INVESTIGATING SCIENCE TEACHERS' VIEWS OF THE NATURE OF SCIENCE BASED ON THE RECONCEPTUALIZED FAMILY RESEMBLANCE APPROACH TO NOS

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ABSTRACT

INVESTIGATING SCIENCE TEACHERS' VIEWS OF THE NATURE OF SCIENCE BASED ON THE RECONCEPTUALIZED FAMILY RESEMBLANCE APPROACH TO NOS

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The purpose of this study is to investigate science teachers' views of the nature of science (NOS) based on the framework of Reconceptualized Family Resemblance Approach to NOS (RFN) (Erduran & Dagher,2014; Kaya & Erduran, 2016b). Using the categories of the RFN framework; aims and values, scientific knowledge, scientific method and methodological rules, scientific practices, social-institutional aspect of science, science teachers' views on NOS, views about RFN integration into their instruction, and views about the curricular emphasis of RFN is investigated. Data were collected from 13 in-service science teachers through semi-structured interviews. Using maximum variation sampling, taking courses or attending seminars about NOS/HOS/POS, reading books about NOS/HOS/POS, and teachers' education level were considered to be able to increase diversity. Interview responses were analyzed using the qualitative content analysis. Results showed that graduate-student teachers showed more informed views regarding NOS. Teachers who had naïve understanding regarding NOS could not provide consistent and meaningful connections from the curriculum. Concerning the NOS integration into their instructions, findings revealed that teachers who had spent more time on NOS tended to include the aspects more than others.

Keywords: Nature of Science, Reconceptualized Family Resemblance Approach to NOS, Science Teachers

ÖZ

FEN BİLİMLERİ ÖĞRETMENLERİNİN BİLİMİN DOĞASI ANLAYIŞLARININ YENİDEN KAVRAMSALLAŞTIRILMIŞ AİLE BENZERLİĞİ YAKLAŞIMI'NA DAYALI BİLİMİN DOĞASI ÇERÇEVESİNDE İNCELENMESİ

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Bu çalışmanın amacı, fen bilimleri öğretmenlerinin bilimin doğasına ilişkin görüşlerini Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımı'na Dayalı Bilimin Doğası (RFN) çerçevesinde incelemektir (Erduran & Dagher, 2014; Kaya & Erduran; 2016b). RFN'nin beş kategorisini kullanılarak, bilimin amaç ve değerleri, bilimsel pratikler, bilimsel bilgi, bilimsel metotlar ve metodolojik kurallar, bilimin sosyal-kurumsal boyutu, fen bilimleri öğretmenlerinin bilimin doğası hakkındaki görüşleri, RFN'nin fen derslerine entegrasyonu hakkındaki görüşleri ve RFN'nin fen bilimleri dersi öğretim programındaki vurgusu hakkındaki görüşleri araştırılmıştır. 13 fen bilimleri öğretmeninden yarı-yapılandırılmış görüşmeler yolu ile veriler toplanmıştır. Maksimum çeşitlilik örneklemesi kullanılması ile, bilimin doğası/bilim tarihi/bilim felsefesi ile ilgili ders veya seminerlere katılmak, bilimin doğası/bilim tarihi/bilim felsefesi ile ilgili kitap okumak ve öğretmenlerin eğitim düzeyi, katılımcı çeşitliliğinin artırılması düşünülmüştür. Görüşme yanıtları, nitel içerik analizi kullanılarak analiz edilmiştir. Sonuçlar, lisansüstü eğitim yapan öğretmenlerin bilimin doğası hakkında daha bilinçli görüşler sergilediklerini göstermiştir. Bilimin doğası ile ilgili yeterli bilgiye sahip olmayan öğretmenlerin fen bilimleri öğretim programında tutarlı ve anlamlı bağlantılar sağlayamadıkları görülmüştür. Fen bilimleri dersine entegrasyonda, bilimin doğası üzerinde daha fazla zaman harcayan öğretmenlerin, derslerine bilimin doğasını diğer öğretmenlerden daha fazla dahil etme eğiliminde oldukları görülmüştür.

Anahtar Kelimeler: Bilimin Doğası, Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımında Bilimin Doğası, Fen Bilimleri Öğretmenleri

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NOS Nature of Science

RFN Reconceptualized Family Resemblance Approach to NOS

CHAPTER 1

INTRODUCTION

Nature of science (NOS) is one of the most debated concepts, yet, its importance shows consilience among and within the sociology, history, and philosophy of science and science education contexts (Irzik & Nola, 2011; Kuhn, 1970; McComas, Clough & Almazroa, 1998; McComas & Olson, 1998;). Teaching science as facts and principles is not the only main focus in science teaching. The center of attention has shifted towards representing science as an endeavor, displaying its limits and social structures, which gave prominence to the NOS in science education research (McComas, Clough & Almazroa, 1998; Schwab, 1958;). Therefore, incorporating the NOS in science curricula documents has become more prominent. While underlining raising students as informed scientific literate individuals, which requires understanding the development, functions, and characteristics of scientific knowledge, the documents emphasized understanding NOS as an important goal and outcome in this respect (AAAS, 1989; Minister of National Education (MONE), 2013; NCCA, 2015; NRC, 1996). Science education studies, documents, and science teaching for over two decades have been mostly based on the consensus view tenets proposed by Abd-El-Khalick, Bell, and Lederman (1998). The consensus view is based on certain aspects that show agreement among researchers about the structure of science and the way scientific knowledge is produced (Chang, Chang, & Tseng, 2010). It frames the nature of science with seven tenets of science, namely empirical nature of the scientific knowledge, the distinction between scientific theories and laws, creative nature of scientific knowledge, theory-laden nature of scientific knowledge, the social and cultural aspect of science, and the myths of scientific methods (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). These tenets have been used as a framework for numerous studies (Abd-El-Khalick &

BouJaoude, 1997; Aslan, 2010; Hacıeminoğlu, 2013; Sarkar & Gomez, 2010; Yakmacı, 1998). In the meantime researchers, criticized its tenets and representation of science and proposed alternative frameworks (e.g., Alchinn, 2011; Erduran & Dagher, 2014; Matthew, 2012). While some researchers advocated that philosophical underpinning should play more role while defining the NOS (Alters, 1997), others focused on how the NOS represented. They promoted that the NOS should be introduced with questions rather than statements to promote discussions (Clough, 2007). Another researcher Yacoubian (2012) criticized the consensus view for being developmentally and practically insufficient. He focused on promoting the critical thinking of the students; hence, considering the developmental process of the content and students' cognitive level, he proposed CT-NOS; critical thinking *about* NOS, and critical thinking *with* NOS (Yacoubian, 2012). Additionally, based on the idea that the consensus view portrays the social aspects of science insufficiently. Alchinn (2011) proposed another view called "Whole Science". The view of Whole Science suggests that the nature of science should also include the uncertainty and errors involved in science (Alchinn, 2011). Criticizing the overemphasis on epistemological considerations, Matthew (2012) drew attention to philosophical considerations that should be included in the structure of the NOS. Thus, he promoted the philosophical, historical, and economic aspects of science together with the social and epistemological depiction of science. He changed the terminology to Features of Science (FOS), attempting to represent a larger view of the nature of science, including mathematization, experimentation, technology, models, feminism etc.

Irzik and Nola (2011; 2014) proposed another framework to NOS that focuses on the epistemic, cognitive, and social system of science and called the "Family Resemblance Approach (FRA)" based on the work of Wittgenstein (1958). They tried to represent the common characteristics of scientific disciplines without excluding their diversity. Later Erduran and Dagher (2014) elaborated the FRA to be included in science education, which also forms the theoretical ground of this study. The last version is proposed by Kaya and Erduran (2016); they reconceptualized the FRA, extended it with pedagogical and instructional intentions, and introduced “Reconceptualized FRA to NOS (RFN)”. The RFN framework intrinsically covers a broader perspective on the aspects of the NOS in a more holistic, flexible, and representative way. It captures both the epistemic-cognitive and social-organizational aspects of science with categories inclusive of aims and values, scientific methods and methodological rules, scientific knowledge, scientific practices, and social-institutional system of science, which contributes to identifying concepts and viewpoints overlooked by the consensus view of the NOS. Thus, the current study is based on the RFN framework, which allows a more comprehensive and detailed investigation of NOS views.

Since raising scientifically literate citizens has implied the importance of being knowledgeable about NOS in the education documents, students were examined whether they have adequate knowledge and understanding of NOS. Most studies showed that students generally do not hold an informed understanding of NOS and have misconceptions regarding scientific knowledge characteristics (Abd-El Khalick, 2002; Dogan, 2011; Lederman, 2007). These results led to investigations focusing on teachers. Some research revealed that teachers’ understanding and interpretation of NOS affect their instruction and practice of NOS in classrooms (Akerson & Hanuscin, 2007; Aslan & Tasar, 2013; Yakmacı, 1998), while others pointed out the opposite claiming that teachers’ views do not necessarily affect their practice (Aslan, 2009; Duschl & Wright, 1989). However, as Hollon, Roth, and Anderson (1991) pointed out “… science teachers must develop knowledge that enables them to make two types of decisions; curricular decisions and instructional decisions” (p. 149). Thus, it is reasonable to say that teachers are obliged to communicate the image of science consistent with the education documents via meaningful discourse effectively. Studies showed that science teachers show either inadequate and naïve understanding of NOS or wrong opinions regarding how science works and scientific knowledge generated (Abd-El Khalick & BouJaoude, 1997; Aslan, Yalcın & Tasar, 2009; Gallagher, 1991; King, 1991). For example, Leden, Hansson, Redfors and Ideland (2015) studied with 12 in-service science teachers and revealed a disparity in teachers' reasoning while talking about the tenets of the NOS and the way they talk about teaching NOS. Thus, it is important to identify the way teachers understand and interpret the NOS before focusing on their practice of NOS in their instruction.

In this regard, to understand teachers' views about NOS, different instruments were developed and applied. The most commonly used ones are Views of Science Test (VOST) developed by Hillis (1975), Test on Understanding Science (TOUS) generated by Cooley and Klopfer (1961), and The Views of Nature of Science (VNOS-C) developed by Lederman and O'Malley (1990). Besides, most measurement instruments consist of Likert-type, multiple-choice, agree/disagree, or open-ended paper and pencil tests. When the structure of the instruments considered, they limit, to a certain degree, the flexibility of both individuals and researchers (Balcı, 2001) and might lead to overlooking the complexity of the opinions (Guerra-Ramos, 2012). Thus, in this study, science teachers' views on NOS were investigated via semi-structured interviews using a qualitative approach to get a deeper understanding from the RFN perspective.

Along with teachers' understanding of the NOS, their views about communicating the NOS in their instruction is another factor to be investigated. There are numerous research showing that teachers do not put enough emphasis on NOS in their planning and teaching due to their poor understanding of the NOS (Duschl & Wright, 1989; Schwartz & Lederman, 2002), lack of confidence (Hacieminoglu, 2014; Leden et al., 2015; Lederman, 1999), believing NOS instruction as unimportant (Aslan & Tasar, 2013; Demirdogen, Hanuscin, Uzuntiryaki-Kondakcı, & Koseoglu, 2015; Duschl & Wrigth,1989), lack of curricular emphasis (Aksöz, 2019; Aslan & Tasar, 2013) and concerns related to the academic level of students (Leden et al. 2015). These studies mostly concern with the teachers' translation of the NOS into their instruction. However, limited studies focused on teachers' opinions of the NOS as a learning object (Hacıeminoğlu, 2014; Leden et al., 2015; Schwartz & Lederman, 2002). Thus, examining teachers' views on NOS teaching along with their views' of NOS would provide to gain teachers' perspectives. This perspective would provide to develop target-driven adjustments and strategies in both pre-service and in-service teacher education programs to promote NOS teaching (Leden et al., 2015).

At this point, it is important to note that it is an undeniable fact that teachers play a critical role as practitioners of the curriculum, which mediates between the content and the practice in teachers' instructions of the NOS. To express differently, teachers' instruction of the NOS is expected to be affected by the curriculum which they are expected to follow. In the literature, the studies examining curricular emphasis of NOS from the RFN perspective (Kaya & Erduran, 2016) revealed that even though the epistemic-cognitive aspect of science, which includes the aims and values, scientific methods and methodological rules, scientific practices, and scientific knowledge categories, was present in Turkish Science Curriculum, social-institutional aspect of science was limited and there was no clear connection among them to depict a holistic and meaningful picture of NOS. Accordingly, while investigating teachers' views on NOS integration into instruction and their views on the curricular emphasis of NOS based on the RFN framework, consistency of their views with the related literature are aimed to be discussed in the current study.

Within this scope, this study is interested in science teachers' views regarding the nature of science, their opinions about integrating the NOS in their teaching practices, and their views on curriculum emphasis of NOS considering the RFN categories.

1.1 Purpose of the Study

The main purpose of this study is to investigate science teacher's views of the nature of science (NOS), integration into their classroom instruction, and their opinions on the curricular emphasis of NOS based on the framework of reconceptualized family resemblance approach (RFN). Aiming to examine the mentioned points, in this research, the following research questions were investigated:

1. What are the science teachers' views about the NOS based on RFN?

2. What are science teachers' views about the curricular emphasis of RFN?

3. What are the science teachers' views about RFN integration into their instruction?

1.2 Significance of the Study

Teaching and learning the nature of science enhance informed decision making and understanding of science (Driver, Leach, Miller & Scott, 1996; Mccomas, Clough, & Almazroa; 1998), and instructional delivery as well (Matthews, 2014). More specifically, Vazquez-Alonso, Garcia-Carmona, Manassero-Mas, and Bennassar-Roing (2013) point out that the teachers' understanding of the nature of science not only affects their process of decision making regarding introducing the curriculum but also their instructions in the class. Thus, it is deemed necessary that teachers should possess an adequate understanding of the NOS, and how NOS can be integrated into their instructional practices.

Furthermore, the newly introduced framework, RFN, has been shown to provide a comprehensive analysis of the nature of science. The RFN framework not only incorporates the criticisms, discussions, and suggestions brought about the NOS, but also proposes highly inclusive, coherent, and holistic categories embracing epistemic-cognitive and social institutional dimensions to depict characteristics of science that can be employed in both educational practice and research area.

Formulating categories as aims and values, scientific practices, scientific knowledge, methods and methodological rules, and social-institutional aspects of science enables the framework to be utilized as analytical research and conceptual tool (Kaya & Erduran, 2016b). For policymakers and researchers, it provides an organized approach to be able to point out the underemphasized and discrepant components that can be improved for the representation of the nature of science in the curriculum and textbook revisions, as well as in the preparations of pre-service and in-service teacher education programs (Park, Wu, & Erduran, 2020). Additionally, the way the framework organized serves as a pedagogical guideline that enables teachers the flexibility to communicate the relevant conceptions from any category to the content and the level of students (Dagher & Erduran, 2016).

In the literature, the RFN framework mostly studied with pre-service teachers (Kaya, 2019), university students (Akgün, 2018; Erduran, Mugaloglu, Kaya, Saribas, Ceyhan & Dagher, 2016; Erduran et al., 2021), and science teachers' understanding of two aspects of RFN which are aims and values and social-institutional system (Aksöz, 2019). Thus, studying with science teachers focusing on all aspects of RFN is believed to be a considerable contribution to science education research, and would provide certain implications for teacher education programs. Investigating teachers' views of NOS based on the RFN framework is believed to shed light on where the intervention is needed and what to focus on in NOS learning and teaching. Additionally, communicating teachers' reflections on NOS integration into their instruction as a learning objective and understanding their rationales regarding NOS teaching would provide significant guidance in the course and curriculum development in order to meet the needs of science teachers. Additionally, there is a gap in the literature concerning focusing on teachers' views regarding curricular emphasis of the NOS. The conducted studies mainly investigate teachers' opinions about the science education program; its content, objectives, applicability etc. (Çıray, 2015; Karaman & Karaman, 2016; Saraç & Yıldırım, 2019). Hence getting teachers' views on the NOS inclusion in the curriculum would enable to see from teachers' perspective to be able to make fruitful revisions in the curriculum regarding NOS teaching for policymakers.

Overall, this study contributes to the analysis of teachers' views regarding NOS understanding, integration, and curriculum emphasis from the RFN framework. Through applying the RFN framework, it is believed to be made a contribution to a more comprehensive NOS analysis, meaning teachers' views about the NOS can be analyzed through the perspectives of aims and values, scientific knowledge, scientific methods, scientific practices, and socio-institutional aspect of science individually, and can portray a more profound, meaningful and holistic view of NOS. It can be said that RFN can be used both shows that RFN can be used as both analytical and conceptual means for developing curriculum and education programs (Kaya & Erduran, 2016).

1.3 Definition of Key Terms

Nature of science (NOS): Erduran and Dagher's framework defines science with regard to cognitive-epistemic and social-institutional systems (Erduran & Dagher, 2014).

Reconceptualized Family Resemblance Approach to NOS (RFN): "Science is a cognitive and social system whose investigative activities have a number of aims that it tries to achieve with the help of its methodologies, methodological rules, system of knowledge certification and dissemination in line with its institutional social-ethical norms, and when successful, ultimately produces knowledge and serves society." (Irzik & Nola, 2011)

CHAPTER 2

LITERATURE REVIEW

In this chapter researches related to this study were provided. Firstly, literature regarding how the nature of science is constructed, and its various definitions were provided. Later the framework of RFN which formed the structure of this study was explained. In the third part, a general insight into the measurements of NOS understanding is provided. In the next part, studies investigating teachers' understanding of NOS are reviewed. In the fifth part, studies analyzing science curriculum with respect to NOS and RFN frameworks are presented. In the last part, researches focusing on teachers' views on integrating NOS in their practices are examined.

2.1 Nature of Science (NOS)

Development of an adequate nature of science understanding is a fundamental component of scientific literacy (AAAS, 1990; Klopfer, 1960; Lederman, 2007) which has been one of the major aims of science education and curricular reforms (AAAS, 1993; MONE, 2013; NRC, 1996). Accordingly, the inclusion of the nature of science in science education programs has been argued as necessary and important by many researchers. Actually, apart from being considered as an important factor for scientific literacy (Bell & Lederman, 2003; Driver et al., 1996; Hodson, 1999 Sadler & Zeidler, 2005), it is deemed as a facilitator for comprehending scientific content (McComes et al., 1998) and as a trigger to students interest toward science (Matthews, 1989).

Diverse groups of scholars have given the nature of science many definitions. McComas, Clough, and Almazroa (1998) describe the nature of science as an area that combines different disciplines which yield a descriptive image of "what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors" (McComas et al., 1998, p.4). Later extending his previous definition Lederman (2007) defined NOS as "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (p.833). These descriptions of NOS are the most accepted ones characterizing what nature of science should comprise in science education (McComas & Nouri, 2016).

Intrinsically, the nature of science communicates different disciplines that investigate scientific endeavors such as philosophy and the history of science. Reviewing various education documents McComas and Olson (1998) deduced that four major disciplines, which are philosophy, psychology, history, and sociology of science, contribute to insight and understanding of the nature of science. Through the years, the definition of the nature of science has been given diverse interpretations, consequently, the concept has become extensive and gained a broader perspective. McComas and Olson (1998) agreed with other researchers that on all parts, there is no convergence about the explanation for the structure of science or the way scientific knowledge is produced (Duschl, 1994; Lederman, 1992). According to the literature review by Chang, Chang, and Tseng (2010) on the nature of science, the research trend between 1990 and 2007 tend to reveal an agreement on some set of the NOS aspects referred to as "consensus view" (Abd-El Khalick, Bell, & Lederman 1998; Gallagher, 1991; Lederman, 1992). Even though there was no total agreement about what should be included as curricular content delineating science, consensus on the objectives of developing an adequate understanding of the nature of science, emphasis on scientific process and inquiry led to consensus view which gained progressive attention in research areas and included in science education standards and programs. Additionally, some authors pointed out that more agreement exists considering the basic aspects rather than conflict (Smith, Lederman, Randy, Bell, McCommas, & Clough, 1997). Proponents of the consensus view framework (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Ackerson, 2004; Lederman, 2004) noted that disagreement among philosophers, science educators, and historians on the meaning of NOS is not relevant to K-12 instruction given the complex and dynamic feature of scientific endeavor.

The consensus view puts emphasis on seven aspects considered as representative of science and appropriate to include in science education (Abd-El-Khalick, Bell & Lederman, 1998). These aspects are: “empirical nature of scientific knowledge”, “scientific theories and laws”, creative nature of scientific knowledge”, “theory-laden nature of scientific knowledge”, “social and cultural embeddedness of scientific knowledge”, “myth of the scientific method”, “tentative nature of scientific knowledge” (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

Empirical nature of science: Differences between observation and inferences should be recognized. When the natural phenomena can be measured by the senses, it can be stated as observation, while inferences are simply described as the statements that are not assessable to the senses, yet described through the impacts of the phenomena.

Distinction between theories and laws: Individuals tend to think that there is a hierarchical relation between laws and theories: according to these individuals, with enough evidence, theories become laws, and laws are more certain entities than theories and cannot be changed. Theories and laws are two distinct types of scientific knowledge. Laws are statements that describe the relation between observable natural phenomena. On the other hand, theories are well-substantiated, established explanations

Creative nature of scientific knowledge: Science is affected by scientists’ creativity and imagination along with its rational and logical thought processes.

*The theory-laden nature of scientific knowledge: S*cience is affected by the prior knowledge, beliefs, and experiences of the scientist.

Social and cultural effects in science: Science is a human-based enterprise, influenced by the context in which it is practiced.

Scientific method: There is no universal, one-way recipe-like method that is used by all science disciplines.

Tentativeness of scientific knowledge: Although scientific knowledge is reliable and empirically based, it is not absolute, is subject to change.

The consensus view of NOS has been a subject of major empirical studies in science education, however, there are various proposals and criticism regarding the elements and representation of it. For example, some authors (Abd-El-Khalick, 2001; Flick & Lederman, 2004; Hanuscin et al., 2006; Lederman, 2006) advocated differentiating scientific knowledge and scientific inquiry (SI) for epistemological considerations as well to eliminate confusion. Scientific inquiry (SI) is defined as the activities scientists engaged in during their research, such as collecting and analyzing data, observing and inferring while nature of scientific knowledge (NOSK) refers to the epistemological structure of the activities and the acquired knowledge (Lederman, 2007). In line with this idea, Lederman (2007) suggested either the use of nature of scientific knowledge (NOSK) instead of the nature of science or implying NOSK while referring to NOS. Underlying NOS and SI are closely related yet different. On the other hand, Grandy and Duschl (2007) argued that inquiry is an inseparable part of NOS thus, they should not be left out.

As stated by, Erduran, Grandy, and Rudolph (2006), a multidisciplinary approach contributed to the development of scientific knowledge. Likewise, it can help to develop and diversify NOS perspectives (Duschl et al., 2006). In addition, Alters (1997) (based on the findings of his research with 418 members of Philosophy of Science Association) believed that philosophers of science are the authorities and their opinions should be taken into consideration while determining tenets of NOS and finding out more about the philosophical underpinning. Actually, the results of the study showed that there was serious criticism of tenets of NOS that science education researchers advocated. Also, philosophers expressed diverse opinions regarding criteria for NOS. He underlined reconsideration of new criteria to represent science and NOS tenets. On the other hand, Efflin et al. (1999) expressed concern regarding Alters' study that there was some basic consensus on tenets among science educators and philosophers of science, and in his study, he blurred this line and poorly delineated the philosophical issues that are argumentative with the tenets. Attempting to elaborate these concerns, Osborne, Collins, Ratcliffe, Millar, and Duschl (2003) conducted a Delphi study aiming to assess experimentally to what degree agreement exists among 23 international leading and acknowledged experts of science educators, scientists from different disciplines, and philosophers.

Along with varying views, there was a great deal of convergence of opinions on the nine themes to include in the science curriculum: scientific method and critical testing, creativity, the historical development of scientific knowledge, science and questioning diversity of scientific thinking, analysis, and interpretation of data, science, and certainty, hypothesis and prediction, cooperation and collaboration. These themes show a high resemblance with the principles McComas and Olson (1998) highlighted in their analysis of science education documents and with the tenets that Lederman et al. (2002) provided. However, Yacoubian (2012) criticized Osborne et al.'s study that the experts in the study do not represent the views of the chosen disciplines regarding NOS.

Clough (2007) considered the consensus view from a different angle, suggesting investigation of the tenets as questions rather than statements. He argued that by reducing the characteristics of the nature of science to tenets, it is highly likely to be misrepresented by teachers, students, and even by researchers. The matter of concern here is that tenets may be perceived as declarative statements to be taught while they should be explored as questions to promote discussions to be investigated and engaged with the contextual structure of it.

Another researcher Yacoubian (2012) criticized the consensus view of NOS for being ambiguous about the diverse goals it tends to achieve; not clear representation of the content and its developmental process, and not portraying developmental course through different levels. More specifically, major concerns about consensus views of NOS included followings: Consensus view 1) has ambiguity concerning the application of NOS-related ideas to a variety of ends, 2) does not provide a clear representation of the content and its developmental process 3) does not developmentally match to students cognitive level at different grades (p.28). In response to this, he proposed an alternative aspect to address NOS by creating a developmentally appropriate framework using critical thinking; CT-NOS. His purpose was to provide NOS curriculum based on this framework, to engage critical thinking in students' learning NOS in school science. The framework is substantially based on contributing to both "critical thinking *about* NOS" which promotes NOS understanding and "critical thinking *with* NOS" which promotes decision making in socio-scientific issues.

From another point of view, Allchin (2011) drew attention to the ability of interpreting and analyzing the reliability of science and scientific claims rather than the content knowledge of science. The reason was that in practice the ideal depiction of what scientists ought to do does not correspond with how scientists produce and establish reliable claims. The path is not error-free. Thus, he pointed out the significance of students to understand the uncertainty and errors in science (Allchin, 2012). He argued that consensus view NOS does not include the issues related to the social characteristic of science such as gender issue, peer review, fraud or misconduct, funding etc. He reframed NOS to include various dimensions and introduced Whole Science (Alchinn, 2011). Furthermore, Grandy and Duschl (2011) asserted that contemporary NOS descriptions do not underpin the logical practices forming the basis for the role of theory, explanation, models, and evidence. They suggested broadening tenets via incorporating epistemic and social structures to become more than conceptual learning (Grandy & Duschl, 2007). Kampourakis (2014) reviewed Allchin's study and said his work does not provide much how to assess NOS views since it is not empirically tested.

Addressing to expand the comprehensiveness and making subtler the emphasis on epistemological attention of the consensus view of NOS, Matthews (2012) suggested changing the terminology of NOS to features of science (FOS). He promoted tenets to be more immersed with philosophy and history of science along with the epistemological and sociological emphasis. The additional issues he proposed to include are experimentation, idealization, models, values and socio-scientific issues, mathematization, realism and constructivism, technology, feminism, religion and world views, explanation, and theory choice and rationality (Matthews, 2012) . This depicts a picture of science from two different views one is epistemological and the other philosophical. According to Dagher and Erduran (2016), Matthews did not provide a comprehensive explanation about the features he proposed which also did not present a consistent perspective.

Apart from the abovementioned considerations, Irzik and Nola (2011) criticized the consensus view as being indifferent to diversity among scientific disciplines, lacking systematic unity, and presenting science from a limited perspective. Embracing the previous discussions and incorporating epistemic-cognitive and socio-institutional aspects of science, they introduced and justified an alternative approach based on the idea of Wittgenstein's family resemblance. Erduran and Dagher (2014) reconceptualized the family resemblance approach to NOS (RFN) and adopted it to science education aiming to improve students' understanding of science via accommodating epistemic, cognitive, and socio-institutional aspects of science. Dagher and Erduran's (2017) proposal incorporates RFN with the preceding NOS approaches. RFN framework includes all proposed aspects, such as it covers Allchin's (2011) concerns about scientific aims and values, and socio-scientific aspects, and incorporates Mathews' (2012) proposal, with the exception of its philosophical positions such as feminism, constructivism, and the like. In essence, RFN introduces a broader, holistic, and descriptive view to NOS including previous frameworks, and expanding with additional stances herewith contributing to metalevel understanding of NOS.

In the following, the recent and comprehensive proposal to characterize NOS is elaborated. In this respect, reconceptualized family resemblance approach to NOS (RFN) established the theoretical base of the study.

2.2 Reconceptualized Family Resemblance Approach to Nature of Science (RFN)

The family resemblance approach is adopted from the work of Irzik and Nola's (2011, 2014) framework and reconceptualized by science educators Erduran & Dagher (2014). Erduran and Dagher (2014) expanded and elaborated the FRA notion and applied it to science education with educational and instructional intentions. Later Kaya and Erduran (2016b) integrated the curricular and educational utilizations and produced the notion of "Reconceptualized FRA-to-NOS" (RFN).

Initially, Irzik and Nola (2011) employed the idea of family resemblance from the work of Wittgenstein. Wittgenstein claimed that giving definitions based on sufficient conditions or defining the fundamental natures does not yield substantive definitions of concepts or terms (Wittgenstein 1958, sections 66-71). He illustrates this condition with the example of "game". There are different kinds of games such as games played with cards, with balls, or just with people no additional items such as hide-and-seek. They all have different kinds of rules or characteristics. For example, when playing tennis and child's throwing a ball to a wall are compared, the latter does not involve winning or losing. Even though they are played with balls some rules do not apply to both, and likewise, when groups of games are reviewed, some resemblances can show up or disappear. What is depicted here is the web of complex similarities that are criss-crossing and overlapping. Wittgenstein asserted that games form a "family resemblance". It is the certain common characteristics and resemblances that justify the term of game applying all the different activities. With the family resemblance analogy, he claims that to define a term or a concept, the similarities, common features, and essences can be used.

In the light of this rationale, Irzik and Nola (2014) employ this approach to describe science. They prefer to ask the question of in what ways the disciplines of science are similar or dissimilar. They identify science regarding epistemic-cognitive and social systems. Epistemic-cognitive system of science refers to the process of inquiry, aims and values, methods and methodological rules, and scientific knowledge. And the social system of science refers to professional activities, scientific ethos, social certification, and dissemination of scientific knowledge and social values. With this categorization, they provided explanations for the unity of scientific disciplines without sacrificing their diversity. Thereafter Erduran & Dagher (2014) reconceptualized and expanded the family resemblance approach (FRA) to achieve educational and curricular ends and categorized the dimension of science as epistemic-cognitive aspects and socio-institutional aspects of science. They extended the depiction of Irzik and Nola's FRA by adding 3 more categories into socio-institutional systems which are social organizations and interactions, political power structures, and financial systems, which are considered critical for the science curriculum. They also developed a holistic model of the "FRA Wheel" (Figure 1.) depicting science as a cognitive-epistemic and socio-institutional system. At the center of the wheel following categories aims and values, methods and methodological rules, scientific knowledge, and scientific practices reflect the epistemic-cognitive aspect. In the outer circles, social values, scientific ethos, professional activities, social certification and dissemination, social organizations and interactions, political power structures, and financial systems delineated with dashed lines reflect the social-institutional aspect of science.

Figure 1. FRA Wheel: Science as a Cognitive-Epistemic and Social-institutional System

Erduran & Dagher (2014) p.28

Additionally, they produced generative images regarding each component of the framework. With the graphic representation, they provided a great deal of depiction to the interrelated, holistic, and visual account of reconceptualized family resembles approach to nature of science (RFN). In the following, each category of the RFN is elucidated.

2.2.1 Aims and Values of Science

Erduran and Dagher (2014) adapt epistemic, cognitive, cultural, social, and political aims and values that are inherent in science to ease inclusion in science teaching and learning. Even though it is hard to separate social and cultural values from epistemic-cognitive values it is intended for educational ends. They are in agreement with Longino (1995) and Allchin (1999) pertaining to diversity of values since they significantly contribute to the growth of scientific knowledge. Epistemic-cognitive aims and values are described in terms of objectivity, critical examination, novelty, empirical adequacy, and accuracy. Social aims and values of science reflect the equality of intellectual authority, honesty, human needs, and decentralizing power. Also, the cultural and political dimensions can be viewed in social aspects. Erduran and Dagher (2014)'s conceptualization of scientific aims and values through epistemic and cognitive aspects is visualized with a triangle whereby each corner represents the range of values including epistemic-cognitive and social values. Since aims and values are inseparable the boundaries between them showed with vague and continued structure. Also, they signify that morality and ethical concerns are not in the realm of aims of science because of the fact that they consider aims as a cognitive matter not moral. Irzik and Nola (2011) expressed that they describe how scientists ought to behave not how they do, meaning science as an endeavor does not address ethical and moral issues. They elaborate these issues in the social-institutional aspects of science.

2.2.2 Scientific Practices

Scientific practices or, in other terms, science as a practice used by philosophers of science to indicate scientists' endeavors during producing and communicating knowledge (Longino, 2002) Erduran and Dagher (2014) focused on three activities as examples of scientific practices which are experimentation, observation, and classification on which science curricula place significant emphasis. Nevertheless, these practices do not contribute enough to the epistemic development of scientific knowledge. Seeking to correlate these activities that are also conceptualized as scientific practices with epistemic, cognitive, and social-institutional aspects of science authors proposed a model. In this way, pedagogical and conceptual coherence can be maintained. And so this model can be used as a guiding instructional tool. The authors made use of the structure and the links of the benzene ring model to illustrate the heuristic. Epistemic and cognitive aspects of scientific practices are represented in terms of carbons which are prediction, explanation, model, data, activities, and the real world. The electron cloud around the carbons is illustrated with the social aspect of scientific practices which are representation, reasoning, discourse, and social certification. With this heuristic, the interrelatedness of epistemic and cognitive dimensions and the influence of social dimensions of science on scientific practices are synthesized and represented in a holistic manner. Besides, the interaction of process skills within and relative to each other is shown (Erduran & Dagher, 2014). The proposed model also enables science educators a pedagogical tool to utilize in lessons (Kaya & Erduran, 2016b).

2.2.3 Methods and Methodological Rules

Alongside the emphasis on collecting empirical evidence in science, it is of fundamental importance to understand what methods and approaches scientists use and what kind of methodological rules go by as they gather data. There is a common representation of scientific method proceeding step by step in science education which begins with asking questions, doing background research, then forming a hypothesis and testing this hypothesis by experimentation, analyzing data, drawing a conclusion, and finally reporting results. This depiction is highly criticized by many scholars due to its problematic and misleading structure and content. It causes students to misunderstand the practices and content of the discipline from the epistemic point of view (Windschilt, Thompson, & Braaten, 2008), purports a single recipe-like method that all science disciplines use overlooking the diversity of methods (Erduran & Dagher, 2014), hence, leading on to students' rejection of some studies and theories or assessing them as less or no scientific because they skip or do not use some of the steps (Dagher & BouJaoude, 2005).

Erduran and Dagher (2014) try to use the evidential and explanatory consilience as a basis to provide a broader theoretical structure for scientific methods and methodological rules. In order to represent the diversity of methods, authors (2014) described experimental and observational types of methods in terms of manipulative, non-manipulative, hypothesis testing, and non-hypothesis testing methods. They also demonstrated gears image to visualize the different methods

Through this model, it is shown that how different methods work together to yield diverse evidences and so explanatory consilience. The proposed perspective also contributes to exploring domain-specific and domain-general features of scientific disciplines through illuminating the similarities and differences among disciplines and the ways they validate their claims. As students are encouraged to design investigations, asking different questions that scientists employed, they would start to acknowledge that methods differ from one another within different domains (Erduran & Dagher, 2014).

2.2.4 Scientific Knowledge

Theories, laws, and models are the forms of scientific knowledge work coherently to develop scientific explanations and thus contribute to the growth of scientific knowledge (Erduran & Dagher,2014; Gierre 1991). Erduran and Dagher (2014) articulated the mechanism of theories, laws, and models (TLM) to signify the domain specificity, explanatory pluralism, and the relations among the types of knowledge that lead to scientific understanding. The mechanism works analogues to Kuhn's (1970) notion of paradigm shift. Such that when there is an inconvenience with the existing law, theory, or a model the new can be presented, leading to transformations of the paradigm. For instance, biological traits of living organisms are described via genetic theory, inheritance laws, and the concept of genes (Erduran & Dagher, 2014). In this way, a particular phenomenon is provided with an explanation through different forms of knowledge. Explanations contribute to unification among TLM components (McCain, 2015). Erduran and Dagher (2014) provide a model depicting the TLM framework in a knowledge growth growing into scientific understanding.

With this framework of TLM, they also underline the domain-specific characteristics of scientific knowledge which appreciates the functions of theories, models, and laws vary in different disciplines of science (Christie & Christie, 2000; Gierre, 1999).

2.2.5 Social-institutional System of Science

To promote science as a holistic and realistic account, not only the epistemic-cognitive but also the social-institutional system of science should be considered. Also, Kuhn (1970) argues that social factors affect the interpretation of evidence and hence scientific thinking (as cited in Elby and Hammer, 2000). Irzik and Nola (2014) provided four components of social categories which are professional activities, social certification, and dissemination, social values, and scientific ethos. Erduran and Dagher (2014) extended the social-institutional representation of science by adding there more categories underpinning the governmental, political and economic (e.g. Erduran & Mugaloglu, 2012) relations, which are social organizations and interactions, political power structures, and financial systems. In an effort to visualize these categorize in a united manner, they proposed a visual which includes two circles, one within the other. The inner circle referred to as core features comprise scientific ethos, professional activities, social certification and dissemination, and social values. The outer ring includes broader features, which concern the larger society, includes social organizations and interactions, political power structures, and financial systems. Scientific ethos is the norms and values scientists ought to abide by during their scientific activities and with their colleagues and provide institutional context (Irzik & Nola, 2014; Merton, 1973). Also, Resnik's norms (Resnik, 2007) shed light on ethical conducts such as social responsibility, intellectual honesty, respect for the environment, non-discrimination, confidentiality etc. Professional activities indicate the scientists' engagement other than producing knowledge, such as attending conferences and academic meetings, presenting research and publishing papers, searching for funding, writing a proposal, and such (Irzik & Nola,2014). Social certification and dissemination of scientific knowledge establish social quality and epistemic control through presenting scientists' works and products to large communities to be reviewed and criticized (Kitcher, 2011). Social values of science embody freedom, social utility, and respect for the environment (Erduran & Dagher, 2014). Apart from these four categories that Irzik and Nola proposed, Erduran and Dagher (2014) added three more aspects to include perspectives from different cultural studies such as anthropology, economics, sociology, politics. Social organizations and interactions imply the socially organized institutions such as universities, research centers, and industrial sites where scientists work and interact with each other (Erduran & Dagher, 2014). Political power structures draw attention to the relation between the governments and states, their interests, race, and gender views with science and technology. The financial systems, lastly, provide insight into the economical dynamics between the universities and research organizations with the governments and states which are the sources of funding that facilitate investigations and studies of scientists.

2.3 Measurement of NOS

For a long period of time, the nature of science has been advocated as an important objective in science education, which also contributed to the development of various types of assessment tools to investigate NOS views. Instruments developed for and/or applied to teachers to assess different dimensions of NOS are presented in Table 2. As shown in the table, the early assessments of NOS dated back around 1960's and have been mostly quantitative including Likert-type, agree/disagree, multiple-choice questionnaires carried out with paper and pencil. Later to attain a deeper understanding of individuals thinking, open-ended questions and interviews were included in the assessment process.

Table 2. Instruments developed to measure teachers' understanding of NOS

Table 2. (Cont'd)

Author(s)	**Instrument**	**Instrument type**	**Measured aspects**
Cooley and Klopfer (1961)	Test on Understanding Science (TOUS)	Multiple choice	Scientific enterprise, scientists, methods, and aims of science
Welch (1967)	Science Process Inventory (SPI)	Agree/disagree	Activities, assumptions, products, and ethics of science
Kimball (1968)	Nature of Science Scale (NOSS)	Agree/disagree	8 characteristics of science: curiosity, process, and orientation, comprehensivene

Table 2 (Cont'd)

			ss and simplicity, scientific method, values of science, human endeavor, dynamic and tentativeness
Billeh and Hasan (1975)	Nature of Science Test (NOST)	Multiple choice	Product, process, ethics, and assumptions of science
Hillis (1975)	Views of Science Test (VOST)	Likert type	Tentativeness of scientific knowledge
Cotham and Smith (1981)	Conception of Scientific Theories Test (COST)	Likert-type	Aspects of scientific theory

Table 2. (Cont'd)

Ogunniyi (1982)	Language of Science (LOS)	Agree-disagree and optional written answer	Scientific knowledge, scientific method, scientific enterprise, and work of scientists
Nott and Wellington (1995)	Critical Incidents	Responding to critical scenarios of classroom events	Tentativeness, theory-laden of NOS, social aspects of science

Table 2 (Cont'd)

Abd-El-Khalick (1998)	Views of the Nature of Science Questionnaire (VNOS C)	Open-ended questions	NOS aspects, social aspect of science, universal scientific method
Lederman and Khishfe (2002)	Views of Nature of Science D (VNOS-D)	Open-ended	Creative, tentative, empirical, and theory laden NOS
Buaraphan and Sung-Ong (2009)	Myths of Science Questionnaire (MOSQ)	Likert-type	Creative, tentative, hypothesis-law-theory, scientific method, science, and technology Nature of science and scientific inquiry
Bartos and Lederman (2014)	Knowledge Structure of Nature of Science and Scientific Inquiry (KS4NS)	Likert-type	Nature of science and scientific inquiry
Özgelen (2012)	Nature of Science Scale	Likert-type	Characteristics of science and scientists, tentativeness, subjectivity and technology, social

Table 2 (Cont'd)

	and cultural structure, theories

In the literature TOUS, VOSTS, and VNOS-C are the most commonly used instruments to measure individuals' understanding of NOS. Test on Understanding Science (TOUS) was generated by Cooley and Klopfer (1961). It is a multiple-choice test consisting of three subscales measuring understanding of scientific enterprise, scientist, and methods and aims of science. Views of Science Test (VOST) is a likert-type questionnaire developed by Hillis (1975) focusing on the understanding tentativeness of scientific knowledge. The Views of Nature of Science Questionnaire (VNOS-C) was developed by Lederman and O'Malley (1990). The test includes seven tenets of NOS assessed with open-ended questions and designed to use subsequent to questionnaires mostly applied to teachers.

Likert-type instruments are the most commonly used tools in studies. It is so, because it is easier to develop, apply, and it enables accessibility to larger samples (Tavsancıl, 2005); it also saves money and time to the researcher, as well as it provides a more accurate assessment of the overall responses (Allen, 2017). On the other hand, these quantitative research techniques impose a certain limitation to the research such that it does not offer individuals flexibility while answering, s/he is limited with the given ideas (Balcı, 2001; Lavrakas, 2008). It introduces a guess, and it is assumed that the individual and the researcher have the same understanding of the statement (Aikenhead, 1988). In fact, Lederman and O'Malley's (1990) study showed trouble with the paper and pencil assessment. They found a contradiction between the interpretation they made based on the student's answers on paper and the interpretation came out during interviews with the students. Thus, Lederman, Wade, and Bell (1998) suggested using a more qualitative and open-ended approach in assessing individuals' conception of NOS to get a more explicit picture and allow participants to express and elaborate their ideas as well as to prevent the researcher from misinterpretation. Guerra-Ramos (2012) asserts that the complexity of ideas that individuals possess is overlooked when they are reduced to scores, dis/agreeing certain statements, or selecting some choices.

2.4 Teachers' Views about NOS

Emphasis on raising scientific literate students led education reformists and researchers to develop more interest and put importance on the nature of science in programs and curricula as an educational goal (Abd-El-Khalick, 2012; Lederman, 2007; Yeh, Erduran, & Hsu, 2019). Thus, NOS has been a subject of research for investigating students' understanding of NOS (Hogan, 2000; Lederman & O'mally, 1990). When studies with students' understanding of NOS yielded unsatisfactory results, researchers attempted to test curricula. Later, they saw that depending on the teachers, results varied and realized that teachers are at the center of the mediators of practicing curricula (Abd-El-Khalick & Lederman, 2000; Brown & Clarke, 1960). Accordingly, studies indicate teachers should have an 'adequate' conception to convey it to the students (Abd-El Khalick & Lederman, 2000; Ball & McDiarmid 1990; Zeidler & Lederman, 1989). Though, there is no consensus on whether teachers' understanding of NOS directly impacts their teaching and their students' understanding or their classroom practice (Lederman, 2007).

However, the nature of science is an inevitable part of science education and even though teachers do not attempt or aim to teach, it is conveyed in teacher language, textbooks etc. (Abd-El-Khalick 2012; Ryder & Leach, 2008;), plus these can draw superficial and limited portray of science (Vesterinen Aksela, & Lavonen,2013). The most studied research line is whether there is a relation between the science teachers' understanding of NOS and their classroom practice. There are studies suggesting that NOS views affect classroom practices (King, 1991; Brickhouse, 1990). At the same time there are positions asserting no such influence (Aslan & Taşar, 2013; Duschl & Wright 1989; Lederman & Zeidler, 1987). In this section, studies enhancing or investigating the relationship between the teachers' understanding of NOS and their classroom practices are excluded, and within the scope of the study, the emphasis is given to the studies examining teachers' NOS views:

In an early study, Miller (1963) compared biology teachers' and secondary students understanding of NOS by using TOUS scores. He found out that 25% of science teachers scored less on TOUS than students ranging from 9th-12th grades, which means teachers understand science not so much better than students and not even enough to teach it effectively. Four years later, Schmidt (1967) repeated Miller's study with a smaller sample, and the study yielded the same results that students from 9th and 12th grades scored higher (respectively, 14% and 47%) than the 25% of the teachers.

Later Carey and Stauss (1970a) assessed science teachers' conceptions of NOS by WISP (Wisconsin Inventory of Science Processes). Consistent with previous findings, results showed that teachers have an inadequate understanding of NOS, and academic variables do not significantly affect their conceptions.

Similarly, in the late 1980's, Koulaidis and Ogborn (1989) studied with science teachers to investigate their understanding of scientific knowledge from a philosophical-epistemological point of view and used a 16-item multiple-choice questionnaire focusing on change in and status of scientific knowledge, criteria for demarcation of science, and nature of the scientific method. Results indicated that their views are mostly irrelevant with a particular philosophical standpoint.

In addition, Abd-El-Khalick and BouJaoude (1997) assessed 20 practicing science teachers' NOS understanding with a modified version of VOSTS. The participants were asked to draw concept maps and were interviewed. Their responses on the interview responses were used to analyze their knowledge structure, function, and development of their disciplines. According to the results, science teachers' knowledge base was inadequate in all respects. They had naïve views about NOS.

In another study, Sarkar and Gomez (2010) explored science teachers' conceptions of NOS in Bangladesh. They focused on the nature of scientific knowledge, scientific enterprise, and scientific inquiry and utilized the Myths of Science Questionnaire (MOSQ) to collect data from 145 science teachers. Findings indicated that the majority of teachers had uninformed conceptions about properties of hypothesis, theories, and laws. Additionally, their responses drew the inconsistent pattern to particular NOS aspects such as even though they agree with the role of imagination and creativity in science, they indicated models as copies of realities rather than the product of scientists imagination, and did not refer to the importance of imagination in the design of experimentation.

In a more recent study, Leden and colleagues (2015) focused on 12 practicing science teachers' way of talking about NOS and teaching NOS. Their framework consisted of five themes of several perspectives of NOS which are tentativeness of NOS, empirical and/or rational NOS, objectiveness/subjectiveness of NOS, rational/creative of NOS, universal/socio-culturally embedded science. In order to investigate teachers' way of talking about NOS, they used the VNOS-C questionnaire, and later two-part interviews were carried out: the first part was a follow-up to questionnaire to elaborate their views on NOS, the second part included questions regarding NOS teaching. Researchers found that teachers possess diverse opinions about a particular theme which could lead to such implications that their reasoning process could be contradictory. Nevertheless, they did not provide as elaborative views about NOS teaching as they talked about NOS.

Overall, the aforementioned studies revealed that teachers tend to have an inadequate understanding of NOS. When the national studies were reviewed, similar results were obtained as well as detailed in the following paragraphs.

For example, Yakmacı (1998) examined 115 prospective and 101 practicing science teachers' views on NOS. The author used 18 adapted items from the VOSTS questionnaire. Results showed that although most of the science teachers possessed realistic understanding regarding the nature of classification, the tentativeness of scientific knowledge, scientific approach in studies, and uncertainty in scientific knowledge and logical reasoning, they possessed inadequate understanding regarding characteristics of hypothesis, theories and laws, and nature of scientific methods.

Aslan (2010) also conducted a study with 74 science teachers to elicit their nature of scientific knowledge understanding by adapting the VOSTS (Views on science-technology-society) questionnaire developed by Aikenhead and Ryan in 1992. The author included the subdimensions of ‘hypothesis, theories and laws’, ‘epistemological status of scientific knowledge’, ‘tentativeness of scientific knowledge’, ‘precision of uncertainty of scientific knowledge’ in his study. Results showed that teachers' views were realistic regarding tentativeness of NOSK (nature of scientific knowledge) and naïve in terms of the epistemology of scientific knowledge and relation among hypothesis, theories, and laws. Another study showed similar results conducted by Koksal and Cakıroglu (2010) with 47 elementary science teachers’ understanding of NOS and its 10 aspects, examined by “open-ended questions” and “Knowledge test”. And the two test results were coherent with each other. Teachers showed the most naïve understanding in the aspects of the relation between the laws and theories and non-universal accepted method of doing science.

Considering the RFN framework there is one study focusing on teachers’ perceptions of NOS views based on the RFN (Aksöz, 2019). She first administered NOS questionnaire to 220 teachers from different branches including biology, chemistry, physics, and science, later interviewed 12 teachers through purposeful sampling based on their scores on the questionnaire. She focused on teachers’ understanding of aims and values and social-institutional system categories of RFN, their perceptions about the educational application of these categories, and about their informal learning environments. The results revealed that majority of the teachers held between moderate to high understanding and their background did not show significant effect on their understanding of the categories. The qualitative data showed that most of the teachers’ responses related to their understanding of the categories were in line with the RFN framework. Also, it was found that teachers who showed higher understanding about the NOS in the questionnaire provided more and detailed codes during the interviews. On the other hand, when the categories taken into consideration separately teachers who had higher education level provided more diverse and relevant responses considering the aims and values while there was no such significant effect observed related to social-institutional aspect category. It was also found that education programs had an impact on their perception related to educational application of these categories.

When the conducted studies were taken into consideration regarding the investigation of science teachers' understanding of the nature of science, the studies were mostly guided by the consensus view of the nature of science as a framework, and quantitative measurements were performed. On the other hand, the newly, presented framework of RFN has been studied with mostly with pre-service science teachers, university students, and in the context of elementary science education. In the literature, there are conference papers, published articles, and thesis using the RFN framework and its 5 categories. These publications focused on analyzing the understanding of NOS of pre-service science teachers, elementary students, university students, and teachers (Akgün, 2018; Aksöz, Kaya, Erduran, Akgün & Tas, 2016; Erduran et a., 2021; Kaya et al., 2017; Sarıbas & Ceylan, 2015), also analysis of curriculum and textbooks as an alternative contextualizing (Cheung, 2020; Kaya & Erduran, 2016a; Kaya & Erduran, 2016b; Yeh, Erduran, & Hsu, 2019; Jho, 2019;). It is seen that study focusing on teachers understanding of NOS through the five categories of RFN perspective is scarce. As explained above RFN proposes a more comprehensive approach to assess NOS understanding. The RFN framework introduces aspects which the previous frameworks did not consider. Also, in line with the research suggesting teachers' understanding of NOS could reflect on their classroom practice, the current study conducted with science teachers using RFN structure aiming to get a more comprehensive and in-depth understanding of science teachers' views on NOS.

2.5 Teachers' Integration of NOS into Instructional Practices

Apart from investigating teachers' understanding of NOS, it is also essential to examine their views on teaching NOS and how they translate their views to the instruction. There are numerous researches related to whether teachers' views affect their NOS integration to the instruction or not. However, these studies yield inconsistent results. The conflicting results may stem from different contextual variables involved in the studies. For example, it may be important to consider teachers' views regarding the necessity for teaching the aspects of NOS.

In one of the earlier studies investigating teachers' knowledge about NOS and their classroom practice, Lederman and Zeidler (1987) studied with 18 biology teachers. They first measured teachers' conceptions using the Nature of Scientific Knowledge Scale (NSKS) and observed their classroom behaviors for a semester. Results indicated that teachers' ideas on the nature of scientific knowledge were not significantly reflected in their teaching. There was even one teacher that had a strong opinion regarding the tentativeness of scientific knowledge but used conflicting expressions during the instruction.

In another study, Duschl and Wright (1989) focused on the decision-making process of lesson planning to see whether teachers take NOS into consideration. With the ethnographic research method, they studied with 13 biology teachers. During observation, researchers realized teachers mostly focused on the curriculum objectives and NOS superficially involved in teaching. Authors deduced that teachers do not emphasize NOS because of their lack of understanding. To test their deduction, additionally, they measured teachers' NOS understanding using NOSS and doing interviews. Results were aligned with their instruction. The survey showed teachers held old images of science, such as most of them considered the scientific method as "hypothetico-deductive" indicating universal five steps of the scientific method, and that is how they emphasized during teaching. Later, the interviews with the same teachers revealed that their lack of emphasis in their planning and instruction about NOS stems from their inadequacy in NOS insight. Additionally, they expressed that teachers also did not exert some components of NOS because they did not think it was important for students to learn.

In addition, Brickhouse (1990) conducted a qualitative study with 3 teachers; two of them were experienced teachers had been teaching for at least 15 years, and the other teacher was beginning teacher had 2 years of experience. The interview data showed a consistency between their epistemic beliefs about science and their instruction of these issues in their classrooms. The way teachers depict scientific knowledge was congruent with the perspective that they expect from their students to gain and the way they construct the lesson plans and instruction. When he found incoherence in teacher's implementation and thinking he stated that this was because of lack of experience of teaching, since it was not clear for the beginning teacher how to overcome the difficulty caused by the institution expectation or his beliefs.

Lederman (1999) also carried out research with 5 biology teachers from different backgrounds. Classroom observations and interviews revealed the year of experience was the prominent factor influencing their practices of NOS and beliefs. Teachers' practices, who had over 10 years of experience related to NOS were coherent with their views, while less experienced teachers were more worried about their competencies and management. Even though they expressed the importance of NOS, they did not consider NOS aspects in their lessons stating these concepts are much more complex and abstract for students. Besides, teachers were more concerned with making students familiar with the basic knowledge.

In a more recent study, Leden, Hansson, Redfors, and Ideland (2015) studied with 12 science teachers in Sweden, who had no particular training about NOS but were supposed to teach about NOS based on the national curriculum, to portray a broad view on how teachers talk about NOS and its implementation. Researchers used the VNOS-C questionnaire at the beginning to get an initial opinion on the way they communicate NOS and later elaborated their views with semi-structured interviews that developed for every individual based on their responses on the questionnaire. Researchers noticed the way some teachers talk about certain aspects is completely different from the way they talk about their teaching these issues. Teachers expressed concerns about students that some would not understand and get confused, and it was easier to provide the basic to which they attribute more meaning. Additionally, they did not consider themselves as well-informed to bring out these issues and carry out discussions and arguments in the class.

In Turkey Hacieminoglu (2013) carried out research to gain more perspective science teachers' ideas about their NOS integration in science courses. Both in-service teachers whom are interviewed expressed the importance of explicit teaching in NOS and they had informed understanding of NOS and training on how to implement it in lessons from their undergraduate studies. They also emphasized that their prior education had been advantageous in their practices. In spite of that, there was an agreement on the not all aspects of NOS were included in their teaching because of the time limit and the expectations of families from teachers to prepare their children in national exams which do not assess these dimensions. Thus she concluded that NOS views of teachers were not reflected in their course of action.

In the following year, Hacieminoglu (2014) studied with more in-service science teachers to understand how NOS and history of science (HOS) were integrated and whether their thinking affected their teaching. This study also supported her earlier research that teachers' views on NOS did not specifically change their practices. She also pointed out that some teachers did not plan to teach NOS aspects explicitly, even though they had access to better resources in their school. . Students were expected to learn certain aspects implicitly through some activities. It can be concluded from this study that it was not about teachers having informed views about NOS, it was more related to their lack of confidence in implementation and not knowing how.

The study of Aslan and Tasar (2013) with 5 teachers provided additional points to consider. They also reached a similar conclusion which indicates that teachers' views on NOS were not transferred to their practice. Some teachers indicated that they did not take into account of NOS while planning their lesson because they did not think it was important for students and did not want to allocate time. Also, it was seen that none of the teachers were willing to explicitly integrate NOS aspects in their classrooms due to pressure from covering the curriculum, preparing students for national exams and the parents.

In the study of Aksöz (2019) based on the RFN framework, she looked into teachers' perceptions about their educational implication of aims and values and social-institutional system. 10 out of 12 teachers mentioned that they were including aims and values of science through teaching the tentativeness of science, mentioning the current studies, making real-life connection, while others expressed they do not teach because of the limitations related to insufficient emphasis in the textbooks and not being included in the national exams. On the other hand, considering social-institutional system the majority of the teachers expressed they do not teach this aspect due to the level of students, restrictive curriculum program, and not having ideas how to integrate into their lessons which indicated the importance of quality of content of teacher education programs. Teachers who were including the category of social-institutional systems were more involved with the NOS related classes during their teacher education programs or had higher level of education, such as doctoral degree.

When the aforementioned studies are considered, it is seen that there are controversial results concerning the translation of NOS views to instructional practice However, in general, the results suggest that the way the teachers convey the NOS aspects is related mainly to their depiction of the science. More specifically, if they think the tenet is hard to comprehend, they abstain themselves from teaching it rather than trying to make the concept easier for students to understand. At this point, it is important to note that most of these studies were based on the framework of the consensus view of NOS and two categories of the RFN. In the present study, on the other hand, it was aimed to gain a comprehensive understanding of teachers' views on whether NOS aspects should be included in teaching and whether they transform their views in their practice, using all categories of RFN as a theoretical framework.

2.6 Curricular Emphasis of NOS

The relation and connection between science, society, and technology have paved the way for the inclusion of the nature of science in school science (Aikenhead, 2000). Understanding the nature of science is acknowledged as a critical component of scientific literacy (NSTA, 1982). Science for All Americans (AAAS, 1989) defined a scientifically literate individual as “one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes”. Westaway (1929) signifies the focus of NOS in the curriculum as:

> Now that science enters so widely and so intimately into every department of life, especially in all questions relating to health and well-being, it is important that the community should have a general knowledge of its scope and aims. (p.9)

After assessing students’ conception of NOS researchers found out that they do not show adequate understanding of NOS, and researchers drew a conclusion that teachers are not attempting to teach NOS, and they turned their attention to curriculum development and assessment (Cooley & Klopfer, 1963; Klopfer & Cooley, 1963; Lederman, 1992). It is advocated that NOS would be conveyed only as an instructional domain to students contributing to understanding how science works, the ways scientists work, produce and validate knowledge, and how science and pseudo-science can be distinguished (McComas & Nouri, 2016; Matthews, 2014).

It is seen that today’s contemporary science education holds a common interest and puts more emphasis on NOS which makes current science standards and curriculum pay attention and include NOS (MONE 2013, NGSS, 2013, NRC, 2012). McComas, Lee, and Sweeney (2009) pointed out after a detailed review of documents in the US context, most states strongly promote NOS, pay attention to and include the facets recommended by science educators, on the other hand, other states hardly ever refer to the topic. It indicates even though the necessity of inclusion of NOS is recognized and emphasized it does not always mean that documents, reforms, or curricula include in their programs.

In this regard, McComas and Nouiri (2016) investigated Next Generation Science Standards (NGSS) to discover where and how accurate NOS categories appear. For comparison, they used 'key aspects' of NOS listed by Alshamrani (2008). Alshamrani (2008) reviewed various sources and discovered 12 key aspects of NOS that are prevalently suggested to be integrated into science education programs. These aspects consist of characteristics of scientific knowledge and scientific methods.

In the analysis of McComas and Nouiri (2016), they found that most of the exemplars are inconsistent with the associated NOS category. In general, 92% of exemplar statements are acceptable, whereas with a much less percentage of those included in the standards. For example, even though 'science as a way of knowing' is included in NOS category in NGSS, in standards, it is not considered at all. For some elements like subjectivity and creativity, they put limited emphasis. Additionally, authors found that there is no consistency regarding the inclusion of some NOS elements across grade levels.

Although there are a number of studies focusing on students' understanding of NOS (Balkı, Çoban & Aktaş, 2003; Doğan and Bora, 2005; Kılıç et al.; 2005), pre-service and in-service teachers' understanding of NOS (Taşar, 2003; Terzi, 2005), enhancing students and teachers NOS understanding through intervention (Terzi 2005), textbook analysis of NOS in the context of Turkey (Erdoğan & Köseoğlu, 2012), studies examining middle school science curriculum is limited (Kaya & Erduran, 2016; Ozden, 2015). In one of the few studies on the Turkish middle school science curriculum regarding how NOS aspects were emphasized, Özden (2015) investigated NOS aspects in terms of explicit approach in 2005 and 2013 Turkish elementary school science curricula through qualitative content analysis. According to the analysis, it was found that both programs lack some aspects of NOS, such as scientific methods, prediction, scientific laws, and theories, and some are insufficient for explicit instruction. In the 2005 curriculum, the term of nature of science is not described. However, the 2005 curriculum covers more NOS elements than the 2013 curriculum. It is because in the 2005 curriculum a more detailed content is provided. Kıvanç (2020) compared the objectives of the 2018 Turkish science curricula and New Zealand science curricula. She found that in the Turkish science curriculum nature of science was integrated into all subject units, yet implicitly, and when compared to New Zealand’s curriculum content of the objectives were rather insufficient

2.6.1 Curricular Emphasis of NOS with respect to RFN

As explained in the previous sections, the family resemblance approach (FRA) is an alternative conceptualization to the nature of science, originally expressed by Wittgenstein (1958). Later Irzik and Nola (2011) applied this notion to the nature of science, and Erduran and Dagher synthesized the FRA approach of NOS with educational applications to science education and referred ‘Reconceptualized FRA-to-NOS (RFN)’. RFN conceptualizes science in terms of the epistemic, cognitive, and social-institutional system. Science as an epistemic-cognitive system includes scientific knowledge, scientific aims and values, scientific practices, and methods and methodological rules, while social-institutional system of science includes scientific ethos, professional activities, social certification and dissemination, social values, social organizations and interactions, political power structures, and financial systems. This holistic characterization to NOS, RFN contributes to pedagogical, instructional, assessment, and curricular studies to which the framework brings coherence (Kaya & Erduran 2016).

The study of Erduran and Dagher (2014a) illustrated the compatibility of FRA with policy reforms. Authors used RFN as a guide in curriculum analysis in the context of the NGSS document. They found a certain overlap of RFN categories with statements in policy recommendations. Epistemic-cognitive aspects of RFN are seen to be in alignment with the epistemic statements in the document, whereas the representation of social-institutional dimension was unclear. A similar case was evident when the draft document in Ireland, Junior Cycle Science, evaluated with the RFN framework (Erduran & Dagher, 2014b). Conducted analyses showed how RFN could be practical and convenient in curriculum studies especially on analyzing and developing curriculum policy document. The framework could guide through the revision, such as it could indicate how to present the contexts in a related and unified fashion and so it would contribute to science curriculum be more engaging and authentic. (Dagher & Erduran, 2016; Erduran & Dagher, 2014b;).

Regarding this, to illustrate utilization of RFN categories as an analytical tool and reflecting the trend in the curriculum development, Kaya and Erduran (2016) analyzed two Turkish curricula, MEB 2006 and MEB 2013, published by the MONE, and compared these curricula with the USA, NGSS, and Ireland, National Council for Curriculum and Assessment (NCCA), documents. The comparison was made in an attempt to see how the RFN approach facilitates curriculum development and analysis from the RFN approach. While both Turkish curricula comprised similar sections such as foundations of middle school science curriculum, general and specific outcomes, and learning areas, MONE 2013 contained less content, and less number of outcomes for each unit, and the organizations of the units differ. Authors generated keywords to analyze the curricula to determine the occurrence of examples of categories. Results of the analysis showed that both MONE 2006 and MONE 2013 have statements that represent science as epistemic-cognitive system, however social-institutional aspect of science was not clearly represented. From bigger picture, it was found that 6 out of 11 categories of RFN were referred in MONE 2006, while in MONE 2013 7 out of 11 categories were presented. Authors concluded that even if it seems like an improvement, there was absence of RFN topics in both curricula need to be enhanced. These results were incongruent with the previous studies (Erduran & Dagher, 2014a, 2014b).

Concerning the comparison across countries, it was found that none of the documents possesses coherent statements that include all categories of RFN. For example, while ‘scientific ethos’ is only referred to by NCCA in Ireland, “social organizations and interactions” is only presented in MONE 2013 in Turkey. It is also noticed that some aspects are never mentioned by any country, such as financial systems and political power structures under the social-institutional system category. Authors point out that the presence of certain statements referring to RFN categories does not lead to the conclusion that they form the comprehensive vision for that category. For instance, even though forms of scientific knowledge are referred to in the statements, they did not express the relationship and connection among theories, laws, and models

Yeh, Erduran, and Hsu (2019) used RFN to analyze the recently revised and launched science curricula of Taiwan in 2019. It was found that when compared to the previous document, there is significantly more emphasis on the aims and values, scientific practices and scientific methods of science and these are interconnected with each other and other categories of RFN. Authors indicated that RFN provided an effective guideline in the analysis of curricula, facilitating structure to see which aspects of science (epistemic, social-institutional, domain specific/general etc.) were emphasized and whether these depictions display connection and coherence within.

Also, recently Jho (2019) analyzed NOS in the Science Laboratory Experiments textbook from three frameworks which are the consensus view of NOS, features of science (FOS), and family resemblance approach (FRA). Three perspectives emphasized different aspects of science in the document. He pointed out that the consensus view mostly featured the tentativeness, creative and empirical NOS throughout the document, while FOS covered largely the practices of science that scientists use to obtain knowledge. In addition to these aspects, FRA provided social-institutional perspective to the structure. Researcher expressed that FRA contributed to the wider viewpoint to NOS, also noting that it should be clear about defining science. Later Cheung (2020) investigated NOS representation in Hong Kong Biology Curriculum and high-state assessments using the FRA as a theoretical framework. He used ENA (epistemic network analysis) to examine which categories were included and especially to show the interconnections among the categories to be able to depict coherent representation. The analyses showed similarity with the previous studies in the sense that there was more emphasis on epistemic-cognitive aspects in the curriculum. This was also evident in the high-stakes assessment. Considering the connections among the categories, it was also apparent that there were relatively less connections in social-institutional aspect in both curriculum and high-stakes assessment. Also, the connections between the two systems were higher in the high-stakes assessment than in the curriculum.

2.7 Summary

There are numerous national and international studies investigating science teachers' understanding of NOS. These studies mostly revealed that teachers had inadequate understanding regarding NOS aspects (Clough & Olson, 2012; Kite, Park, McCance & Seung, 2020; Schwartz & Lederman, 2002).

When the measurements are taken into consideration, it can be seen that quantitative measurements are mostly used type of measurement even though they are followed by interviews and open-ended questions (Aslan, 2010; Leden et al., 2015). Indeed, for a more detailed analysis and understanding, qualitative approaches like interviews are suggested (Lederman, Wade & Bell, 1998).

Teachers' integration of NOS into their practices is also another important perspective in the related literature (Aslan & Tasar, 2013; Schwartz & Lederman, 2002). In these studies, apart from investigating whether they make NOS integration or not, the researchers also examined teachers' perceptions regarding how they integrate the NOS aspects into their instruction (Hacieminoglu, 2013; Lederman, 1999). The study of Aslan and Tasar (2013) showed teachers were not interested in introducing NOS into their classrooms because they thought it was an incidental part of the course subjects that should be covered. While Leden, Hansson, Redfors, and

Ideland (2015) pointed out that teachers who were expected to teach about NOS as a curricular objective, communicated certain NOS aspects in the lessons different from the way they explained to the researchers. Teachers expressed concerns about not being informed enough to lead discussions and students not being able to comprehend. Besides, teachers with whom Brickhouse (1990) studied showed consistency with the way they talked about scientific knowledge and the way they taught in their class. In his study, the experience year of the teachers was the prominent effect, such that more experienced teachers were more confident and organized about how to instruct and what to expect from children. Additionally, there was not distinctive research focused on teacher views on NOS implementation in the teaching program. Mostly, teachers' decision-making process based on curriculum implementation was researched (Siuty, Leko, and Knackstedt, 2018) or their general NOS implementation (Aslan, 2009; Clough & Olson, 2011; Hacıeminoglu, 2013). Thus in this study, additionally, teachers' views regarding the inclusion of RFN categories in the science teaching program were analyzed.

Regarding the curricular emphasis of NOS, researchers mostly used the consensus view of NOS (Abd-El-Khalick, 2012; Lederman et al., 2002; Ozden, 2015). The recent studies investigating curricula through the FRA framework provided a more detailed representation of the NOS even though the texts were found to have a lack of representation of some categories. For example, two Turkish curricula (MONE 2013; MONE 2006) were analyzed based on both FRA categories (Kaya & Erduran, 2016) and consensus views of NOS (MONE 2005; MONE 2013) (Ozden, 2015). In Ozden's (2015) study, it was found that both curricula gave little or no attention to explicit instruction and adequate content of some NOS aspects such as scientific methods, empirical nature of science, inferences, and theoretical entities. Also, the researcher underlined that the 2013 curriculum had limited integration, including much less NOS aspects when compared to the 2005 curriculum. Kaya and Erduran's (2016) analysis showed that both MONE 2006 and MONE 2013 curricula include categories of epistemic-cognitive system of science; however, categories of social-institutional system of science were rather limited.

CHAPTER 3

METHOD

This chapter provides methodological details of the investigation of the science teachers' views about NOS from the perspective of reconceptualized family resemblance approach to nature of science (RFN), about RFN integration to their instruction, and about the curricular emphasis of RFN. In the following sections, research design, sampling, instrumentation, data collection and analysis, and ethical consideration are presented.

3.1 Analysis of Teachers' Views

3.1.1 Research Design for Analysis of Teachers' Views

Science teachers' understanding of NOS was examined using qualitative survey design (Jansen, 2010). This study has been considered as a qualitative research since it was intended to investigate the diversity of understanding of the teachers' perspective and the meaning they attribute to the phenomenon and their experience related to NOS using semi-structured interviews (Merriam, 2009). Jansen (2010) argues that labeling this type of research only as 'qualitative study' is inadequate and proposes the concept of qualitative survey research. According to his argument survey as a methodology refers to quantitative studies concentrating on the frequencies and distribution of variables while survey as qualitative study focuses on the diversity of the topic in that population. Since it is intended to get the diverse perceptions and meaning constructed by science teachers about NOS via semi-structured interviews, qualitative survey design was adopted in the current study.

According to Jansen (2010) a qualitative survey can be classified as open/inductive survey or pre-structured/deductive survey. He defined survey as inductive when the categories and the dimensions of the subject matter emerge during the study, while in the deductive survey, these are pre-determined. In the present study, the teachers understanding of NOS was investigated based on RFN framework. Accordingly, categories of RFN which consist of 5 main aspects including aims and values of science, scientific practice, scientific knowledge, methods and methodological rules, and socio-institutional systems of science formed the outline of the interview questions. Thus, the study can be considered mainly as deductive because the characteristics (aspects) of NOS to be analyzed were defined previously. In addition, during data analysis, for each aspect, 3 parent codes, namely, meaning, curricular emphasis, and integration to instruction were determined deductively considering the structure of the interview questions. However, the child-codes were identified both deductively (as predetermined child-codes) and inductively (as emergent child-codes). Interview questions prepared based on the RFN categories were piloted with two science teachers. Some revisions were made in the questions to get more in-depth and elaborated responses as detailed in the sub-section related to interview questions. In the main study, semi-structured interviews were conducted face-to-face with 13 in-service science teachers.

3.1.2 Participants

The sample of the study consists of 13 in-service science teachers practicing in public and private schools. Participants were chosen by maximum variation sampling. The purpose of maximum variation sampling was to increase heterogeneity and diversity of the findings regarding the phenomena (Creswell, 2007). For a wide range of representation, the following characteristics of the science teachers were considered;

- taking courses or attending seminars about NOS/HOS/POS or not
- reading books about NOS/HOS/POS or not
- different education level (e.g. having a bachelor degree, being a graduate student)

In this study, the purpose was not to make a comparison among teachers with different backgrounds, it was assumed to consider these characteristics would contribute to a variation in the representation of NOS views. Additionally, in the literature, it was suggested that the purpose of the researcher using maximum variation sampling would not be generalizing, but to illustrate both the diversity and the common patterns in that diversity (Patton, 1990). Accordingly, in the current study, interviews were carried out until no relevant new codes were appearing which indicated a point of saturation (Merriam, 2009). It was observed that after the 11th interview, the codes were recurrent, and no new codes were generated from interviews. Yet, two more interviews were conducted to ensure that no new codes emerged. Thus, interviewing 13 teachers provided enough saturation to reach redundancy.

At the beginning of each interview, demographic questions, whether they attended to class/seminar related nature of science [NOS], philosophy of science [POS], history of science [HOS]; whether they read books related to NOS, FOS, and POS; and their general ideas about NOS were asked to teachers. In Table 3.1, data about teachers' demographic information, whether they read a book and took class concerning NOS, FOS, and POS, were given.

Of the sample, 11 (84.6%) were females, 2 (15.4%) were males. The teachers' years of experience varied from 1 to 22 years. Two teachers (15.4%) teachers had 1-5 years of teaching experience, and there were no teachers with 6-10 years of experience. The number of participants having 11-15 years of experience was 2 (15.4%). The majority of the participants (n = 8, 61.5%) had 16-20 years of experience, and only one of the participants (7.7%) had 21-25 years of teaching experience. In addition, 10 teachers (76.9%) were practicing in the public schools while the rest (n = 3, 23.1%) of them were teaching in private schools.

Ten teachers (76.9%) hold bachelor's degrees, and 3 of the participants (23.1%) were graduate students in the science education program. Teachers graduating from faculty of education constituted 84.6% (n = 11) of the sample. Of the participants who graduated from faculty of education, 7 of them were graduates of science education; 3 of them graduated from physics education, and one of them graduated from chemistry education. One of the remaining participants was a graduate of the Physics department, and the other was a graduate of the Biology department. The teachers were assigned alphabet letters (Teacher A, Teacher B, etc.) to keep their names anonymous

Below, the demographic characteristics of the teachers are provided in detail.

Teacher A

Teacher A is 38 years old science teacher working in a public school. She graduated from the science education department. She has 16 years of experience and currently teaches 5^{th}, 6^{th}, 7^{th} and 8^{th} grades. She did not take classes or seminars regarding NOS, FOS, or POS. She did not read any books related to these areas either, but she stated that she read science related books. She described the nature of science as notions related with living things such as animals, humans, microscopic organisms.

Teacher B

Teacher B graduated from physics education. She is 38 years old and has been teaching for 18 years. Currently, she teaches 5^{th}, 6^{th}, 7^{th} and 8^{th} grades in a public-school. She said that she had taken lessons related to the NOS, but she could not remember since it was a long time ago. She read books related to NOS which were about scientific facts and how to integrate them into real life. She described the nature of science as an endeavor studying the existence since nature of science and life are inseparable.

Teacher C

Teacher C is 38 years old graduated from science education. She has 18-year experience and currently teaches 5^{th}, 6^{th}, 7^{th} and 8^{th} grades in a public-school. She did not take any class or attended seminar related NOS, FOS, or POS and also did not read books about the related topics. Considering NOS, she depicted it as an entity of which every endeavor in the world was comprised.

Teacher D

Teacher D is 45 years old science teacher with a 20-year of experience. He graduated from physics education. He is teaching in a public school to 5th, 6th, 7th and 8th grades. He did not take any classes or read books related to NOS, FOS, or POS. He described the NOS as the component elements of science and its branches.

Teacher E

Teacher E graduated from the biology department. She is 45 years old and has a 20-year of teaching experience. She is teaching to 5th, 6th, 7th and 8th grades in a public school. She said she attends the seminars when the school or MONE organizes science related seminars. She defined the NOS as the link between the livings and non-livings.

Teacher F

Teacher F is a 44-year-old science teacher with 19 years of experience. She had been appointed as a primary school teacher; later, she began teaching in middle school. Currently, she is teaching 5th, 6th, 7th and 8th grades. She graduated from chemistry education. She did not take any class about NOS, FOS, or POS. She said she read books related to the history and philosophy of science. She depicted the NOS as a characteristic of both nature and science which are inseparable.

Teacher G

Teacher G is 47 and graduated from the physics department. She has a 20-year of experience and currently teaches 6th and 8th grades in a public school. She did not take classes regarding NOS, POS, or FOS. Considering books, she sometimes reads magazines of Bilim Teknik and Bilim Çocuk. She described the nature of science as an entity that has already been involved with every aspect of life.

Teacher H

Teacher H is 35 years old and graduated from the science education department. He has been a teacher for 15 years and teaching 8th grade in public school. He said he had attended a seminar in education faculty which was about theories and laws. He did not read a book related to the NOS. According to him, NOS is the continuous evolution of science from the beginning of the existence to the present.

Teacher I

Teacher I is a public school teacher in Konya graduated from the physics education department. She is 45 and has been teaching for 22 years. She teaches 5^{th} and 7^{th} grades. She did not read or attend seminars related to NOS, POS, and FOS. She thinks of the NOS as the knowledge that has been justified and approved everywhere.

Teacher J

Teacher J is in her 15^{th} year of teaching and graduated from science education. She is 38 years old and teaching 5^{th}, 6^{th}, 7^{th}, and 8^{th} grades. She did not take classes related to NOS, FOS, or POS. She said she reads books about science but not about these specific subjects. She added that these books were not academic, mostly about how to make science fun for the students. She described the NOS as interaction within the environment, humans, and its nature.

Teacher K

Teacher K graduated from science education and is currently a graduate student writing her thesis in the same field. She is 25 years old and has been teaching for 2 years. She works in a private school and teaching 5^{th}, 6^{th}, and 7^{th} grades. She took a course related to NOS, which introduced the FRA framework when she was a senior. In this course, they read about one aspect of NOS for each week. The instructor of the course requested lesson plans regarding these aspects. And they developed 3-D models related to these aspects. She said she did not read a book about NOS, POS, or FOS but took a course. While answering her understanding of NOS she told about what she remembers from the course. She mentioned that there is theory-law-model structure. She told some topics including characteristics of a scientist, publication of studies, panels, aims, and values that they cannot be separated, scientific knowledge can change and develop.

Teacher L

Teacher L is 25 years old and has a one-year of experience. She graduated from the science education department and is currently a graduate student in science education. She is teaching 5th, 6th, and 7th grades in a private school. She said that she took courses about NOS, but it was implicitly covered. In these lessons, they analyzed the articles and talked about them, such as whether the information given was scientific if it were how it was supported. Also, they prepared lesson plans, and they were asked to emphasize NOS in the plans. Additionally, she said that she learned more about the NOS with research she conducted for a research course. She said she did not read books but articles about NOS, POS, and FOS. She said that the NOS is about things that are related to science, its structure, characteristics, and how it is constructed.

Teacher M

Teacher M is 47 years old, and she had been working as a computer teacher for 16 years. For the last 3 years, she has been teaching science in a private school. She is teaching 5th and 6th grades. She graduated from the science education department and continues in her graduate studies in the same department. She took courses related to NOS in her undergraduate study. In the course, they analyzed one aspect of NOS in each lesson and prepared lesson plans, and they discussed how they could integrate these into their classes. According to her, the nature of science incorporates both framework and the content in order to help students to gain scientific thinking skills. She mentioned the aspects of nature of science which were observations and interpretation in the scientific process; science being in a constant development that it searches for new evidence and data; that it is tentative and developing; scientists affecting from their environments. She mentioned that she read articles about NOS and a guidebook prepared by Hacettepe University that introducing NOS integrated lesson plans and how to integrate these in the class, but not a book specific to the topic.

Table 3.1 provides a summary of the participants' demographic characteristics

Table 3.1 Demographic information of teachers

Teacher	Age	Experience [year]	School type	Teaching grade	Graduation department-Degree	Taking course/attending seminar about NOS, HOS, POS	Reading book related NOS, HOS, POS
A	38	16	Public school	5^{th}, 6^{th}, 7th, 8^{th}	Science education-bachelor’s degree	No	No
B	38	18	Public school	5^{th}, 6^{th}, 7th, 8^{th}	Physics education bachelor's degree	Yes	Yes
C	38	18	Public school	5^{th} ,6^{th} ,7^{th} ,8^{th}	Science education-bachelor’s degree	No	No
D	45	20	Public school	5^{th}, 6^{th}, 7th, 8^{th}	Physics education-bachelor’s degree	No	No

Table 3.1 (Cont'd)

E	45	20	Public school	5th, 6th, 7th ,8th	Biology- bachelor's degree	No	No
F	44	19	Public school	5th, 6th, 7th ,8th	Chemistry education- bachelor's degree	No	Yes
G	47	20	Public school	6th and 8th	Physics- bachelor's degree	No	Yes
H	35	15	Public school	8th	Science education- bachelor's degree	Yes	No
I	45	22	Public school	5th and 7th	Physics education- bachelor's degree	No	No

Table 3.1 (Cont'd)

J	38	15	Public school	5th, 6th, 7th, 8th	Science education-bachelor's degree	No	No
K	25	2	Private school	5th, 6th, 7th	Science education-graduate student	Yes	Yes
L	25	1	Private school	5th, 6th, 7th	Science education-graduate student	Yes	Yes
M	47	19	Private school	5th and 6th	Science education-graduate student	Yes	Yes

3.1.3 Development of Interview Questions and Implementation

Semi-structured interview questions were prepared based on 5 categories (aspects) of RFN framework developed by Erduran and Dagher (2014). The semi-instructed interview was used because it enables participants to elicit their opinions, as well as the researcher to be more flexible and responsive to the situations and answers given by the interviewee (Merriam, 2009). As Merriam (2009) pointed out, since the study at hand sought certain information from the participants, it also required some structured part in the interview.

Literature related to NOS and RFN (Erduran and Dagher, 2014; Allchin, 1999; Wong and Hodson, 2010; Clough, 2007; Kaya, Erduran, & Akgün, 2017) guided the development of the interview questions. The questions were examined by two experts in science education. The questions were pilot tested with two in-service science teachers, who only participated in the pilot study, to assess interview questions. Interviews lasted approximately 40 minutes. One of the teachers was an in-service teacher working in a private school, and the other was an in-service science teacher working in a private institution and also a graduate student in science education. The teachers provided feedback regarding clarity, understandability, and wording of the questions. In addition, after transcribing interviews, the transcription and the questions were again examined by the experts in the field to determine whether there was a need to revise the questions to get richer, more elaborated data regarding teachers' NOS views. Based on both the teachers' and experts' feedback, some of the questions were revised. For example, question related scientific practices were abstract for teachers, so it was revised as science process skills if the teacher was confused with the previous concept. After revisions about wording, the final list of the interview questions was formed (see Appendix B)

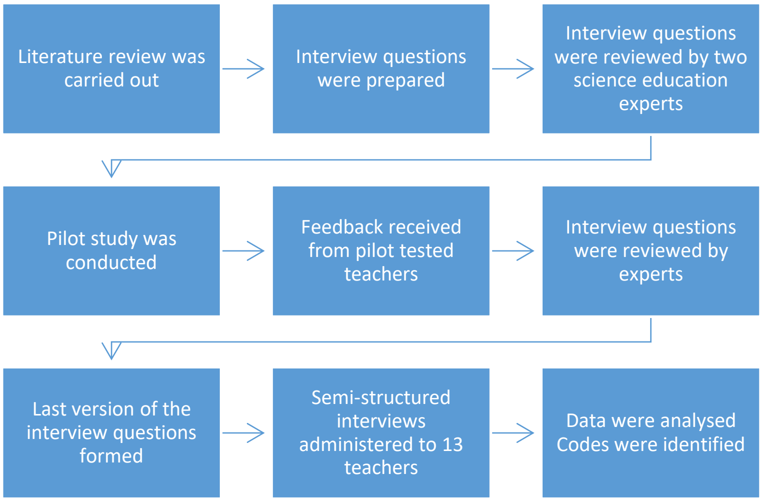

Figure 2: Sequence of Methodology

The time and place of the interviews were decided by the participant teachers. As seen in Appendix B), at the beginning of the interview, teachers were asked about demographic characteristics including, age, year of experience, teaching grades, department of graduation, graduate degree, whether they attended seminar/class concerning NOS, POS, HOS, and whether they read a book about NOS, POS or HOS. Additionally, they were asked about their general ideas about the nature of science. The following questions were designed to get a deeper understanding of their views about the 5 categories of the NOS.

In relation to the research questions related with the science teachers' views about NOS from the perspective of RFN, teachers were asked about their views about each RFN category, their views about RFN integration to their instruction, and their views about the curricular emphasis of RFN categories. During the interviews, sometimes, the order of the questions was changed to enable the natural flow of the conservation and at the same time to uncover the teacher's views which had not been explored by the previous questions yet.

3.1.4 Data Collection

After approval of this research by the ethics committee of the university [İAEK] and Ministry of Education [MONE], the study was conducted. Interviews were carried out face-to-face. with the teachers who agreed to participate in the study in their places of work [schools; 11 teachers] or in their homes [2 teachers]. For the teachers who were interviewed in the working hours, firstly, school principals were asked for permission. Then, with volunteer teachers, in their available times interviews were carried out in a quiet place available in the school. At the beginning of the interviews, teachers signed a consent form including information about their rights and the purpose of the study. Interviews lasted approximately 40-45 minutes and were conducted by the researcher. Depending on the teachers' responses, this duration was extended. The conversations were audio-recorded with their permission and later transcribed for analysis.

3.1.5 Data Analysis

Interview responses were examined using the qualitative content analysis which enables organizing and working out the meaning of the collected data (Bogdan & Biklen, 1992). It goes beyond labeling the data just with words, it is about linking the data to the idea (Saldaña 2009).

Codes can be generated inductively as emerging codes from the collected data or deductively referring to pre-determined themes (Ryan Bernard, 2003). In this study, considering the structure of the study, hybrid coding in which inductive coding was harmonized with deductive coding was employed (Saldaña, 2013). More specifically, in the present study, interview questions were prepared based on the 5 aspects (categories) of RFN framework (i.e, aims and values of science, scientific practices, methods and methodological rules, scientific knowledge, and social-institutional system of science). For the data analysis, for each aspect, 3 parent codes, namely, meaning, curricular emphasis, and integration to instruction, were identified deductively based on the structure of the interview questions. Parent codes are also called the most general codes (Gibbs, 2018). The parent (general) codes suggested extensive categorization that required sub-codes which are also referred to as child-codes, to provide comprehensive interpretation (Gibbs, 2018). The child-codes (sub-codes) were generated both as pre-determined that were expected to be found based on the available literature (e.g. Erduran & Dagher, 2014; Erduran, Kaya, Çilekrenkli, Akgün, & Aksöz, 2021; Aksöz, 2019) and as emergent that was driven from data. In fact, in data analysis, Saldaña (2013) organized coding in two sections which are "First Cycle coding" and "Second Cycle coding". The methods of First Cycle coding involve the first codes given to the pieces of data. And the Second Cycle coding is used when it is necessary to reorganize the results from the First Cycle codes. For this study, "subcoding" belonging to First Cycle coding was used. Subcoding is used when more comprehensive categories or subcategorization is needed after the general codes to provide more detail (Miles, Huberman, & Saldaña 2013).

3.1.6 Ethical Issues

Before conducting the study, necessary permissions from the ethics committee of METU and the Ministry of National Education were obtained. To ensure confidentiality and anonymity volunteered teachers were asked to sign a consent form confirming their rights. The names of the participants were not revealed, they were addressed with letters in the study (e.g. Teacher A, Teacher B, etc.)

3.1.7 Trustworthiness

The validity and reliability of a qualitative research are defined differently from the quantitative research based on the philosophical assumptions (Merriam, 2009). Thus, instead, trustworthiness of the study is discussed. Lincoln and Guba (1982) addressed the constructs of credibility, transferability, dependability, and confirmability to refer to internal validity, external validity, reliability, and objectivity respectively. curriculum analysis sections trustworthiness of the study is discussed.

Credibility is defined as the similarity between the participants' views and the data obtained from them (Korstjens and Moser, 2018), and measuring what is intended (Shenton, 2004). To ensure credibility, a number of strategies were suggested including prolonged engagement, persistent observation, triangulation, and member check (Lincoln & Gubba, 1985). Triangulation was applicable for the analyses in this study. Different triangulation forms were proposed. These include data triangulation which uses multiple data sources, method triangulation which refers to two or more approaches to collect data, investigator triangulation using two or more researchers, and theory triangulation employing at least two theoretical perspectives to analyze data (Denzin, 1989). Credibility for analysis of interview was aimed to be ensured by investigator triangulation through consulting with two researchers about the formation and analysis of the codes.

Another concern is the transferability which deals with the applicability of the results to other settings (Korstjens & Moser, 2018). Even though in qualitative study findings are specific to that context, it is considered as valuable to present descriptive information to enable understanding to what extent researchers could relate and transfer the results in their studies and settings (Shenton, 2004). Thus, Merriam (2009) suggests using 'thick description' which refers to depicting the results, context, sample, and process from which data obtained, and using maximum variation sampling to provide a wider range of representation or purposive sampling (Guba & Lincoln, 1982) in that purpose. Thus, to assure transferability for the interview analysis detailed description of the characteristics of the participants, the settings and the findings with the excerpts from interviews were presented. Also, using maximum variation sampling is believed to contribute to a wider representation.

Additionally, dependability which concerns the replicability of the study which could be problematic in qualitative study considering changing nature of human experience focuses more on the consistency of the results with the data collected (Merriam, 2009). Merriam (2009) states, ‘audit trail’, ‘peer examination’, ‘investigator’s position’ and ‘triangulation’ as strategies to ensure dependability. Also, Lincoln and Guba (1985) pointed out that demonstrating credibility suggests dependability. And the last construct is confirmability which deals with the impartiality of the researcher. Within this construct, the results and interpretation should reflect the participants’ experiences and ideas, not the researcher’s viewpoint (Shenton, 2004). Methods of triangulation and audit-trails are suggested to ensure credibility (Shenton, 2004). The triangulation method was emphasized for both dependability and confirmability and to minimize the investigator’s bias. For dependability and confirmability of the analysis of interviews, triangulation method and detailed descriptions of the data development, collection, and analysis to reduce the bias of researcher were tried to be employed.

CHAPTER 4

RESULT

This chapter presents the qualitative results concerning science teachers' views about NOS from the perspective of reconceptualized family resemblance approach to nature of science (RFN), RFN integration to their instruction, and about the curricular emphasis of RFN.

Teachers' Views of NOS

Science teachers' views regarding NOS were collected via semi-structured interviews. Interview questions were developed based on the main aspects of the "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) (Erduran & Dagher, 2014). This framework analyzes NOS from the five aspects, which are scientific aims and values, scientific methods and methodological rules, scientific practices, scientific knowledge, and socio-institutional system of science. For the analysis, interviews were transcribed, and data were analyzed using deductive coding; however, there were also new codes [emergent codes] which emerged during data analysis. Thus, for the analysis, hybrid coding was applied. More specifically, inductive coding was used as a complementary to the deductive coding (Saldaña, 2013). The main predetermined interview questions were related to getting general views of teachers' opinions of each aspect, and the follow-up questions were asked when a more detailed perspective is required. The main questions were about their views about the meaning of each aspect (category), their views about the curricular emphasis of RFN categories, and how they integrate these categories into their instruction. Accordingly, three parent codes were determined related to each aspect of RFN which are meaning, curricular emphasis, and integration to instruction. All responses from interviews were individually analyzed, and sub-codes were determined (Table 4). The resulting codes were either a predetermined or an emergent codes.

Table 4 Codes from the interviews of science teachers

ASPECTS	Parent Code	Sub-code (Child Code)
Aims and Values	Meaning	Serving to humanity Produce knowledge Value-free and ethics Honesty Objective, clarity, free from bias Other
	Curricular Emphasis	Not integrated Insufficient Implicit Irrelevant example
	Integration to Instruction	Lack of student interest Difficult to teach Examples from the history of science Daily life examples Activities involving consideration of aims and values

Table 4 (Cont'd)

Methods and methodological rules	Meaning	<u>Methods;</u> Steps of the scientific method • Stating a problem • Forming hypothesis • Doing research • Data collection • Testing • Experimentation and observation Hypothesis Domain-specific methods Historical evidence Observational evidence <u>Methodological rules</u>; Controlled experiments Considering different opinions Ethical considerations
	Curricular Emphasis	Not included Sufficient Experimental methods Single method

Table 4 (Cont'd)

		Included
	Integration to Instruction	Complicated Insufficient laboratory conditions Limited time High curricular load
Scientific Practices	Meaning	Communication Creative thinking Critical thinking Observation Experimentation
	Curricular Emphasis	Sufficient emphasis Insufficient guide (for teachers) Experimentation, observation, classification Manipulation of variables

Table 4 (Cont'd)

	Integration to Instruction	Necessary Explicit integration Implicit integration Insufficient resources
Scientific Knowledge	Meaning	Testable Universally acceptable Tentative Trustworthy Consistent Laws as proved theories as observed phenomenon, Theories as proved hypotheses as unconfirmed prediction, as explanations Models as visualization
	Curricular Emphasis	Insufficient guidance No objective

Table 4 (Cont'd)

		Insufficient emphasis Presence of types of scientific knowledge
	Integration to Instruction	Inadequate understanding Hard to teach Emphasis on models Inadequate guidance in textbooks
Social-Institutional system of science	Meaning	Social and cultural context Ethos Dissemination of scientific knowledge Social organizations Political powers Financial system
	Curricular Emphasis	Superficial emphasis No emphasis Emphasis in textbooks
	Integration to Instruction	Not useful Necessary No curricular emphasis Science projects

Science Teachers’ Views about RFN

To reveal science teachers’ views of NOS through RFN, semi-structured interviews were conducted considering the five aspects of RFN. *Meaning, curricular emphasis,* and *integration to instruction* were determined as parent codes and applied through all aspect. The obtained child codes were either pre-determined or emergent codes and varied across the aspects. In the following sub-sections, collected sub-codes for each parent code are elaborated. More superficially, results were presented separately for each parent code (i.e. meaning, curricular emphasis, and integration to instruction) under each aspect (i.e. aims and values, scientific methods and methodological rules, scientific practices, scientific knowledge, and socio-institutional system of science). Accordingly, firstly, the results concerning the *meaning* parent code, then *curricular emphasis* parent code, and finally, *integration to instruction* parent code were reported in the following sections.

4.1 Science Teachers’ Views about the meaning of the RFN Categories

4.1.1 Meaning of Aims and Values

Concerning the aims and values aspect, the child codes were given in Table 4.1.1 were identified. In the following paragraphs, they were elaborated using sample excerpts.

Table 4.1.1 Codes from the meaning of aims and values

Parent Code	Child-code	Explanation of the code
Meaning	Serving to humanity	Meeting the needs of society, contributing to public welfare and to the development of economy and technology
	Produce knowledge	Producing knowledge to pursue the unknown, with the aim of sharing it with people
	Value-free and ethics	Science should be free-from all values and boundaries or science should be conducted under certain values and moral issues including rights of the people and animals
	Honesty	Scientists being honest about the data and results they provide
	Objective, clarity, and free from bias	Characteristics of scientific claims that scientists present which are independent from particular groups biases
	Other	The role of aims and values in the scientific process

4.1.1.1 Serving to humanity

Teachers' responses to the interview questions related to the aims of science mostly related to the social aspects, such as the relation and role of science with the human being and its environment. They focused on the contribution of science to public welfare, to the development of the economy, technology, and health services. In other words, according to their views, scientific knowledge should be used for public welfare, should be applicable to human needs, and should not be used to give harm to human being. Most of the teachers emphasized the applicability of science to human needs. The followings were two science teachers' words:

> "It should be making life easier, but of course, it is not just that. Contributing to the economy, comfort, and again making life easier, studies in health and treatment, these all are among the aims of science" (T. B)

> "Scientific knowledge should accommodate technological conditions and answer to needs; we should be able to use it. When we use scientific knowledge, then the aims of science achieved." (T. A)

Also, except for the teachers who were graduate students, the participants mostly used technology or technological development interchangeably with science:

> "Science should be a place where scientists work in peace, but sometimes some scientific branches can be harmful. Suh as the internet can do both harm and good, or that various machines are devised for

> the humans' comfort or bombs are invented to kill people." (T. D)

Another teacher approached the interaction between humans and the environment from a historical perspective. She focused on the things that humans have been doing to understand the nature affected the way they think which promoted their thinking skills:

> "When the aims of science are mentioned, the aims of scientific thinking come to my mind. In a word, for example, observing the nature around us, deducing from them because humanity developed through these impacts we had on nature. As we had an impact on nature, so we gained things that made us who we are. To do so, observing and experimenting… all this important. Since all of these happened in the course of time, we can also talk about the history of science or changing of scientific knowledge." (T. M)

4.1.1.2 Produce Knowledge

Another most common code was producing knowledge to follow the unknown and satisfy one's curiosity. While stressing producing scientific knowledge, all the teachers who were graduate students expressed the importance of aiming to publish and share it with the people without any limitations that all should be able to reach. Example quotations can be given below:

> "Science aims to discover the scientific knowledge through the scientific way. And aims to share it for the benefit of people." (T. L)

> "I think science aims to pursue the unknown, search, tell and inform the people. Besides if a

researcher hides information to him/herself, then
s/he is not doing a scientific study." (T. K)

4.1.1.3 Value-free and Ethics

In addition to the aims of science, regarding the values of science, teachers held diverse and sometimes conflicting opinions. Five teachers (T. H, T. C, T. E, T. I, T. A) initially expressed that science should be free from values because science should be common to all the people around the world. However, they also expressed while practicing science, it should be regulated by certain values such as societal, religious, etc., which were mostly explained in the realm of morality. With the other teachers who adopted values as a characteristic of science, the common view held by all was ethics that was considered as inevitable to value of science. It was generally used to express the idea of not harming the livings and nature, also protecting the rights of the animals and humans in scientific experiments. For example, Teacher C stated:

> "Science is independent from values. But of course
> it is like how you are free until you violate others'
> rights, science as well should not harm other
> beings' lives and distort the natural balance" (T. C)

4.1.1.4 Honesty

It is seen that only graduate-student teachers attributed honesty as a value which is expressed as being able to think independently from the societal effects. Teachers pointed out academic integrity, plagiarism, not lying, and not distorting the information in this context. The following is the example quotation:

> "Actually, there are many things under the ethics,
> while I conduct my study the respect I hold for the

other researcher, that I do not steal from his/her study is one of them. Or the extent that I inspired by his/her research" (T.K)

4.1.1.5 Objective, Clarity, and Free from Bias

All graduate-student teachers (T. K, T. M, T. L) and two from science graduate teachers (T. J, T. A) especially focused on the objectivity, clarity of the process scientists follow, and not being controlled by certain groups. Afterward, they also pointed out the importance of communication and having a consensus among the experts for that purpose. Quotes from teachers are given in the following:

> "While evaluating scientific knowledge, one should be thinking independently from some effects, societal effects, or the impacts that made us who we are, maybe these constitute values...It should not reflect the interest of some groups or social rank. I mean it should not be a tool to put pressure on certain groups." [T. M]

> "It has to be objective… especially if s/he is going to publish which s/he will somehow, my professor told me that some studies do not get published unless some scientists give consent. I found that odd because whether you approve it or not, this is a scientific research, you cannot publish that scientific research just because it did not get approved by your opinion. The standards must be predetermined (T. K)

> "The process, method which is followed to produce scientific knowledge should be explained clearly.

> You discovered that okay, but you have to show how did you do it whether it is supporting or contradicting with the literature. Science also has a social aspect, after all, the information should be communicated among scientists, it must be supported" (T. L)

4.1.1.6 Other

Teachers also revealed different views regarding the roles of aims and values in the production of scientific knowledge. Some teachers asserted that scientists take these aims and values to set a base for their study which are used as criteria or standards in their research. For example, three teachers [T. E, T. J, T. K] stated that during scientific research, science should favor using the knowledge that is based on scientific, plausible data that should be able to explain the questions in mind.

Some teachers who are graduate students [T. L, T. M] also put emphasis on the power structure in the decision-making process of the scientific study. They added that values affect the process of a study whether getting support or being in favor of particular groups' interests. For example, Teacher L explained as in the following:

> "Aims are the starting point of scientific studies… and values are in the process. It can also be this that whether scientific knowledge is supported or granted by government affect the study." [T. L]

Teacher M commented on the roles of aims and values in a criticizing manner,

"When I say public interest, I mean, for example, we have unlimited production power, but we do not have such a system to feed all the people. We know that scientific knowledge does not work like that. And this shows that it serves to a certain goal, but this goal is not a common goal for all the people."

4.1.1.7 Summary of the Findings Regarding Science Teachers' Views about the Meaning of Aims and Values

Overall, teachers stated serving humanity, producing knowledge, being value-free, ethical, honest, objective, and free from bias as the aims and values of science. The prominent point was that teachers mostly referred to social aims and values. The code of science being free from values held different ideas, such as teachers who asserted science should not hold values also expressed that moral values should play a role in the process. It was noticed that teachers who read books about the NOS adopted the opinion that values are inherent in science. Another point was that only graduate-student teachers expressed honesty that holding academic integrity as a value of science. In general, it can be said that teachers who were graduate students provided more consistent and informed opinions.

4.1.2 Meaning of Methods and Methodological Rules

Table 4.1.2 presents the child-codes identified under the meaning parent code for methods and methodological rules aspect. They were identified from teachers' answers to methods and methodological rules of science and expanded with excerpts.

Table 4.1.2 Codes from the meaning of methods and methodological rules

Parent Code	Child-code	Explanation of the code
Meaning	<u>Methods;</u>	
	Steps of the scientific method	The universal steps scientists follow during scientific studies
	• Stating a problem • Forming hypothesis • Doing research • Data collection • Testing • Experimentation and observation	
	Hypothesis	The role of forming hypothesis in scientific studies

Table 4.1.2 (Cont'd)

	Domain-specific methods	Different methods used in different branches of science
	• Historical evidence • Observational evidence	
	<u>Methodological rules</u>;	
	Controlled experiments	Making sure to set up the same conditions and controlling the variables to minimize the occurrence of possible errors
	Considering different opinions	Recognizing different opinions during the research
	Ethical considerations	Certain values that include concerning the rights of the subjects

4.1.2.1 Steps of the Scientific Method

As it is seen, teachers' views of scientific methods were diverse. The most stated view [T.I, T.L, T.H, T.A, T.B, T.J, T.C] about scientific methods were the steps of stating a problem, forming a hypothesis, and testing the hypothesis for verification. Teachers were more likely to explain the scientific method with the consecutive steps of processes. Also, according to teachers, doing experiment, observation, and research are essential methods in testing hypotheses. For example, Teacher J explained the steps of the scientific method in the following:

> "You state a problem, ask questions about it and propose an idea or hypothesis for a solution. And to verify this hypothesis, observations and experiments were conducted, and if it is verified, it proceeds as theory and law." [T.J]

Graduate student teachers talked about both scientific methods and research methods together in their explanation:

> "There is a standard method we follow. We state the problem and purpose, observation is in every step, you gain background knowledge. Then you form a hypothesis and follow a scientific process to test the hypothesis. This process could include experimentation, modeling, different practices would produce scientific knowledge. We generally talk about experiment or modeling, argumentation is also another method. After collecting data through these processes we connect these data to a conclusion, then analyze and interpret. Then we go back to our hypothesis to check whether it is

> verified or not. And, the literature review is in every step of it." [T. L]

> "For example, since I am doing a scientific study, data collection, data analysis, observation, based on quantitative and qualitative observation writing results, discussions, suggestions these kinds of thing come to my mind… In the qualitative study, you conduct an interview instead of an experiment" [T. K]

Some teachers understanding of scientific methods was related to the practices and tools they used in classrooms. Such as Teacher D, who had a bachelor's degree in physics education, mentioned about using visualization, smartboard, and laboratory settings when scientific methods were asked. Another teacher's (T. B) first thoughts on scientific methods were doing research, preparing posters and projects, presentation, outdoor activities etc. Another teacher (T. G), graduated from physics, first implied doing experiments in the science lessons and then added doing research, discussing different opinions as methods.

4.1.2.2 Hypothesis

While talking about scientific methods, most of the teachers [T. F, T. I, T. E, T. D, T. B, T. J, T. G, T. C] stated that forming a hypothesis is essential in scientific studies. They see the hypothesis as stating the purpose of the study, or an opinion to investigate. The following presents examples from teachers:

> "Forming hypothesis is a part of a scientific study. How can one know what to study without stating the hypothesis? When you think from the student's perspective, it does not seem necessary, they always ask us why do we write this. In order to

achieve the aim, you should propose a hypothesis and show whether it is right or false in your study. I do not think one can carry out a study without it." [T. B]

> "In TUBİTAK projects, we undertook every study having hypothesis. For example, there were studies of social studies, mathematics, information technologies, design and technology, and in all these we proposed our hypothesis, asked questions, analyzed and done things" [T. J]

The rest of the teachers (T. H, T. K, T. L, T. M) who took course/seminar about the NOS and one who did not [T. A] indicated constructing a hypothesis was not required in every study.

> "In some subjects, it is needed. In experimental studies that involve dependent and independent variables. Not in every study" [T. A]

"I do not think it is always required. Sometimes it could restrict the scientist" [T. M].

4.1.2.3 Domain-specific Methods

While teachers talked about the diversity of scientific methods, they focused on the methods of experimentation and observation. Mostly they attributed observation to biology studies and experimentation to physics and chemistry studies. For example, teacher E expressed his views in the following:

> "It changes according to the scientist and science. For example, if it is history s/he needs to investigate different cultures, whichever society s/he

> investigates needs to collect data accordingly. In biology generally data collected from the environment and nature, chemistry collects data in laboratories via trial and error, and in physics, physics rules are different that they can use mathematics and collect data." [T. E]

Additionally, some teachers who were among the ones read books and took course/seminar related to the NOS mentioned about the methods used in non-manipulative studies along with the indication of domain-specific methods. They emphasized collecting historical evidence based on the observations from previous research studies and making predictions and deductions regarding the phenomenon. For example, Teacher M's explanation indicated the diversity of the methods provided below:

> "When I say scientific methods, I think of, for example, experimental, theoretical methods like the theoretical side of physics or in space studies methods of observation or modeling… In the past, there were specific steps to follow, but now we teach children that these steps can be different… For example, in space research, they can collect data via observation. In social studies, we may only collect data by reviewing old letters. data can be collected via experimenting, or by modeling and by making simulations data can be collected." [T. M]

The following codes are related to teachers' responses on their understanding of the methodological rules that scientists should consider during their studies.

4.1.2.4 Controlled Experiments

The most prevalent code among the teachers (T.L, T.C, T. E, T. F, T. G) was conducting controlled experiments to minimize the errors in scientific studies. They added it was necessary to try to set up the same conditions and repeat the experiments many times. An example excerpt can be given below:

> “While doing experiment s/he should be careful about setting up the same conditions, should repeat the same experiment in the same conditions couple of times or should do it with a second observer”.(T.C)

4.1.2.5 Considering Different Opinions

Some teachers (T.E, T.J, T.C, T.H, T. M) stated it was important to have a second observer or consulting and sharing the results with other scientists during the study. The following is the example quotation:

> “(S/he) should consider the other scientists’ opinions. (S/he) should review the scientists' views who investigated the same subject. Later should be careful about the experiments and observations s/he is going to do and should set control points, do controlled experiments.” (T.E)

4.1.2.6 Ethical Considerations

Another common view held by teachers (T. A, T. C, T. H, T. K, T. L, T. H) as a must was the ethical issues involved in scientific studies that use animals and humans. Teachers underlined not harming the subjects, being responsible and respectful for the livings’ lives, and protecting diversity should be a priority. Teacher K and

Teacher L (graduate-students) additionally stressed getting consent from the subjects, and permission from ethical commissions was crucial to make sure that data will be used only for scientific purposes. Teacher L expressed her views in the following:

> "For example, while doing experiments with humans there is a permission issue, they need to take consent for sure, they can predict the possible effects based on the previous studies what kind of implication may occur."

4.1.2.7 Summary of the Findings Regarding Science Teachers' Views about the Meaning of Methods and Methodological Rules

While talking about scientific methods, most of the teachers mentioned the stepwise methods, while graduate-student teachers emphasized the non-successive nature of the methods, including research methods. Also, hypothesis, historical and observational evidence, doing controlled experiments and taking different opinions into account, and ethical considerations were among the codes teachers mentioned. It can be said that teachers who took classes/seminar and read books about the NOS were more inclined to provide the diversity of the methods. Additionally, the code of considering different opinions and ethical considerations emerged from teachers' interviews answering the methodological rules to be considered in studies. Teachers thought ethics is an important factor scientists should consider during their studies, while in the RFN framework, these issues are discussed in the social-institutional category. Besides, the responses indicated that teachers used scientific methods and practices interchangeably.

4.1.3 Meaning of Scientific Practices

Teachers were asked what they think about scientific practices that are used in scientific studies. In the case of whether teachers were not familiar with the term of scientific practices, it was addressed as science process skills. the child-codes identified under the meaning parent code were presented in Table 4.1.3, and elaborated in the subsequent sub-sections.

Table 4.1.3 Codes from the meaning of scientific practices

Parent code	Child code	Explanation of the code
Meaning	Communication	Engaging arguments and discourse related to findings
	Creative thinking	Thinking differently, developing new solutions to problems
	Critical thinking	Ability to question, analyze, make informed judgments and decisions
	Observation	A scientific practice of gathering data using all senses through attentive watching, noticing, or making inference from people or objects
	Experimentation	A scientific practice of conducting investigations carried out through testing, manipulating variables to produce and collect reliable data

4.1.3.1 Communication, Creative thinking, Critical thinking

Teachers' responses regarding the meaning of scientific practices varied. One teacher (T. I) did not give an answer, two teachers (T. A, T. B) interpreted it as physical skills that some students have or as an interest in certain subjects. At first, T.A explained it as that boys were more competent in the subjects of electricity and girls were more interested in biology topics. And another teacher (T. H) said that the word practice reminded him the applicability of knowledge to real life.

When the question was readdressed as science process skills, teachers' responses (T.K, T. L, T. D, T. M) revealed that they view 21st century skills like communication, critical thinking, and creative thinking as scientific practices. Teachers' explanations can be given as the following:

> "I think the child has reasoning skills, based on questioning, factor leading to his/her creative thinking. For example, when s/he connects his/her prior knowledge to the new concepts s/he learned through reflective thinking s/he gains creative thinking skills. You cannot teach one that has no questioning skills. I think science literacy is also another skill. Also, the skills that lead to that are important." (T. K)

> "When I say science process skills, I think that there is information around us and methods to acquire and use it in a way to integrate it to our lives and needs… I think of it as a whole; acquiring knowledge, using knowledge, producing it, and disseminating it… Also, it reminds me communication. Like in the science process skills communication, sharing…scientists communicate with each other" (T. M)

4.1.3.2 Observation

Among teachers (T. L, T. H, T. K, T. E, T. A) the most expressed practice was observation. They considered observation as a scientific practice because it follows certain steps to search for answers, and it enables elaboration, objectivity, justification, and presenting ideas independently in scientific studies. Teacher L explained as in the following:

> "What makes observation scientific is to base it on something. For example, when we observe the planets' movement, we ask whether there is a pattern or standard. Observing with asking these kinds of questions, if you are leading with the questions like what it affects, what it changes, or what it causes in your observation if you are looking answer to these questions then you conduct the scientific observation." [T. L]

4.1.3.3 Experimentation

Teachers generally used experiment and observation together while talking about both scientific practices and methods. However, some teachers (T.D, T.F, T.B, T.J, T.H) explained an experiment as an activity or process conducted to see the results and products of research. Example quotations are provided below:

> "I can define experiment as the observation process conducted under the light of existing information to reach new information." (T.H)

> "The characteristics of an experiment, I think, is to see the product of the research for which we study and formed hypothesis" (T.B)

Teachers K, L, and I emphasized the characteristics of manipulating variables that contribute trial and error process. However, one of the teachers (T.G) said that she does not know how to explain the concept.

4.1.3.4 Summary of the Findings Regarding Science Teachers' Views About the Meaning of Scientific Practices

Regarding scientific practices, teachers talked about communication, critical thinking, creative thinking, experimentation, observation. Other practices considered in RFN like classification, prediction, explanation, model, representation, etc. were not expressed as a practice. Creative thinking and critical thinking were emergent codes revealed from teachers' interviews characterizing their understanding of scientific practices.

4.1.4 Meaning of Scientific Knowledge

Teachers were asked about their views of scientific knowledge, its characteristics, and the forms of scientific knowledge, which are laws, theories, and models, as explained in the RFN structure. The codes revealed from the interviews were given in Table 4.1.4

Table 4.1.4 Codes from the meaning of scientific knowledge

Parent code	Child code	
Meaning	Testable	Information that is gathered through sets of scientific methods
	Universally acceptable	It is believed and accepted by everyone without no disagreement
	Tentative	Changes in scientific knowledge with new evidence
	Trustworthy	Reliable knowledge that has been justified by various methods
	Consistency	Acquiring the same results when the study is repeated in different times and places
	Laws	
	as proved theories	Theories become laws when enough evidence is collected
	as an observed phenomenon	A form of scientific knowledge that describes the relationships among the observed phenomena in the natural world
	Theories as proved hypotheses	A hypothesis becomes theories when they are proved
	as unconfirmed prediction	Theories are predictions that have not reached certainty
	as explanations	A form of scientific knowledge that explains how natural phenomena work
	Models as visualization	A form of scientific knowledge that is a representation of the system of ideas

4.1.4.1 Testable

When teachers were asked about their understanding of scientific knowledge and its characteristics, most of them described scientific knowledge as tested and proven to be true via sets of scientific processes. In other words, it was conceptualized as testable information obtained through experiments and observations based on rational reasoning. Some excerpts are provided below:

> "I think information which gone through the scientific process is scientific knowledge. I mean data is examined with experiment or observation, with processes relevant to its nature and presented explicitly." [T. M]

> "Scientific knowledge, I mean, is supported, went through a process, acquired with logical cause and effect relation." [T. L]

4.1.4.2 Universally Acceptable

Some teachers also emphasized being accepted by the majority as a characteristic of scientific knowledge. When information is researched and proven, it has to be approved by all around the world. Teachers further attributed this to be universal. Examples are as the following:

> "Scientific knowledge is the knowledge that producing the same results everywhere in the world. I mean, it should not show diversity and variance. It is universal, not tentative, accepted by all the people." [T. B]

> "What makes knowledge scientific is that it is being universal. Approved by everyone, does not change [with respect to] by a person or by occasion." [T. G]

While these teachers associated being accepted with being unchangeable, Teacher K indicated otherwise.

> "When I say scientific knowledge, I think of objective knowledge that is tentative, universal, accepted by everyone, but its tentativeness is accepted as well."

4.1.4.3 Tentative

All the teachers agreed that scientific knowledge has a tentative nature. However, there were teachers (T.B, T.G) asserted conflicting views, such as while expressing scientific knowledge is absolute and does not change, also expressed scientific knowledge is tentative. For example, Teacher B stressed that it does not change, but it can be updated. In a similar vein, Teacher G indicated that while scientific knowledge is universal and does not change, she also said that as long as people constantly improve themselves, science will change and develop over time. Teachers' beliefs regarding the tentative nature of scientific knowledge are based on the number of reasons. The majority of the teachers believed that scientific knowledge changes and develops with respect to developments in technology, level of development, and the economy of the countries.

> "Why does it change because science is constantly changing, you learn new things all the time. You discover new things, so the scientific knowledge you acquired years ago is limited to that time's conditions. So as the amount of information increases, technology develops, so many different things come up." [T. K]

Another teacher pointed out the political attitude adopted by a country to its scientists was another point to consider.

> "I think it is closely associated with the level of development, economy, the financial opportunity of the country. The respect, the value it gives to its scientists, maybe the fee-paying to scientists, all important" [T. A]

Four of the teachers' [T. K, T. L, T. M, T. E] point of view implicitly linked to the development of scientific knowledge with the paradigm shift which implied as to the accumulation of knowledge that scientists develop by adding up to the previous which were inadequate or rejected. Example quotation is given below:

> "… Else, judgments can sometimes change such as religious judgments like in geocentric vs. heliocentric models or evolution, somethings it can be so obvious they change as well. Their change results in reaching more people leading to more interaction. Other than its effects, humanity changes. Devices people use change, and that can also affect I think." [T. M]

4.1.4.4 Trustworthy

Some teachers (T. L, T.D, T.E, T.M) asserted that scientific knowledge should be trustworthy that should be realistic, and should not mislead people. While Teacher L emphasized that providing evidence to support the claim was important in the process, Teacher E interpreted it as the scientific knowledge being consistent with the natural world and coherent with the existing knowledge. Teacher M focused on contradiction in the process:

> "Actually, the knowledge that went through the scientific process is scientific. But sometimes, as in the cancer example, some institute in America says we still work on finding a cure to cancer, someone else comes up and says it has already been found using stem cells. I think it should not create conflict. You think it followed the procedure, but somethings corrupt it, we know the issue of making money that compels the process."

4.1.4.5 Consistent

The most asserted aim in the process of producing scientific knowledge was the consistency of the data. Teachers (T.M, T.C, T. H, T.G, T. E) expressed reproducing the same result when the experiment and studies were repeated at different times, and places were important to be accepted as scientific knowledge.

When it comes to forms of scientific knowledge, teachers were asked about their understanding of laws, theories, and models based on RFN.

4.1.4.6 Laws as proven theories, Laws as observed phenomena

Teachers' responses regarding scientific laws basically fell under two explanations. One opinion that most of the teachers (T.I, T.F, T.J, T.C, T.D, T.B) held was, laws are proved theories. Further, they explained laws must be accepted by everyone, their validity and accuracy are proven, and they are absolute truth. Based on the assertion of laws being the final form of knowledge, they agreed that laws cannot change. Related examples are given in the following:

> "Law, its validity firmly proven… knowledge changes but I don't think at the law level, it does not change." (T.F)

> "Law is the next step of theories, accurate. If the theories are proven in many ways that won't lose its validity, then it can become law." (T.J)

The second explanation about laws was provided by two teachers who were graduate students (T. K, T. M.) indicating statements that describe the observed phenomenon.

> "I think scientific laws are observable, repeated phenomena. Such as we observe gravity, we say this happens that when (we) drop something from a certain height it falls towards to earth then we produce theories to explain it." [T. M]

Together with two other teachers who could not provide a reasonable answer regarding scientific laws (T.G, T.E, T.A) and graduate-student teachers (T.K, T.L, T.M) expressed that scientific laws can be changed based on the latest discoveries. However, it was noticed that while T.L, T.K, T.M supported their ideas through the tentative nature of scientific knowledge, the explanation of other teachers was either irrelevant or based on wrong justification. It can be seen in the following excerpt:

> "There is no such thing that laws cannot be changed. They can be accepted internationally but still can change. For example, before, everybody agreed upon the idea that monkeys are descendants of humankind, but many countries refuted this."(T.E)

4.1.4.7 Theories as proved hypotheses, theories as unconfirmed prediction, theories as explanations

Considering theories, some teachers (T.J, T.C. T.E) defined them as scientifically proven hypotheses or ideas that were tested and searched upon. On the contrary, some teachers described theories as unconfirmed predictions, not proven, or inconclusive research-oriented knowledge (T.F, T.D, T.A). The teachers who are graduate-students (T.K, T.L, T.M) expressed theories as statements that are used to explain the phenomenon.

4.1.4.8 Models as visualization

Regarding models, only one teacher who was a physics graduate (T.G) mentioned when explaining theories as presenting opinions and modeling. But in general, teachers did not talk about models as a form of scientific knowledge. When their views about models asked, there was a consensus definition on its visualization and physical representativeness of the concepts on a larger or smaller scale. Teachers pointed out different properties. Some teachers (T.D, T.L, T.M, T.A, T.J, T.F, T.K) pointed out the explanatory power of the models. They asserted that models make the concepts and phenomena easier to explain and comprehend through enabling physical representation and simplification of the complex. Additionally, two teachers (T.M, T.E) indicated that their representation is not exactly the same as the original. Teacher M expressed his/her views in the following:

> "As a property, I can say that they are not always exact. Like in atom theories, if it provides a solution or meets the needs, we use it, if it does not, then we start to research again why it does not." (T.M)

We can see from this example that she implicitly referred to the mediation role of the models in the growth of knowledge.

4.1.4.9 Summary of the Findings Regarding Science Teachers' Views About the Meaning of Scientific Knowledge

Teachers addressed scientific knowledge as tested, universally accepted, tentative, and trustworthy. The tentativeness of scientific knowledge revealed different justifications, such as some attributed to the advancement in developments while some pointed out the paradigm shift in thinking. Also, some teachers could not provide elaborative answers regarding the tentativeness of the scientific knowledge, which led to the contradiction in their interpretation. Teachers' responses revealed three emergent categories characterizing teachers' understanding of theory, laws, and models, which were laws as proved theory and as an observed phenomenon, theories as a proved hypothesis, unconfirmed predictions and as explanations, and finally, models as visualization and physical representation. It was noticed that while codes did not vary based on characteristics of teachers however the explanations showed graduate-student teachers displayed more informed explanations.

4.1.5 Meaning of Social-Institutional Aspect of Science

Teachers' views on whether science involves social and institutional aspects and their thoughts on the related matter were asked. The revealed child codes were presented in table 4.1.5 and explained in the following sub-sections.

Table 4.1.5 Codes from the meaning of social-institutional aspect of science

Parent Code	Child-code	
Meaning	Social and cultural context	The effect of the social and cultural context of societies on scientific processes
	Ethos	Attitudes that scientists are expected to display during their scientific activities

Table 4.1.5 (Cont'd)

	Dissemination of scientific knowledge	Sharing and publishing the findings of scientific studies through various events
	Social organizations	Institutions where scientists work such as universities, research centers
	Political powers	Effect of politicians and ideology of governments on scientific processes
	Financial system	The role of economic resources and fundings in scientific studies

4.1.5.1 Social and cultural context

Teachers talked about the mutual relationship between the scientists as an individual and the society, culture, religious behaviors in which s/he is raised. All the teachers asserted that the cultural and social context of the society has an impact on the practice of science, its dissemination, and its development. Some teachers claimed these values sometimes restrict the study. Teacher E explained as:

> "Being influenced by cultural environment, such as the moral codes imposed by in religious societies could limit the studies." (T.E)

They also stated that the approaches of the societies toward scientific development or studies could also play a role in science. Example excerpts are provided below:

> "What is produced even one person produced it, it becomes public knowledge, social. The societal dynamics, like relations of production as feudal or capitalist, affect scientific knowledge in terms of both accessing the information and disseminating it. For example, someone comes and says, I thought about it lately, say the earth is flat, that does not get accepted by the society, always encounters resistance, engages in a struggle that is why I think it is mutual" (T.M)

> "it can affect all the livings and humans, for example, artificial skin impacts everything. Scientific processes can be influenced by the social environment. For example, today's technology may be advanced more than we know, or they come up with things that we don't know, like DNA or human lifetime. But since the social and cultural structure of the societies are not readily suitable for these, they are not made public" (T.J)

4.1.5.2 Ethos

All teachers mentioned about the attitudes that scientists should adopt during their studies and interactions. Mostly expressed values were respecting the lives and the rights of the livings and environment, respecting the diversity of the opinions, being open-minded, being collaborative with their colleagues, and acting with the common goal of contributing scientific knowledge. Teacher L expressed as in the following:

> "It is universal they use the shared common literature, and they should try to abide the ethical values comes within the diversity of people or the cultural differences which are the accepted inevitable parts." (T.L)

Teachers who were graduate students additionally put forward the values of academic integrity such as not plagiarizing, not holding or distorting any information they found even though they are not supporting the previous or current studies.

4.1.5.3 Dissemination of scientific knowledge

Teachers also talked about the importance of the dissemination of scientific knowledge. Attending conferences, seminars, lectures given in universities, or via technology and even social media were stated as the mediums that scientists could share their findings. They asserted that these activities would contribute to sharing new ideas to the larger masses, which enable broaden their point of views. While most of the teachers considered from the scientists' perspective, graduate-student teachers also took into consideration of the people who are not scientists. Through these means, people, as well, could access or even contribute to the studies. The following excerpt points out the case:

> "I looked for something about the theory of the formation of the moon. And I heard there was a certain consensus formed in China, which means that the conferences, seminars scientists hold and come together are effective to reach consensus…I read something recently, there is a system that everybody can measure their soil quality and upload it to some server. Who uses and for which purposes they use the database is another issue, but everybody can contribute to the science" (T.M)

4.1.5.4 Social organizations

Teachers also provided answers for the organizational structure in science. Most of the teachers mentioned the universities, institutions like CERN, NASA, and TUBITAK where scientists do science. One teacher (T.G) said that science should not be conducted under organizations; scientists should be supported and left free. Teachers also asserted that status difference like graduate student, associate professor, and hierarchy within these institutions could impact the interactions of researchers in and out of these settings. While most of the teachers talked about the challenges researchers might face, like being dictated by the superior or being overshadowed, or facing obstacles while publishing their studies, some teachers (T.K, T.I, T.C) also added opportunities come with working in such organizations such as gaining status in the eyes of others, or being more motivated by these challenges.

4.1.5.5 Political power

Political power structures were another aspect that teachers commonly referred. All teachers mentioned about the impacts and consequences of the ideology or policy adopted by the countries on scientific researches and development. They pointed out that governments' intentions, priorities, and funding could change the way science is practiced, its purpose, scientists' research, and publication orientations. Such that certain studies' processes or data might be concealed, which would hinder further research, or only particular research areas get funding. Some (T.J, T.A, T.D) drew attention to the movement of academics from their country to other countries where they could continue their research in better conditions resulting in brain drain. There were also teachers mentioned the impacts on the public. For example:

> “Other than, some do not say that this country has already found aids but does not spread over which can lead to inequality among people. Or the thing that we always talk about, for example, intervention before birth, maybe it does not impede the development of scientific knowledge but universalism. “(T.M)

4.1.5.6 Financial systems

All the teachers shared the view that financial systems were a significant part inherent in scientific endeavors. Financial opportunities of the researchers such as for equipment, funding allocated to the institutions, making capital out of products, and pursuit of profit were the points teachers considered. Such as:

> “Scientific knowledge today produced by universities or technology through the industry. In both cases, if they do not produce exchange value or put those on sale, they are not supported… Even concerning the simplest disease for which we all know the cure, people’s recovery time changes based on their economic status, which is inequality, I think.” (T.M)

This teacher pointed out how the financial context of science closely concern and functions at the institutional level and the public.

One teacher indicated the impact on the accessibility to the information:

> “Today information should be reachable, unfortunately, some journals, for example as a scientist when I publish an article it pressed by a journal and that journal does not make it accessible for a period

> of time to make people buy it, I do not find this ethical. The purpose of producing knowledge should not be commercial." (T.L)

Also, another teacher emphasized how it can be used as a source of power over other countries:

> "For example, making rockets, establishing nuclear power stations are highly costly practices; therefore, they are correlated. It was also important at the beginning of the era of the cold war. In fact, you can see the political power. In space studies, politics (and) economy were particularly more important. For example, the commerce of power plants shows a certain power since it is a commercial activity. Yes, there is a scientific study, but since it (that country) is founding it on your country, for example, Russia is planting, hence it has a certain pressure on you. Accordingly, the economic superiority posed on you actually affects (your) scientific work. You cannot work freely, for example" (T.K)

4.1.5.7 Summary of the Findings Regarding Science Teachers' Views About the Meaning of Social-Institutional Aspect of Science

Teachers' responses about social-institutional systems revealed the codes of social and cultural context, attitudes, professional activities and dissemination, social organizations, political power, and financial system which were consistent with the related literature of RFN. Considering the aspect of social-institutional teachers' views differed in terms of examples they provided, but there was no correspondence between their characteristics identified in the study.

4.2 Science Teachers' Views about the curricular emphasis of RFN

The second research question was about teachers' views regarding the integration of RFN aspects into the science curriculum. Teachers were asked about whether there is an emphasis on the related aspect in the curriculum and were asked to provide an example. Analysis of their responses revealed the child-codes presented in Table 4.2. The results concerning the science teachers' views about the curricular emphasis of RFN were presented for each aspect separately.

Table 4.2 Codes form teachers' views on curricular emphasis

Aspects	Child-code	Explanation of the code
Aims and Values	Not integrated	There are no objectives about the aims and values
	Insufficient	Not all the characteristics included, mostly social values
	Implicit	The section about values education or scientific literacy but not explicitly presented as objectives
	Irrelevant example	Teachers gave examples about the aims of the scientific experiments and observations
Methods and methodological rules	Not included	No objective related to scientific methods
	Sufficient	Sufficient emphasis is given regarding the level of students
	Experimental methods	Data collection practices including experimentations, data manipulation, using dependent/independent variables
	Single method	The portrayal of the steps of the scientific method
	Included	Presentation of different scientific methods; data collection via both manipulative/non-manipulative methods

Table 4.2 (Cont'd)

Scientific Practices	Sufficient emphasis	Scientific skills that students are expected to develop
	Insufficient guide (for teachers)	The objectives are not clear enough for teachers
	Experimentation, observation, classification	There are objectives stating students be able to explore, experiment, make observation etc
	Manipulation of variables	Mostly objectives related to practices involving variable manipulation such as testing the brightness of a lamp
Scientific Knowledge	Insufficient guidance	The relationship among the theories, laws, and models are not given clearly for teachers to connect to the production of scientific knowledge
	No objective	No objectives about the characteristics, forms of scientific knowledge, and relationship among the types
	Insufficient emphasis	No sufficient details were given about the characteristics of the laws, theories, and models
	Presence of types of scientific knowledge	Scientific laws, theories, and models are included

Table 4.2 (Cont'd)

Social-Institutional system of science	Superficial emphasis	Teachers expressed curricular emphasis was superficial but did not elaborate his/her response
	No emphasis	No objective included related to the category
	Emphasis in textbooks	Short passages about the lives of the scientists included in the science textbook

4.2.1 Aims and Values

Regarding the aims and values of science, most of the teachers asserted science curriculum does not integrate the aims and values of science enough. One teacher (T.I) uttered that these were not included, and she even specified that there is no need to include them because students already did not understand the basic concepts. Three teachers (T.K, T.L, T.M) said that the aims and values of science were implicit in the curricular level and not clear such that it is all up to teachers whether to teach in their lessons. T.M explained this through comparison with the previous program:

> "Not explicitly, it is getting less and less. For example, I think that in the program of 2004 they were explicit, but I was not a teacher then, but when I go back and look at it, there were aims, now only it says science literacy should be mentioned and history of science should be stated, but they do not make the connection with the NOS that is why I think not enough."

> "These are implicit in the program. There is values education, there is something we call attitudes, but these are not given as objectives… it is totally up to the teacher" (T.L)

One teacher, when she asserted aims and values were referred in the curriculum, the example she gave was irrelevant to the aspect.

> "With the recent curriculum doing an experiment, forming hypothesis during this process, doing scientific research, drawing a conclusion, maybe at the end of it, this year these are put, presenting, publicizing are put in the program" (T.B)

4.2.2 Methods and methodological rules

While three teachers (T.J, T.C, T.G) expressed that they were not included in the curriculum, the majority of teachers thought the curricular emphasis was enough regarding methods and methodological rules. However, one teacher's justification of enough emphasis was based on the low academic level of students.

> "In the simplest form, they do not even understand a certain process, so (whatever inside the book is) enough. Maybe they (program makers) can do this; prepare a different curriculum for high intelligence students to whom these methods can be taught. But what we have is (level of students) obvious, so there is no need." (T.I)

Additionally, some teachers (T.L, T.A, T.E) pointed out that mostly experimental methods were included in the program. An example is given as the following:

> "The different scientific methods are in the curriculum. Recently these are started to be included in the curriculum, these scientific methods, engineering design cycle, something we did in this year with 5th grades. Mostly there are experimental methods, and we mentioned dependent independent variables. I tried to tell as much as I can that there are different methods, experimentation is not only one, but it is not clearly specified (in the program)."(T.L)

Another teacher talked about how the methods included in the curriculum could promote the portrayal of single-method and how this depiction in the program could lead to misconception.

> "We mention something about scientific methods in applied science class; how do we do science, how do we solve problems but not in other units… it is given as steps in the program. But since it is given in a successive order does not mean there is a hierarchal order, in that sense, you cannot say anything to program makers. He does not tell you this is that, follow this order, just says these are the steps considered in scientific studies." (T.K)

4.2.3 Scientific practices

All the teachers agreed that scientific practices were included in the science curriculum. They emphasized science process skills such as experimentation, observation, and classification were in the program, they communicate these in the lessons since they follow the program. One teacher (T.M) elaborated that inclusion was not enough.

> "When I think of the new curriculum it mentions, it says (students) explore through experimentation. I mean, in the objectives s/he explores variables affecting the brightness of the lamp with experiments., but that is it. There used to be teacher guidebooks, but not now. That depends on how the teacher structures that exploring process, if s/he does. Whether via argumentation or a group project etc., it is all up to the school or teacher. Because of it, it is insufficient." (T.M)

> "For example, classification of substances like solid, liquid, gas; livings as vertebrate, invertebrate or the plants, we do these kinds of classifications." (T.J)

Other teachers referring to the recent studies on curriculum stated the practices were started to be addressed more. One of the teacher's interpretation is provided below:

> "With the recent updates on the curriculum, there are more attempts to place these in the program. They are trying to put teachers in guidance positions to help students contribute to the scientific process." (T.B)

Another teacher asserted that these were comprised in the curriculum, yet practicing these was troublesome.

> "We have questions (objectives) like explores, makes experiment, tests etc. when we examine the structure of the program there is no much problem… but I think there is a problem in the application…

> There is classification, experimentation, what else, observation. For observation, the student observes the phases of the moon and draws." (T.L)

4.2.4 Scientific knowledge

All teachers, except two (T.G, T.I), asserted that the types of scientific knowledge were included. Additionally, graduate-student teachers (T.K, T.L, T.M) underlined the lack of indication of the relation among them. Another point was that these were not clear enough for all teachers to comprehend in an intended way and put into practice. Excerpts from teachers are as follows:

> "Regarding characteristics scientific knowledge not much… but there is no objective about characteristics of scientific knowledge, and I don't think most of the teachers will teach. If there, it is implicit not understood in the same way by everyone." (T.L)

> "We take it as a historical process we teach atom theories. How you plan the lesson is important. It changes depends on that whether do we consider it as information that students memorize and to be asked about later or do we teach to provide a point of view." (T.M)

Also, another teacher (T.G) expressed a similar view that she did not think these were in the curriculum because there was not much guidance in the program. Other teachers shared the idea that the terms of laws, models, and theories were present, yet, they did not provide an opinion regarding the characteristics of scientific knowledge.

4.2.5 Social-institutional system

When it comes to social-institutional systems of science, most of the teachers (T.J, T.C, T.K, T.G, T.I, T.F) said that these aspects were not included in the education program. And the other teachers mentioned that these were either in the program or superficially represented that teachers cannot make the connection. Examples are provided as the following:

> "I think nothing is clear in our program, or it is open to interpretation. … we could only push the objective to include such as media and science or the nature of science. It is open to interpretation. I think it needs to be clearer, I mean, what they were thinking when they wrote that objective what kind of practices can be done with that should be clearly written." (.TM)

> "There is no direct mention. There is something about the structure of science, attitudes, or values education. But when you look inside, it does not say these should be communicated, it is again up to the teacher." (T.L)

Some teachers referred to the textbook inclusion while talking about curriculum integration which indicated social values and organizations. Such as:

> "Scientists' lives sometimes are shortly given in the textbooks. They mention the values. For example, what Einstein said, short story about his life is given." (T.E)

> "These are present but shallow…there are lots of things in our book regarding on what chemical engineering have an effect, on what biotechnology have an effect, on what genetic engineering have an effect, on which institutions have an effect, but superficial I mean in only one or two pages." (T.H)

4.2.6 Summary of Teachers' Views about Curricular Emphasis of RFN

According to teachers' responses, the aims and values aspect emerged as the least mentioned aspect in the curriculum. Regarding scientific methods generally, teachers stated that inclusion was enough, and experimental methods were prevalent. Regarding scientific practices, teachers stated that there was enough emphasis on the practices, including experiments, observation, and classification. On the other hand, a lack of guidance for teachers on integration was also mentioned. When it comes to scientific knowledge, all teachers, except two, agreed on curriculum emphasizes the forms of scientific knowledge, while it lacks the inclusion of how they are linked. The social-institutional aspect appeared to be another least included aspect when the teachers' views were taken into consideration. While the majority thought it was not included or implicit, others pointed out the social values and social organizations referred to in the textbooks.

Overall, teachers did not provide examples regarding the aspects when they thought it was insufficient or implicit. They gave irrelevant examples to the aspect, such as one teacher while talking about aims and values; the example she provided was about scientific practices. The other prominent view regarding the inclusion was that even though teachers expressed the aspect was mentioned, the way it was presented was not clear enough for all teachers to comprehend and apply from the same perspective.

4.3 Science Teachers' Views about RFN integration to their instruction

The third research question was "How science teachers integrate NOS into their lessons based on the RFN?" In the light of this question, teachers' views regarding whether these aspects should be taught to students and how they would integrate if they think it is necessary were also asked. In the following teachers' views for each aspect were elaborated with excerpts.

Table 4.3 Codes from teachers' views on RFN integration into their instruction

Aspects	Child-code	Explanation of the code
Aims and Values	Lack of student interest	Would not integrate because students would not be interested in this side of science
	Difficult to teach	It is both difficult to teach for teachers and learn for students, especially in middle school
	Examples from the history of science	Incorporating the history of science into the instructional process, such as providing historical information about the origins and the development of the scientific studies
	Daily life examples	Mentioning the controversial recent events in the country and the world
	Activities involving consideration of aims and values	Doing activities that encouraging students to engage in discussions related to scientific aims and values

Table 4.3. (Cont'd)

Methods and methodological rules	Complicated	It is hard for the student to understand because it is complicated and abstract
	Insufficient laboratory conditions	Cannot integrate experimental methods because the laboratory conditions are insufficient
	Limited time	The number of science lessons is not enough to allocate time to elaborate the aspect
	High curricular load	Primary concerns about covering the high number of objectives in the curriculum limits teachers instruction

Table 4.3. (Cont’d)

Scientific Practices	Necessary	Considers necessary for students to learn because it would promote students to gain self-confidence and make familiarize with the scientific procedures
	Explicit integration	Directs students attention to the practices and their roles in the process
	Implicit integration	Teachers make demonstrations or ask students to perform certain practices such as observation, experimentation, however, do not deliberately give details and make explanations overtly
	Insufficient resources	Due to limited conditions in the schools cannot practice scientific practices such as experiments
Scientific Knowledge	Inadequate understanding	Teachers do not hold adequate understanding about the characteristics and the forms of scientific knowledge to teach confidently
	Hard to teach	The concepts are compelling for teachers to teach
	Emphasis on models	Compared to laws and theories, emphasis is mostly given to the representation of the scientific models in the lessons

Table 4.3. (Cont'd)

	Inadequate guidance in textbooks	The given content is not clear enough for teachers how to include and relate to the development of scientific knowledge in their instruction
Social-Institutional system of science	Not useful	It is not useful for students to learn this aspect because it is not fun and would not attract students' attention
	Necessary	Considered necessary for students to learn this concept because it would raise students' awareness related to science's different aspect
	No curricular emphasis	Do not integrate because there are no objectives in the curriculum
	Science projects	Teachers include this aspect with having students to involve in science projects

4.3.1 Aims and Values

Teachers' beliefs about integrating scientific aims and values into lessons showed diversity. Two teachers (T.D, T.E), who were among the ones that did not take NOS related course/seminar, thought the inclusion of aims and values of science was not necessary because students would not be interested and would not comprehend. Thus, they expressed that they did not mention these issues in the lessons.

> "It might be too much for the middle school because we even have difficulty teaching about hypothesis… but in high school, these can be taught." (T.E)

> "Maybe after the 7th or 8th grades. These would be necessarily beneficial, but there are problems in our education that from students' perspectives they are not interested in the lessons. I do not know how much these would interest them. We don't mention these because we mostly proceed knowledge-based and prepare (students) to exams." (T.D)

All the others agreed on the aims and values that should be taught to students because they thought it would be beneficial for students in their future careers, contribute to think critically, or change the way they think about science.

Teachers provided different examples regarding their inclusion of aims and values into their lessons. Some teachers (T.A, T.B), while asserting that these should be taught and they try to do it, examples they provided were about doing experiments, explaining its steps, and making connections to real life. At a certain point, that was consistent with their understanding of scientific aims, which was applicability and usefulness in real life. For example, Teacher A stated her views in the following:

> "… by changing the physical conditions of schools, enriching the equipment in the laboratories. Even though we have the equipment, the times when it is not enough for every student, we try to do group works, and there is a time limit… we try to have

> students do experiments… like yesterday we said when the length of conductor wire increases the resistance increases. So we should be careful the cables of an electrical appliance in the house should be short. Why the charger cables of cellphones are getting shorter in recent years, to charge quicker, I try to adapt the information they learn to daily life in every opportunity" (T.A)

Some teachers (T.C, T.J, T.H) stated they try to integrate these via showing animations and documentaries or reading short excerpts about scientists' studies and lives written in the textbooks, which mostly refer to social values.

> "(Students) should learn in early ages that science is refined, that it is a formation completely beneficial for the society and environment, and not only for certain societies or peoples, but it is also for all humanity… In the textbook, it is already integrated. There are subjects about sustainable development, biotechnology, the importance of recycling, gene studies… I try to talk about these more than the curriculum proposes." (T.H)

Three teachers (T.K, T.L, T.M) provided more elaborated examples.–Even though examples incorporated the same points, graduate-student teachers' inclusion depicted a more relevant view.

> "Maybe not much in physics, but actually through the history of science these also could be given. For example, in physics, the subject of electricity Thomas Edison and Nicola Tesla, let's do research about their lives. I gave them homework related to that, and the turned in assignments were mostly copy-paste, and with that, I mentioned about plagiarism that is wrong. When I told them this is basically theft, the students were really shocked… even though it is not included in the curriculum, the integration totally up to the teacher, the teacher's role is effective in this case." (T.L)

The other teacher (T.K) mentioned different inclusion that she practiced in her lesson. She said that while students are designing something, these aims and values could be given as criteria that students should follow during their studies. Additionally, graduate-student teachers emphasized the teachers' role and knowledge in this case coincided with another teacher's comment on the challenges.

> "Middle school students are more curious, but we don't know how to guide them. It was different in 20 years ago we don't know how to do research or how to guide a student who is doing research… We cannot allocate time for these issues. It would be hard… I didn't think before how to teach." (T.G)

4.3.2 Methods and Methodological Rules

All the teachers, except three (T.I, T.J, T.C), showed consensus on the necessity of teaching the scientific methods. Other teachers (T.I, T.J, T.C) thought that teaching scientific methods and methodological rules would be too complicated for middle school children, and they would not understand. Even though these teachers expressed the unnecessity of teaching these concepts, they also expressed that if there is a section in the textbook related to the activities, they implement accordingly. Teacher C's example is given below:

> "I say s/he investigated like that. The guy who flied kite discovered light this interests the kid, first telling this than beginning the lesson draws students' attention… with making a story out of it (I integrate) at this age group, (telling) he did the experiment like that but it was too dangerous if he had insulator for example if he had worn glove, you could not do the experiment as you wish." (T.C)

The majority of teachers stated that they were trying to apply the experiments and observations as suggested in the textbooks. Yet, there are distinctions among their implementations. Such as Teacher I's statement shows more clearly that, though it is superficial, which she attributes to the level of students, she implements the methods the way textbooks display.

> "Maybe superficially, but we cannot even manage to tell specific process, I don't know how these would be taught or whether students would understand. I don't think it will be any benefit.

Maybe I'm thinking of this school, we don't have any bright students. We barely teach 2 times 2 (equals) 4, don't think we can teach those. To integrate these, there should not be curriculum to catch only. We engage too little… The only thing we can do germination experiment. We give the steps of the process, I want them to form a hypothesis. I give the questions such as does germination depend on the light, for example, and ask them to form a hypothesis like it depends or not, whether true or not, try their hypothesis… I say this because I observed this with my students, different groups can show different dynamics" (T.I)

Another teacher stated they only give definitions related to the method but does not practice the activities:

"…how the scientific studies began and developed, I mean we give the definitions, what is an experiment, observation, a hypothesis we tell these, but at the basic level" (T.D)

Teachers' answers implied that even though they try to implement experimental and observational methods in their lessons, they did not consider these as a holistic process. Additionally, while some teachers (T.E, T.F) found it enough to have students make experiments, other teachers also expressed the restricting factors for them to integrate the scientific methods in the class, which were the insufficient resources and laboratory conditions, the limited time allocation for the science lessons in the program, and the large number of subjects to be covered in the curriculum. Teachers complained that even though they had a laboratory, they did not have the necessary equipment for the activities. When they try to supply what was needed, there were too many protocols to follow. And if they get what they needed, by the time the equipment arrives, it would be too late for them to use because they had to move on to other subject units.

The other teachers who were among graduate-students (T.K, T.M) also expressed the diversity of the methods in their lessons. Also, T.K mentioned that during the activities, students could explore the dynamic structure of the scientific methods.

"For example in the 5th grades in the last unit… we told step by step they were both writing, seeing and applying those steps with

> examples… for example, we told as steps, like define the problem, collect data produce alternate solutions, the child told me while I am finding alternative solutions won't I collect data as well? The child him/herself says this. The other one said that, for example, aren't I collecting information while I am trying out the solutions? The child already can understand that it is a cycle that they are related not step-wise" (T.K)

Whether teachers thought communicating scientific methods were necessary or not, based on their comments, it was clear that they were integrating the scientific methods in their lessons because scientific methods were included in the curriculum and textbooks, as they expressed. However, the way they integrate these to their lessons varied based on their understanding and the importance they attribute to the teaching of the related concept. For example, if the teacher mostly focused on the subject, s/he pays attention to the process, does not spend much time on discussing the structure or contribution of the related method to the scientific knowledge. It is noticed that if the teachers were aware of the dynamics of the scientific methods, they were also mentioning these explicitly in their lessons.

4.3.3 Scientific Practices

Regarding scientific practices, teachers pointed out that learning these practices encourages students to gain self-confidence that at least they can try, also make them see that science is not something unattainable. These practices make them familiar and closer to what scientists do and help them to change their view of science.

Three teachers (T.D, T.I, T.G) said since the school conditions were not ideal, they were not implementing in their lessons, and another teacher (T.E) uttered it would be more appropriate in the 7^{th} and 8^{th} grades because at earlier ages, students would be confused. However, it was noticed that when scientific practices were readdressed as the way they mentioned, such as experiments and observations, they told they already teach these because it is in the textbook. This indicated that teachers could not relate what they were referring to as scientific practices. Besides, all the other teachers agreed that students should be involved with these at earlier ages.

Teacher H, C, J, and F stated that they were teaching the scientific practices of the experiment, classification, and observation in line with the teaching program since these are already included in the textbook. Teacher A and Teacher B mentioned the TUBİTAK projects they carried out with students, which promoted students to exercise these practices. There were also teachers specified they do not mention the names of certain practices, such as hypothesis, deliberately in the class with the thought of not confusing students, which suggests certain practices were implicitly integrated into their lessons.

Apart from that, Teacher K, L, and M additionally expressed they were making explicit discussions about the practices, which comprised more practices the other teachers referred to such as discourse, explanation, data, reasoning etc. An example excerpt is given as the following:

> "For example, for 5th grades, we tried to prepare student workbooks considering the new program. Listening to each other or providing data while listening to each other. For example, when they look at an experiment, they check variables, and sometimes we had to do uncontrolled experiments why (do we do that) they notice these… they are more interested in the statements of NASA or (students ask) could there be any mistakes in the photographs Voyage2 takes, who photographed this Voyager, like that they approach more critically." (T.K)

4.3.4 Scientific Knowledge

Teacher B, G, and D told students would not understand such difficult terms and would not be interested in learning. On the other hand, some teachers expressed learning different types of scientific knowledge and their characteristics would help students to be more skeptical not to believe everything they see and hear, to be scientifically literate citizens. Teachers stated that since these concepts, especially models, were included in the textbooks, all were teaching these in the lessons. However, the divergence can be discerned clearly in their inclusion, resulting from how they perceive these concepts. Moreover, there was one teacher (T.I) who expressed her lack of understanding said she did not teach these.

> "These should be taught, first lets we understand then teach the students… these would only make them knowledgeable nothing else… I think these are not included in the program or maybe I

> don't teach… honestly, program makers should think about how to integrate into lessons." (T.I)

Teachers who showed naïve understanding and misconceptions regarding the theories and laws were also prominent in their examples. The following shows some examples:

> "We tell models like this is the model of that. We tell theory, the reality of science. As a law, we actually tell them as well that the symbols that internationally accepted symbols... like we tell you are going to see the information is the same wherever you go in the world…But (concerning) theory and law rather than stating the names, they are implied in the subjects." (T.E)

> "It would be good (for students) to see which steps something goes through till it becomes a law, that at the beginning they were proposed as theories, nothing just happens overnight" (T.D)

Most of the teachers advocated that teaching laws and theories and their difference was hard to teach and learn, so they dwell more on models. They asserted that models enable students to learn through visualizing what can be perceived as abstract. Also, while they agreed that they included laws and theories as well, they meant as titles not elaborating the forms. Related statements are given below:

> "They are already included…such as the theories explaining the formation of universe the Big Bang Theory, Newton theories. There are laws as well, such as the law of gravitation." (T.H)

> "Without models, it would be abstract in the students' minds… it makes it easier to learn. Theories don't interest them as much… for this level of age those would be so verbal in science context…in the textbook, it goes from models to modern atom theory, but we don't elaborate on that" (T.C)

Some teachers also expressed that since the forms of scientific knowledge and its characteristics are not elaborated in the textbook, they did not discuss these topics in classrooms. Two science teachers' statements can be given as the following:

"There could be more inclusion in the book, but I say students are not interested… since our education system is competitive, it is enough for students to learn the (basic) information… We also use what is given, we do not have opportunity to search these." (T.D)

"Modelling is easy because they can see, but laws and theories, their difference we do not tell… When I first started teaching, we taught what is theory, law, hypothesis. These were among the subjects we taught in 8th grade, I think. But now, we do not teach what law, theory, hypothesis is. We used hypothesis in TUBITAK projects." (T.J)

There were also teachers expressed that even though in the program these were not elaborated, they try to emphasize the characteristics of scientific knowledge, such as its tentativeness. Example quotations are given below:

"… when something is learnt it is hard to change later. It is harder to change misconception rather than teaching from scratch… The information is given at school perceived as certainly true. Students need to learn that knowledge can change and that science has a dynamic structure… When we talk about laws and theories, we don't directly give the definitions… Especially when we do experiments, we try to discuss a lot the structure of scientific knowledge." (T.L)

"… students begin to reach information at early ages with documentaries or with the events around them. This (teaching) could make them understand the contradictory situations. For example, one of my students got crossed with me because I said theory of moon's formation because I said "theory" (s/he) got really upset, then I told about theory. Actually, we present them something understandable, transparent. Otherwise, they think scientific knowledge is not achievable… There are objectives say to be able to do models… I like saying that models are not exact,

> it is like a breakpoint. Such as, we did this model, (but) to what extend this looks like the real one, what is lacking how can we do better this, (telling these) feels good." (T.M)

4.3.5 Social-institutional System

Regarding social-institutional system of science, two teachers opposed the idea of promoting this aspect. They (T.J, T.I) said these themes were not fun to learn, would not attract students' attention, and would not be useful for students to learn.

There was one teacher (T.D) asserted there were too many objectives in the curriculum, and since these did not appear in the content, he did not include them in his lessons. Apart from that, all the other teachers claimed these aspects, especially social aspects of science, should be taught to students.

Teachers also expressed that teaching the social and institutional aspects of science would raise students' awareness that there are many aspects influencing the scientific study, that if they were going to have a career in science, they should be aware there are also financial, political factors, besides they would also know there are ethical values and attitudes to be considered which also would make students less alienated from science.

Teachers provided diverse examples regarding the integration of social-institutional aspects of science into lessons. Some of them are provided below:

> "These could be told with stories such as a king not supporting science… I try to tell what the conditions were when the research began, what kind of things had been told in that time or how it had been studied nevertheless, apart from the curriculum... More or less, I try to include the history of science". (T.C)

> "As we teach the topics, we mention about Einstein or Newton, Franklin that everybody died but why did not she when she was doing that experiment, (we ask) different questions… and if curious students made research they want to tell, meanwhile we can also mention. Otherwise, there is not much history of science in the program" (T.G)

> "Company visits can be planned in the chemical industry subject. For example, we tell this happens that happens… Behaviors and attitudes yes, for example, yesterday I showed them a video about Edison's life… students get surprised we try to introduce scientists" (T.A)

Teachers mostly mentioned about the inclusion of social values of science through the lives of scientists. Some teachers (T.L, T.B) mentioned that when students were involved with the science projects like TUBİTAK, they could be aware of the financial aspect to a certain degree, that some projects get funded, and some do not.

Another teacher provided a more elaborated example of how she was integrating the social and institutional aspects into her lesson.

> "The scientific studies in rocket design, how scientists were influenced in atom models, how it is useful to the society, or what kinds of advantages do rockets have, economic societal values, I mentioned we discussed these… Or in human environment (interactions) establishing nuclear power plants, students considered many different factors while we were discussing. For example, they took into consideration objectives like social benefits, employment…" (T.K)

4.3.6 Summary of Teachers' Views about RFN integration to their instruction

For the aims and values, some teachers held a reluctant attitude towards integration into their lessons because they believed that students would not be interested and understand. Others believed talking about scientific aims and values was important because it would promote their critical thinking. According to teachers, the implementation could be carried out via history of science or socio-scientific issues such as sustainable development, biotechnology etc. Teachers who try to include mention these issues through having classroom discussions or setting these as an objective in the activities or in the assignments. This was also similar with the educational application approach teachers who had higher level understanding, expressed in the study of Akgün (2019). For the methods and methodological rules, since most of the teachers focused on experiments and observation, they expressed that the inclusion was challenging because of the school conditions and limitations regarding the curriculum. If the teacher were aware of the dynamic structure of the methods and considered it important, they mentioned the diversity of the methods in their lessons. When it comes to scientific practices, some teachers considered it would be confusing for students, and it would be more useful for students in higher grades. However, since some practices such as doing experimentation, observation, and classification are included in the subject units, teachers implemented these as suggested in the science textbook. Additionally, teachers who were aware of the other practices such as data collection, discourse, reasoning explicitly discuss these in their activities and classroom discussions. Considering scientific knowledge, there was a general opinion that the types of scientific knowledge, especially laws and theories, were not explicitly brought to the discussion because there was no such implication in the curriculum and the concepts are too complex for students and teachers as well. Mostly models are practiced and discussed during their instructions. Teachers who had more informed views about the characteristics of the types of the scientific knowledge, allocate more time to reflect on the concepts. It was noticed that majority of the teachers were more confident in talking about the social-institutional aspect of science because they could make relation to real life. They tried to implement these topics via the life of scientists, bringing recent socio-scientific issues into class, mentioning the history of science, or having students carry out projects. On the other hand, three of the teachers considered teaching this aspect as unnecessary due to students' lack of interest and attention, insufficient or lack of emphasis in the curriculum, and curricular overload. They also considered teaching the social-institutional aspect as not practical for students. However, the majority of the teachers who believed that being aware of the social-institutional aspect of science would be beneficial for students, appeared to make an effort to integrate related issues into their instruction. Results showed similarity with the study of Aksöz (2019), teachers who believed it was unnecessary to teach this aspect because of the level of students and curriculum restrictions expressed that they did not integrate these into their lessons, on the other hand teachers who had higher level understanding provided more detailed examples of integration such as student-centered activities, conducting projects and creating discussions related to controversial issues.

CHAPTER 5

DISCUSSIONS AND CONCLUSION

This chapter discusses the results obtained through the interviews about science teachers' views on NOS based on the RFN framework, on the curricular emphasis of RFN, and on the RFN integration to their instruction. In addition, the limitations of the study and recommendations for future research are presented.

5.1 Discussion of the Results

Science teachers' views about the NOS based on RFN

Teachers' views about NOS were examined based on the five categories of RFN, namely aims and values, scientific knowledge, methods, and methodological rules, scientific practices, and socio-institutional systems. Overall, it was noticed that teachers who had more experience in science education research showed a more holistic view and consistent understanding about the NOS.

Concerning the aims and values category, teachers were more elaborative about the social structure of scientific aims and values. For the aims of science, the commonly emerged codes were honesty, serving to humanity in terms of contribution to public welfare, economy, technology, objectivity, being free from bias etc. Based on this finding, it can be said that in general, teachers held inadequate views regarding epistemic-cognitive aims; most of the teachers focused on the social aims of science. On the other hand, regarding values, science teachers held different views. Teachers who initially expressed that science should be free from values because it would limit science also indicated that it should be regulated by certain values emphasizing ethical consideration. It can be said that teachers used ethics explaining both scientific values and scientific ethos, which is described under the social-institutional aspect of NOS by Erduran and Dagher (2014). This outcome shows similarity with the findings of Aksöz (2019). She investigated 12 science teachers' understanding of aims and values and the social-institutional aspect of the

NOS based on RFN structure. She found that 9 out of 12 teachers explained the values of science by making a connection to ethics. In addition, the studies in the literature based on the RFN framework conducted with pre-service teachers, pre-intervention results showed that most participants had limited understanding regarding aims and values (Kaya, Erduran, Aksöz, & Akgün, 2019). In their study, pre-service teachers' understanding showed significant development; after the 11-hour intervention, they could generate relevant codes regarding the aspect. While these findings revealed pre-service teachers' views, Aksöz's (2019) study with in-service teachers also showed a similar case; only a few teachers mentioned the epistemic-cognitive side of aims and values.

Regarding the methods and methodological rules category, teachers attempted to explain scientific methods in terms of the universal scientific method as successive steps to follow, such as stating a problem, forming a hypothesis, and testing it via experiments and observations. Considering the number of research investigating teachers' views on NOS based on the seven aspects of the consensus view of NOS, this interpretation is widely common (Abd-El-Khalick & BouJaude, 1997; Aslan & Tasar, 2013) this could be resulted from the representation of scientific methods in the textbooks and curriculum (Irez, 2009). In another research studying university students' views on NOS using the RFN structure, participants expressed scientific methods as stereotypical steps (Akgün, 2018). Furthermore, their naïve understanding regarding methods revealed their limited conceptualization of the relationship between laws and theories. On the other hand, graduate-student teachers expressed more informed and detailed views putting emphasis on non-linear interaction and diversity of the scientific methods. Even though all teachers mentioned similar methods such as experiment and observation, with further questioning, teachers who have read books, attended seminars/class, and graduate-students expressed more confident responses regarding domain-specific methods scientific disciplines employ. Also, the findings revealed that teachers use the terms scientific methods and practices interchangeably, which can imply that they do not categorize methods and practices *separately*. Related to methodological rules, teachers mostly uttered ethical issues that scientists should contemplate. In the RFN framework, Erduran and Dagher (2014) delineate methodological rules as the ways to minimize the occurrence of potential errors during the scientific investigation, such as doing controlled experiments, or eliminating observer effect. Thus, considering methodological rules, generally, teachers held inadequate views.

With regard to scientific practices, results showed that teachers could not assess practices separately from methods. They used the concepts interchangeably. In addition, the scientific practices category appeared to be the least answered category. One teacher could not provide an answer, and some of the teachers misinterpreted the concepts consistent with the findings in Akgün's (2018) study with university students. In the present study, in order to clarify the meaning of scientific practices, the interviewed teachers were told that they could consider practices as science process skills. After this explanation, teachers mentioned about creative and critical thinking, which refer to 21st century skills. This finding indicated that teachers did not have a clear understanding about scientific practices. However, being consistent with the description provided in the RFN framework, experimentation and observation were stated as practices, and teachers mostly provided informed descriptions regarding those concepts. Considering Benzene Ring Model, one graduate-student teacher mentioned the discourse aspect; other than these, none of the teachers mentioned the elements of the scientific practices as introduced within the RFN structure.

For the scientific knowledge category, the majority of the teachers expressed that scientific knowledge is testable, based on empirical research, and tentative. However, in general, some teachers lacked consistency within their responses. For instance, while advocating scientific knowledge is tentative on the one hand, they claimed that it is certain and cannot change on the other hand. And one teacher insisted on the term of updating, such that he argued scientific knowledge does not change but is updated. Even though most teachers advocated tentativeness of scientific knowledge, graduate-student teachers' responses can be regarded as informed since they implied the paradigm shift in their explanations. Also, it is noticed that teachers hold misconceptions regarding the relationship between the types of scientific knowledge; laws, and theories. When teachers' understanding of laws, theories, and models was asked, answers showed the diversity that can be categorized as naïve or informed. Most of the teachers either could not define or had a hierarchical view of laws and theories; they stated laws as proved theories and as the final form of scientific knowledge that cannot be changed. According to them, theories are proved hypotheses or unconfirmed predictions. These results align with the related research conducted with teachers, demonstrating that most of them hold a naïve understanding of the relation between theories and laws (Abd-El-Khalick & BouJaoude, 1997; Aslan & Tasar; 2013; Doğan Bora, 2005; Guerra-Ramos, 2012; Wahbeh & Abd-El-Khalick, 2014). The minority of the teachers, graduate-student teachers, provided more informed views which could be related to their research background.

The category of the socio-institutional system of science is the one that teachers presented more elaborated answers than the other categories of RFN. There was no distinct difference based on the teachers' background and characteristics considered in this study. Some distinctions appeared only in the details that they provided for their explanations which could be influenced by their past readings on the nature of science. The codes identified based on their responses were in line with the RFN framework. The results were, in general, consistent with the findings of the study conducted by Aksöz (2019), which demonstrated that there was no significant difference among the in-service teachers with different backgrounds (i.e. educational level, teaching experience, and school types) with respect to views on the socio-institutional aspect of NOS. The participant teachers were found to be aware of the involvement of social and financial factors in scientific studies.

Science Teachers' Views about the Curricular Emphasis of RFN

The second research question was about the science teachers' views regarding the curricular emphasis of RFN categories. According to Kaya and Erduran (2016b), RFN categories covered in the cognitive-epistemic system of science, such as aims and values, scientific practices, methods and methodological rules, and knowledge, are emphasized in the Turkish science curriculum. When teachers' opinions regarding the inclusion of these categories in the curriculum were asked, they all agreed on sufficient emphasis on the scientific practices category**.** At this point, it is important to note that although the interviewed teachers did not have a clear understanding of scientific practices as indicated in the previous sub-section, consistent with the RFN framework, they mentioned about experimentation and observation under this category. Regarding curricular emphasis on scientific practices, on the other hand, they pointed out that experimentation, observation, and classification are already in the curriculum, and they integrate these into their lessons. Teachers' comments were in line with the curriculum analysis of Kaya and Erduran (2016b). More specifically, they stated that along with the inclusion of scientific activities like experimentation and observation, these are also presented with discourse and argumentation in the curriculum (Kaya and Erduran, 2016b). The related statement in the curriculum as indicated by Kaya and Erduran, (2016b, p.1123) is: “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” (MEB 2013, p.III). Considering scientific methods, three of the teachers expressed that these are not included**,** and others pointed out that mostly experimental methods, manipulative methods, are included. The analysis of Kaya and Erduran (2016b) showed that scientific methods representation in the curriculum fit in with the definition of the RFN framework, which implies both manipulative and non-manipulative methods. In fact, as pointed out by Kaya and Erduran (2016b, p.1124), in the curriculum there is a statement that "Inquiry process is addressed not just as exploration and experimentation but also as explanation and argument" (Kaya & Erduran, 2016, p 1124; MEB 2013, p.III). This indicates that even though teachers were aware of the non-manipulative methods, they could not associate with curricular emphasis. Another teacher, who had informed understanding about the non-successive structure of scientific methods, added a comment on the portrayal of the related category. She emphasized that the science curriculum does not portray scientific methods in step-wise order, however, it does not make clear the structure of scientific methods for the teachers either. Another general agreement was about the inclusion of the types of scientific knowledge. Teachers expressed that laws, theories, and models were presented with their names, such as atomic theories, ohm's law etc., in the curriculum, but their definitions were not introduced. In addition to this, graduate-student teachers, who were aware of the interactions of the types of scientific knowledge, made it explicit that even though laws, theories, and models are included in the subject units, there are no clear connections established within. This criticism was pointed out by Kaya and Erduran (2016b) as well. They expressed that even though there are references to the generation of scientific knowledge and its types, there is no clarification of how laws, theories, and models work together and interact to form scientific knowledge. For example in the curriculum it is stated as: To assist in grasping how scientists generate knowledge, what processes knowledge generation goes through and how knowledge generated is utilized in new research (Kaya & Erduran, 2016b; MEB 2013, p.II). For the aims and values, the teachers agreed that these are not integrated or very implicitly mentioned, or there was no connection established to the nature of science in the curriculum. However, the following statement in the curriculum indicated by Kaya and Erduran (2016b, p.1124) refers to the inclusion of aims and values; "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" (MEB 2013, pIII). Teachers' interpretation could be resulted from the section where the statement is presented in the curriculum. Aims and values emphasis is given under the section of "The Main Approach of Science Teaching Program" (Kaya & Erduran, 2016), which indicates that there could be no clear emphasis given in the curriculum objectives.

Apart from the cognitive-epistemic system of science, the categories mentioned earlier, considering the social-institutional system of science, the participants all agreed that it was not included in the curriculum. Two graduate-student teachers indicated that these are so subtle that there is no clear guided instruction for teachers to make the connection to these categories. For instance, teachers mentioned the short stories of scientists depicted in the textbook, which they could make the connection to some aspects such as scientific attitudes, social values, or professional activities. However, they emphasized that these were too superficial and it was up to teacher's decision to bring them out in the lessons. Also, some teachers expressed that there were objectives which could be related to social organizations and interactions, again pointed out the implicity of the inclusion. When the curriculum integration is taken into consideration, some of the views were consistent with the findings of Kaya and Erduran (2016b). According to Kaya and Erduran (2016b), compared to the cognitive-epistemic system, the social-institutional system of science is underemphasized. Authors stated that three out of seven aspects of the social-institutional system as depicted in the RFN framework were included in the curriculum, yet too implicit. According to the authors, the social-organizations and interactions are stated as: "To enable students' appreciation of how science is developed collaboratively among scientists from different cultures"; social values mentioned as: "Scientifically literate person is aware of how social values of the culture and societal structures and beliefs influence how knowledge is cognitively processed"; and social certification and dissemination indicated as: "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" (Kaya & Erduran, 2016b, p.1124-1125)

In general, it was seen that teachers who had a naïve understanding of the NOS aspects expressed there was no or too little inclusion, or gave irrelevant examples. For example, one teacher' illustration, while talking about the occurrence examples of aims and values in the curriculum, was related to scientific practices. On the other hand, teachers who held informed understanding provided meaningful and coherent connections from the curriculum. It can be said that teachers holding adequate and informed views on the integration of the RFN categories into the curriculum were consistent with the related curriculum analysis conducted by Kaya & Erduran (2016b). Specifically, teachers expressed that inclusion of the aspects was implicit, and there was no clear guidance on how to implement it. Besides, even if some aspects were presented, e.g., scientific knowledge, and scientific methods, there was no meaningful connection drawn within and among them to correlate to the nature of science. Similarly, Kaya and Erduran (2016b) stressed that the presentation of the RFN categories lacked coherency and would not contribute to holistic instruction of the nature of science.

Science Teachers' Views about RFN Integration to Their Instruction

The last research question is based on teachers' opinions regarding the integration of RFN categories into their instruction and whether they are implementing them. Teachers' opinions about communicating the categories coincide with whether they feel necessary and important for students to learn these aspects of science. For the aims and values, two teachers who did not take NOS related lesson/seminar and had a naïve understanding of NOS stated that it was too complicated for students and it would not be interesting for students, so it was unnecessary to teach these aspects. Other teachers expressed the importance of teaching aims and values, and they thought it would promote critical thinking and change the students' point of view about science. They emphasized that the social aims and values are referred to in the textbooks, and thus they employ these in their lessons such as sustainable development, biotechnology, or through excerpts from scientists etc. Some teachers expressed aims and values of science could be integrated into the lesson with science projects, history of science, or argumentation. Additionally, it was noticed that teachers mostly referred to scientific practices and scientific knowledge integration while talking about teaching aims and values, which was parallel with the findings of Aksöz (2019), in her study as well teachers mostly referred to scientific knowledge and scientific methods when explaining aims and values applications.

For the methods and methodological rules, all teachers, except three who think it would be too complicated for the students, expressed that it is important for students to learn. Despite the diverse opinions on whether it is necessary to teach scientific methods, all teachers told that since experimentation and observation are already in the lesson units, they teach and try to apply these concepts. This also points out another implication that teachers' understandings of the aspect affect their instruction. For example, teachers mentioned scientific practices as methods and explained how they include or not these practices. And most of them do not elaborate on the concepts in the classroom. On the other hand, graduate-student teachers who were found to have informed understanding on the diversity of the methods reported that they integrate this aspect, pointing out the dynamic structure of the scientific methods.

Teachers were confident the most with the inclusion of scientific practices. Because, even though they cannot carry out experiments or observations in the classroom environment, they address these practices during lectures since they are included in the curriculum and textbooks. Additionally, they mentioned that with the projects they carry out, such as TUBITAK, students get a chance to be involved in such activities. Graduate-student teachers also expressed the other practices such as discourse, reasoning, data collection etc., are being discussed in their lesson.

When scientific knowledge was taken into consideration, teachers mentioned that since models are explicitly included in the lesson units, they are teaching those concepts. Three teachers considered types of scientific knowledge would be too complicated for students to understand, thus it is not necessary to include them in class. Furthermore, it is clear that the way teachers conceptualized the concepts of laws and theories affects their teaching of these concepts: for example, teachers who had misconceptions about the characteristics of theories explain theories as the way they know in their lessons. Some said that since theories and laws are too abstract for students, they do not teach these concepts explicitly, only put emphasis on the models. Graduate-student teachers pointed out that even though they are aware of the characteristics of scientific knowledge and the connection, since these are not explicitly included in the program, they had to create extra time and opportunity to teach those concepts.

For the category of the social-institutional system of science, three of the teachers expressed that they do not teach this aspect. Their reasons were that it is not interesting for students, there is no emphasis on the curriculum, there are too many objectives to cover, and it will not be useful for students. The rest of the teachers promoted teaching the aspect since it would make students see science as a whole system and raise their awareness. Some of the teachers expressed that presenting the social-institutional aspect of science would encourage students to see the other side of the science that would make them less alienated from science which was also put forward by Aikenhead (2007); enabling a more humanistic perspective for students. Teachers told that they try to include this aspect via the history of science, establishing argumentation environment, planning visits to companies etc. Their efforts and suggestions can be considered as in line with the researchers' proposals in the field encouraging students' involvement in activities similar to scientists to promote this aspect (Aksöz, 2019; Çilekrenkli, 2019; Kaya, Erduran, Akgün & Aksöz, 2019).

During the interviews, teachers expressed that to be able to teach these to students, firstly, they, as teachers, should have knowledge about these concepts and be competent enough to integrate these into their lessons, but they are not. Also, some teachers pointed out that most of the aspects would not interest students and/or they cannot comprehend the topics in question thus should not be taught. In line with the former statements, graduate-student teachers indicted that even though some categories are included in the curriculum, there is no feasible guidance for teachers to make the connection to NOS or how to include them in the lessons to make instructions effective. Moreover, besides their competencies, teachers added the conditions of classrooms, level of students, overloadedness of the teaching program that there are so many subjects to cover, and the time limit hinder them to allocate time to teach NOS. The points teachers draw attention which also support the related literature that being knowledgeable about and willingness to teach NOS affect teachers' NOS instruction (Akgün, 2019; Clough & Olson 2011; Mıhladız & Dogan, 2013; Schwartz & Lederman, 2002). The study of Schwart and Lederman (2002) with two science teachers indicated that informed NOS understanding and subject matter knowledge promote teachers’ communicating the NOS in their lessons. Additionally, if they consider NOS teaching is valuable, and they have strong intentions to implement they could manage to deal with most of the challenges teachers mention.

5.2 Implications

In general, teachers were more confident while talking about the social aspect of science since they could give examples from real life experiences. On the other hand, they had misconceptions while defining the types and relation of scientific knowledge and naïve understanding while defining scientific practices and characteristics of the scientific method. This is in line with the related research based on the seven tenets of the consensus view of NOS such that teachers mostly show naïve understanding about theories, laws and the nature of scientific knowledge, and non-linear interaction among scientific methods (Aslan, 2009; Aslan & Taşar, 2013; Niaz, 2009). However, results of the interviews suggested that graduate-student teachers and teachers who spent more time reading and attending NOS related studies appeared to provide more informed views. Between these two types of teachers (graduate-students vs. those spending time on NOS) graduate-student teachers appeared to have better NOS understanding which can be related to their research background. In addition to teachers’ level of understanding of the NOS, their perception of educational application is another critical point to be considered. It is noticed that if the teacher is aware of the concept and considers it important, they try to mention it. Some teachers uttered that they consider the NOS instruction insignificant, and most of them indicated they did not know how to integrate the NOS in their instructions. These expressed issues lead to significant concerns regarding teacher education and training programs. It has been shown in the literature that intervention studies regarding teachers' understanding, perception, and intention of NOS teaching are largely effective on teachers' professional development and boosts their practical implementations (Cofré, Núñez, Santibáñez, Pavez, Valencia, & Vergara 2019) for both pre-service and in-service teachers (Akgün, 2019; Kaya et al., 2019; Schwartz & Lederman, 2002; Wahbeh & Abd-El-Khalick, 2014). Thus, the structure of both pre-service and in-service teacher education programs should be developed to provide teachers with improving their understanding, attitude, and competence in integrating the NOS into their instruction. In order to achieve that, in pre-service science education programs, students should be more involved with activities and courses enriched with NOS content enabling students to prepare NOS integrated lesson plans and activities together with opportunities to implement these in classroom environments to boost their confidence. Considering in-service science teachers, initially to improve their understanding and views about NOS, sessions should be included in teacher education seminars that science teachers get involved in NOS related readings and discussions. Additionally, to promote their NOS integration into their lessons, sample lesson plans and activities that explicitly incorporate NOS aspects can be shared, and opportunities that encourage them to prepare their own lesson plans and activities with workshops or seminars should be provided. More specifically, it has been seen that teachers provided fewer codes to the category of scientific practices and could not differentiate scientific methods from scientific practices. Also, the practices such as experimentation and observation were considered as scientific methods, while in the RFN framework, these were discussed in methods category. This observation was also in line with the recent study of Erduran and colleagues (2021), with pre-service science teachers from both Turkey and England. They observed that participants from both countries produced less keywords about the scientific practices compared to other categories and talked about practices while discussing methods. Additionally, considering this study, teachers' responses related to scientific knowledge showed that most of them presented low understanding related to the characteristics of laws and theories. In the light of these results, education programs for both pre and in-service science teachers should explicitly involve discussions and activities for improving teachers' views related to scientific practices, methods, and scientific knowledge. The study of Erduran et al. (2021) showed that with the introduction of the RFN framework and with discussion sessions, participants were able to focus and direct different issues related to the categories.

Another implication is regarding the curricular emphasis. The interviews showed that even though teachers are aware of certain aspects such as aims and values or socio-institutional aspects, they do not deliberately include these in their lessons because there is no objective in the curriculum. Additionally, as in the case with graduate-student teachers, who are more knowledgeable regarding NOS aspects, expressed that to implement those in their lessons, they needed to prepare extracurricular activities and later make up for the time or prepare their own syllabus through modifying the program with their group of science teachers to include explicitly NOS objectives and make them relevant to the curriculum. Hence the curriculum revision can be made according to teachers' suggestions and needs regarding the NOS inclusion and applications. More specifically, the NOS aspects should be explicitly and coherently integrated into the program, the categories related to aims and values, scientific practices and methods, and the characteristics of the types of scientific knowledge and their relationship should be clearly expressed within the realm of growth of knowledge. Besides, the curriculum should provide sufficient guidance to the teachers to contribute to holistic and meaningful NOS instruction without giving rise to any confusion or hesitation.

5.3 Limitation

There are certain limitations of this study. Even though teachers from different backgrounds and experiences participated, these categories could be broadened in future studies.

Another limitation would be the method of the study as such that to be able to talk more about the generalizability of the results, both quantitative and qualitative methods could be followed. Developing and using questionnaires and later getting a deeper understanding with more extended interview questions can contribute to a different outcome to evaluate. Also, further research, including observations teachers' classroom practices, could provide a wider and consistent perspective on their understanding and practice of the NOS concepts. Accordingly, for further research, both teachers' understandings and their classroom practices can be investigated to get a deeper perspective to see the relation. Additionally, studies including interventions through the means of workshops or interactive courses based on the RFN framework to investigate the effectiveness and examine the difference in teachers' perceptions, attitudes, implementation intentions, and skills regarding NOS can be studied.

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APPENDICES

A. Permissions Obtained from METU Human Subjects Ethics Comittee

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05 NİSAN 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Semra SUNGUR ve Prof. Dr. Jale ÇAKIROĞLU

Danışmanlığını yaptığınız yüksek lisans öğrencisi Zeynep Merve DEMİREL'in "**Fen Bilimleri Öğretim Programı'nın ve Fen Bilgisi Öğretmenlerinin RFN Yaklaşımı Doğrultusunda Bilimin Doğası Anlayışının İncelenmesi**" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-EGT-056** protokol numarası ile **06.04.2018 - 30.09.2018** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Doç. Dr. Emre SELÇUK
Üye

Dr. Öğr. Üyesi Pınar KAYGAN
Üye

B. Interview Questions

Bu görüşmenin amacı, Fen bilimlerine yönelik görüşlerinizi almaktır. Soruların doğru ya da yanlış cevabı yoktur. Hiç bir şekilde kimliğinizin belirlenmesi söz konusu olmayıp, vereceğiniz yanıtlar sadece araştırma amacıyla kullanılacaktır. Bu yüzden soruları içtenlikle yanıtlamanızı rica ediyorum. İzin verirseniz görüşmeyi ses kaydına almak istiyorum.

1 Kaç yaşındasınız?

2 Kaç yıldır öğretmenlik yapıyorsunuz?

3 Hangi sınıf seviyelerinde öğretmenlik yapmaktasınız?

4 Üniversitede mezun olduğunuz bölüm nedir? En son aldığınız derece nedir? (master-doktora)

5 Bilimin doğası, bilim tarihi ya da bilim felsefesi ile ilgili herhangi bir ders veya eğitim aldınız mı?

Ne zaman bahsettiğiniz dersi/eğitimi aldınız?

Almış olduğunuz dersin/eğitimin içeriği hakkında bahseder misiniz?

6 Bilimin doğası, bilim tarihi ya da bilim felsefesi üzerine kitap okudunuz mu?

Kitabın içeriği hakkında bahseder misiniz?

7 Bilimin doğası dendiğinde aklınıza ne geliyor? Bilimin doğası size ne ifade ediyor?

8 Bilimin amaçları dendiğinde aklınıza ne geliyor? Bilim neyi amaçlar?

9 Bilim değerlerden bağımsız mıdır? Bilimin sahip olduğu değerler nelerdir?

10 Amaç ve değerler bilimsel bilginin üretiminde ve gelişiminde nasıl rol oynar?

11 Bilim insanin cinsiyeti ya da sahip olduğu ırk/köken yapmış olduğu işin niteliğini etkiler mi?

12 Bilimin amaç ve değerleri sizce ortaokul öğrencilerine anlatılmalı mı?

Bilimin amaç ve değerlerini anlatmak nasıl bir fayda sağlar?

13 Fen bilimleri dersi öğretim programda amaç ve değerlere ne ölçüde değinildiğini düşünüyorsunuz?

14 Sizce, bilimin amaç ve değerleri fen derslerine nasıl entegre edilebilir?

15 Siz derslerde bu entegrasyonu ne ölçüde yaptığınızı düşünüyorsunuz? Lütfen örneklerle açıklayınız.

16 Bilimsel yöntemler deyince aklınıza ne geliyor?

17 Bilim insanlarının veri toplama yöntemleri çeşitlilik gösterir mi? Nasıl gösterir?

18 Deneysel süreç içermeyen araştırmalarda ileri sürülen iddiaların geçerliliği/güvenilirliği nasıl sağlanır?

19 Bilim insanları oluşacak hataları minimuma indirmek için nelere dikkat etmeli?

20 Sizce bilimsel metotlar ortaokul öğrencilerine anlatılmalı mı?

Anlatmak nasıl bir fayda sağlar?

21 Fen bilimleri dersi öğretim programda bilimsel metotlara ne ölçüde değinildiğini düşünüyorsunuz?

22 Sizce, bilimsel metotlar fen derslerine nasıl entegre edilebilir?

23 Siz derslerde bu entegrasyonu ne ölçüde yaptığınızı düşünüyorsunuz? Lütfen örneklerle açıklayınız.

24 Bilimsel pratikler dendiğinde aklınıza ne geliyor? Bilimsel pratik ifadesini duymadıysanız, bilimsel süreç becerileri (bsb) hakkında bildiklerinizden bahseder misiniz?

25 Tüm bilim dallarında kullanılan ortak/farklı pratikler var mıdır? Neler?

Deneyin özelliği nedir? Yaptığımız işlemi deney yapan nedir?

Gözlem pratiğini bilimsel kılan özellik sizce nedir?

Sınıflandırmanın özelliği nedir? Nasıl bir fayda sağlar?

26 Sizce bilimsel pratikler ortaokul öğrencilerine anlatılmalı mı?

Anlatmak nasıl bir fayda sağlar?

27 Fen bilimleri dersi öğretim programda bilimsel metotlara ne ölçüde değinildiğini düşünüyorsunuz?

28 Sizce, bilimsel pratikler fen derslerine nasıl entegre edilebilir?

29 Siz derslerde bu entegrasyonu ne ölçüde yaptığınızı düşünüyorsunuz? Lütfen örneklerle açıklayınız.

30 Bilimsel bilgi dendiğinde aklınıza ne geliyor? Bir bilgiyi bilimsel kılan nedir?

31 Bilimsel bilginin özellikleri nelerdir? Örneğin bilimsel bilgi zamanla değişebilir mi?

Bilimsel bilgi neden değişir? Bilimsel bilgi nasıl değişir ve gelişir?

32 Bilimsel bilgi türleri nelerdir?

Kanunun özelliği nedir? Şimdiye kadar değişen veya tamamen geçerliliğini yitiren kanunlar var mı? Değişmesini veya geçerliliğini yitirmesinin sebebi neler olabilir?

Teorinin özelliği nedir? Şimdiye kadar değişen veya tamamen geçerliliğini yitiren teoriler var mı? Değişmesini veya geçerliliğini yitirmesinin sebebi neler olabilir?

Modellerin özelliği nedir? Hangi amaçla kullanılırlar?

33 Ortaokul öğrencilerine bilimsel bilginin özellikleri ve farklı türlerinin olduğunu anlatılmalı mıdır?

Anlatmak nasıl bir fayda sağlar?

34 Programda bilimsel bilginin özellikleri ve kanun, teori ve model konularına (farklı bilimsel bilgi türleri) ne ölçüde değinildiğini düşünüyorsunuz?

35 Sizce, bilimsel bilginin özellikleri ve türlerii fen derslerine nasıl entegre edilebilir?

36 Siz derslerde bu entegrasyonu ne ölçüde yaptığınızı düşünüyorsunuz? Lütfen örneklerle açıklayınız.

37 Bilim sosyal mi yoksa bireysel bir faaliyet midir?

Bilim hangi kurumsal çatılar altında yapılır?

38 Bu kurumlarda çalışan bilim insanları arasında statü farkı/hiyerarşi var mıdır? Nasıl etkiler?

39 Bilimsel süreç sosyal ve kültürel ortamdan etkilenir mi? Nasıl?

40 Bilim evrensel midir?

Bulunduğu ortamdan etkileniyorsa nasıl evrenseldir?

41 Bilim ile devletlerin ya da otoritenin sahip olduğu politik güç yapısı arasında bir ilişki var mıdır? Bilimsel süreç bu yapıdan/ ilişkiden nasıl etkilenir?

42 Finansal yapı ile bilim arasındaki ilişki nedir?

43 Bilim insanları hangi yollarla çalışmalarını başkalarıyla paylaşır?

44 Bilim insanlarından meslektaşlarıyla ve bilimsel araştırma süreçlerinde nasıl tavır ve tutum

sergilemeleri/nasıl bir davranış benimsemeleri beklenir?

45 Bilimin sosyal ve kurumsal yönleri ortaokul öğrencilerine anlatılmalı mı?

Anlatmak nasıl bir fayda sağlar?

46 Programda bilimin sosyal ve kurumsal yönlerine ne ölçüde değinildiğini düşünüyorsunuz?

47 Sizce, bilimin sosyal ve kurumsal yönleri fen derslerine nasıl entegre edilebilir?

48 Siz derslerde bu entegrasyonu ne ölçüde yaptığınızı düşünüyorsunuz? Lütfen örneklerle açıklayınız.

C. Consent Form

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Matematik ve Fen Eğitimi Bölümü yüksek lisans öğrencisi Zeynep Merve Demirel tarafından Prof. Dr. Semra Sungur ve Prof. Dr. Jale Çakıroğlu danışmanlığında yüksek lisans tezi kapsamında yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı, bilimin doğası hakkındaki görüşleriniz hakkında bilgi sahibi olmaktır.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, sizden yaklaşık bir saat sürecek araştırmacıyla görüşme yapmanız beklenmektedir. İçerik analizi ile değerlendirilmek üzere cevaplarınızın ses kaydı alınacaktır.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Çalışmada sizden kimlik veya kurum belirleyici hiçbir bilgi istenmemektedir. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Katılımcılardan elde edilecek bilgiler toplu halde değerlendirilecek ve bilimsel yayımlarda kullanılacaktır.

Katılımınızla ilgili bilmeniz gerekenler:

Görüşme, genel olarak kişisel rahatsızlık verecek sorular veya uygulamalar içermemektedir. Ancak, katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz görüşmeyi yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda görüşmeyi uygulayan kişiye çalışmadan çıkmak istediğinizi söylemek yeterli olacaktır.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Görüşme sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Prof. Dr. Semra Sungur ya da yüksek lisans öğrencisi Zeynep Merve Demirel ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad　　　　Tarih　　　　İmza

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T.C.