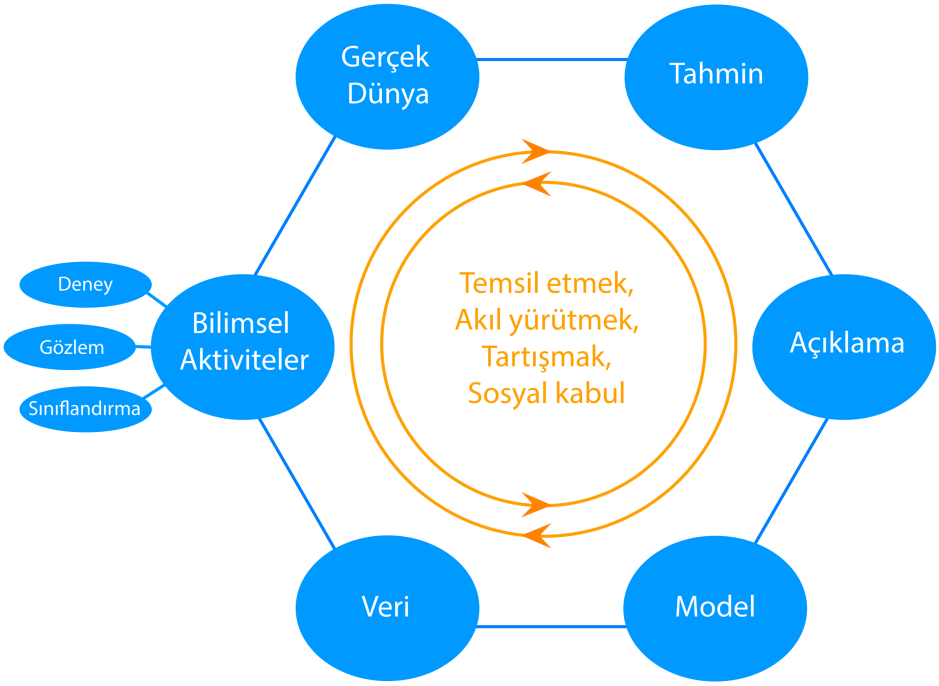
6. Arabaya etki eden kuvvetler nelerdir?

7. Kuvvetlerin araba üzerindeki etkisi nedir?

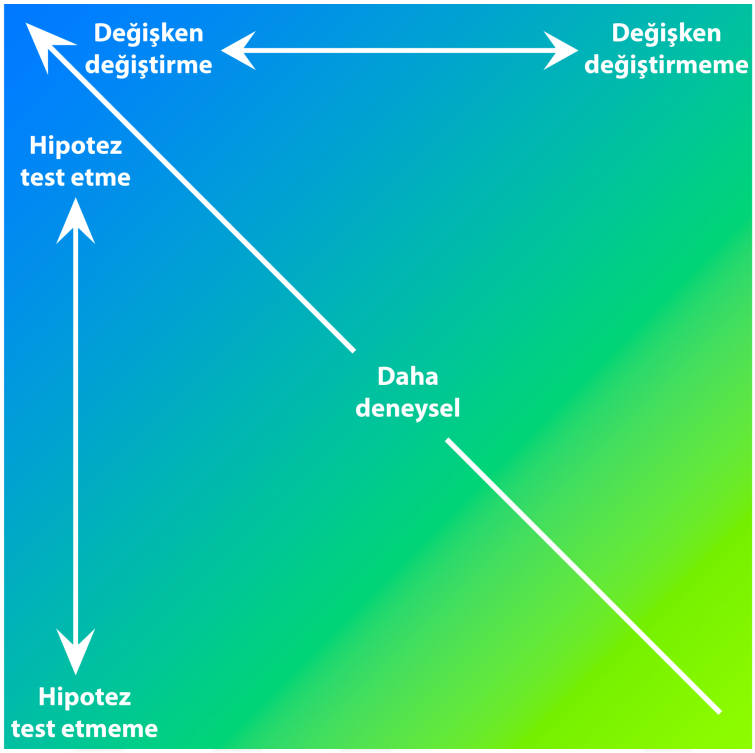
APPENDIX H: ADAPTED VERSIONS OF GENERATIVE IMAGES OF SCIENCE

1. FRA Wheel

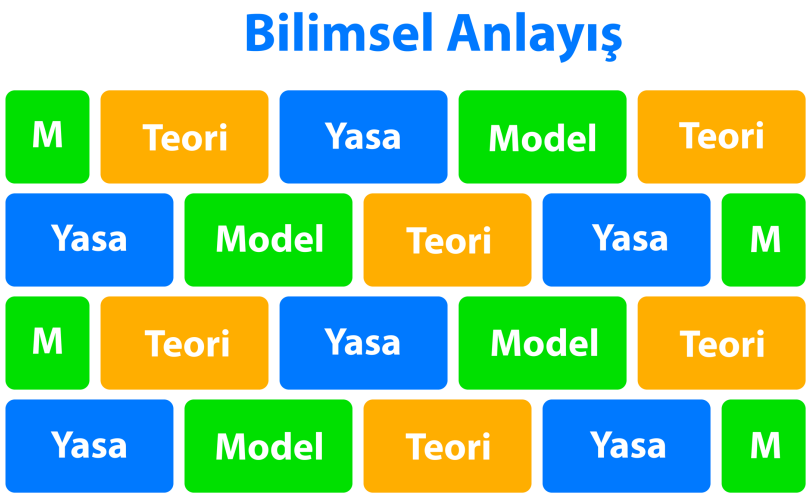




3. Methods and methodological rules of science



4. Scientific Knowledge



5. Social-institutional categories

