THE RELATIONSHIP BETWEEN STUDENTS' UNDERSTANDING OF NATURE OF SCIENCE AND THEIR METACOGNITIVE AWARENESS

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Dedicated to my dear mom, Dilek Gören

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ABSTRACT

THE RELATIONSHIP BETWEEN STUDENTS' UNDERSTANDING OF NATURE OF SCIENCE AND THEIR METACOGNITIVE AWARENESS

The Reconceptualized Family Resemblance Approach to Nature of Science (RFN) have been the holistic account in the nature of science education (Erduran & Dagher, 2014; Kaya & Erduran, 2016). The nature of science (NOS) can be closely related with students' cognitive/metacognitive process and skills which contribute their NOS learning (Peters-Burton & Burton, 2020). The aim of this study is to investigate the relationship between middle school students' RFN understanding and their metacognitive awareness with quantitative and qualitative perspectives. Furthermore, examining students' RFN perceptions and metacognitive awareness were also another focus of the study. In total 701 students (180 5th, 167 6th, 170 7th and 184 8th grade) were attended to the study. The data sources were a 37 item "RFN Student Questionnaire" (Cilekrenkli, 2019), RFN interviews, "The Metacognitive Awareness Inventory for Children" (Karakelle & Saraç, 2007) and metacognitive awareness interviews. As a result of the quantitative data analysis, Pearson r correlation showed that there was a significant positive relationship between middle school students' RFN understanding and their metacognitive awareness, and this relationship was evident among each grade level (5th,6th,7th and 8th) students separately. The qualitative data also showed and supported that the students who were metacognitively aware had higher RFN perception and similarly, students with low metacognitive awareness had low RFN perception. Moreover, there were differences between different grade level students' RFN understanding and perception according to the quantitative and qualitative results. Most students were limited in viewing science as epistemic-cognitive–social system holistically and making relationship between categories of science. In metacognitive awareness, while some students were using metacognitive strategies and skills more consciously, low level students were limited in these skills. The study opens up new research focus for experimental and causal comparative studies in terms of inclusion of metacognitive awareness RFN teaching.

ÖZET

ORTAOKUL ÖĞRENCİLERİNİN BİLİMİN DOĞASI ANLAYIŞLARI İLE ÜST BİLİŞSEL FARKINDALIKLARI ARASINDAKİ İLİŞKİ

Erduran ve Dagher' ın (2014) önerdiği ve Kaya ve Erduran' ın (2016) isimlendirdiği Yeniden Kavramsallaştırılmış Aile Benzerliği Yaklaşımına Dayalı Bilimin Doğası (RFN), bilimin doğası eğitiminde kapsayıcı bir yaklaşımdır. Bilimin doğası öğrencilerin bilişsel/üst bilişsel süreçleri ve becerileriyle yakından ilişkili olabilme potansiyelindedir (Peters-Burton & Burton, 2020). Bu çalışmanın amacı ortaokul öğrencilerinin RFN anlayışları ile üst bilişsel farkındalıkları arasındaki ilişkiyi nicel ve nitel açılardan incelemektir. Ek olarak, öğrencilerin RFN anlayışlarını ve üst bilişsel farkındalıklarını da incelemek çalışmanın diğer odaklarındandır. Çalışmaya toplam 701 (180 beşinci, 167 altıncı, 170 yedinci ve 184 sekizinci sınıf) ortaokul öğrencisi katılmıştır. Veri kaynakları 37 soruluk "RFN Öğrenci Anketi" (Cilekrenkli, 2019) ve RFN temelli görüşmeler, "Çocuklar İçin Üst Bilişsel Farkındalık Ölçeği" (Karakelle & Saraç, 2007) ve üst bilişsel farkındalık görüşme sorularıdır. Pearson r korelasyonu ortaokul öğrencilerinin ve her sınıf seviyesindeki öğrenci gruplarının (5. 6. 7. ve 8. sınıf) RFN anlayışları ve üst bilişsel farkındalıkları arasında istatistiksel olarak anlamlı pozitif bir ilişki olduğunu göstermiştir. Nitel veriler ise bu sonuçları destekleyecek biçimde olup üst bilişsel farkındalığı yüksek olan öğrencilerin RFN algılarının da yüksek olduğu görülmüştür. Benzer şekilde üst bilişsel farkındalığı düşük olan öğrencilerin de RFN algılarının düşük olduğu görülmüştür. Ek olarak farklı sınıf seviyelerindeki öğrencilerin RFN anlayışları ve algıları arasında hem nicel hem nitel sonuçlara göre farklar olduğu, çoğu öğrenci bilimi epistemik-bilişsel-sosyal bileşenleri bütünsel olarak görmediği ve bilimin kategorileri arasında ilişki kurmadığı görülmüştür. Üst bilişsel farkındalık sonuçlarında ise bazı öğrencilerin üst bilişsel stratejileri daha bilinçli olarak kullandığı görülürken, düşük seviye öğrencilerin bu stratejileri kısıtlı kullandığı görülmüştür. Bu çalışma üst bilişsel stratejilerin RFN öğretiminde deneysel ve nedensel-karşılaştırma araştırmalar için zemin hazırlamakta olup yeni araştırma odağı sunmaktadır.

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LIST OF ACRONYMS/ABBREVIATIONS

AV	Aims and Values of science
EBA	Eğitim Bilişim Ağı
FRA	Family Resemblance Approach
FS	Financial Systems
H	High Level RFN Understanding
L	Low Level RFN Understanding
M	Methods and Methodological Rules
M	Moderate Level RFN Understanding
MAI	Metacognitive Awareness Interview
MEB	Milli Eğitim Bakanlığı
NOS	Nature of Science
PPS	Political Power Structures
RFN	Reconceptualized Family Resemblance Approach to Nature of Science
SCD	Social Certification and Dissemination
SE	Scientific Ethos
SI	Social-Institutional Systems of Science
SK	Scientific Knowledge
SOI	Social Organizations and Interactions
SP	Scientific Practices
SV	Social Values

1. INTRODUCTION

The nature of science (NOS) has been one of the critical fields of science education that has been studied through the decades (Abd-El-Khalick *et al*., 1998; Conant, 1947; Erduran & Dagher, 2014; Hodson & Wong, 2017; Lederman *et al.*, 2002). The reason and interest for studying NOS widely is improving science education in the way of raising scientific literate persons, engagement and use of content knowledge, practicing scientific activities, arguing in socio scientific issues and justifying the scientific arguments and claims (Arriola, 2017; McComas & Olson, 1998). Enhancing students' understanding, conceptual process and thoughts on NOS in terms of cognitive perspectives are important for NOS teaching for inclusion and reflection of NOS in lessons effectively. In this perspective NOS has been appraised with many cognitive constructs such as epistemology, metacognition, metacognitive strategies and metacognitive awareness (Abd-El-Khalick & Akerson, 2009; Oliveira *et al*., 2012; Peters, 2007).

In the NOS literature, since 1960s NOS has been defined widely and the interest on NOS has been increased after the Golden Age of Science Education period. In this period, it has been associated mainly with scientific knowledge and scientific inquiry as intertwining concepts. However, the term NOS has been changed and far from how it has been defined so far. The contemporary accounts or views on NOS has been constructed in science education literature (Abd-El-Khalick *et al*., 1998; Allchin, 2011; Duschl & Grandy, 2012; Erduran & Dagher, 2014; Hodson & Wong, 2017; Irzik & Nola, 2011; Matthews, 2012; Osborne, 2017).These contemporary accounts are ''Consensus View'' (Abd-El-Khalick *et al*., 1998) ''Whole Science'' (Allchin, 2011), ''Features of Science'' (Matthews, 2012), "Family Resemblance Approach to NOS" (Irzik & Nola, 2014), ''Reconceptualized Family Resemblance Approach to NOS (RFN)'' (Erduran & Dagher, 2014; Kaya & Erduran, 2016). From these accounts the most outstanding one is, "Consensus View" (Abd-El-Khalick *et al*., 1998) which has been studied and used in the NOS education widely. However rather than bringing consensus for NOS education, this view caused more discussions and disagreements in the literature.

Main critiques to this view are the omission of epistemic, cognitive and social systems of science, method and methodological rules, philosophical, historical aspects, domain specificity in science which restrain the scope and understanding of science. The critical controversial points are e.g., objectivity, subjectivity of science and cultural bound of scientific knowledge which are ambiguous in 7 tenets of "Consensus View" (Hodson & Wong, 2017; Irzik & Nola, 2011; Matthews, 2012).

Another critique is done by Erduran and Dagher (2014). They advocated for the need of new framework where NOS was represented in compact theoretical basis within holistic system. The approaches from philosophy and, domain specificity perspectives are needed to reflect NOS in science education. Then current new perspective that ''Reconceptualized Family Resemblance Approach to Nature of Science (RFN)'' (Erduran & Dagher, 2014; Kaya & Erduran, 2016) has been brought in the science education literature. Although previous account (Irzik & Nola, 2011) defended the importance of epistemic-cognitive and social institutional aspects as well, the educational applications have not been taken into consideration in which holistic, systematic and collective perspectives of science have been broadened. This framework allows to view the use of conceptualization in science to learn and understand the categories of science (Erduran & Dagher, 2014). The key value of this framework is the educational dimension in curriculum policy context in addition its contributions to science education. In later paper (Kaya & Erduran, 2016) this framework of Erduran and Dagher (2014) has been attributed to the coined term of RFN. Thus, in this study RFN term was be used and theoretical basis of this study was based on this approach.

Teaching and learning NOS are the crucial aims of science education in which NOS promotes students' understanding of what science is, how science and scientists' work, the relationship of science with society, philosophy and history of science (Allchin, 2011; Hodson, 1991; McComas *et al*., 1998). Knowing students' NOS understanding which also pave the way for developing students' scientific literacy help teachers, stakeholders and curricularist to improve science teaching and learning for a desired outcome of science teaching. Thus, in this perspective students' understanding of the nature of science is critical for utilizing public understanding and one of broad aims of NOS. Teachers are the main actors of NOS teaching who affects their students' perceptions, ideas and understanding of NOS (Abd-El-Khalick & Lederman, 2000; Lokollo *et al*., 2019). In these perspectives, investigating students' NOS understanding is very important for improvements in NOS education. However, for this aim students need to have consciousness on their thinking, learning or evaluation and regulation of their thinking and learning process. Students should think deeply for understanding NOS with aware of how they learn or form these key concepts, terms and processes of NOS (Baraz, 2012; Peters, 2007; Peters-Burton & Burton, 2020). Therefore, from this perspective NOS and metacognitive awareness can be linked and it is essential for understanding students' awareness and conscious in their learning process in NOS. The studies also show the importance of metacognition and metacognitive awareness in NOS learning. As Akerson and Donnelly (2008) stated "Prompts for metacognitive awareness built into NOS instruction facilitate NOS learning" (Akerson & Donnelly, 2008, p 47). Understanding of the relationship between metacognition and NOS understanding is very important for the inclusion or use of metacognitive strategies or techniques in science classrooms to increase students' awareness which in turn benefit for NOS learning. When these metacognitive skills and techniques have been practiced in science lessons, students' NOS understanding enhance. Thus, this relationship study paves the way for the appraising the link of metacognitive strategies or utilization of students' metacognitive awareness with NOS understanding which can lead to improvements in NOS education.

Furthermore, the studies that examine students' RFN understanding, metacognitive awareness and the relationship between students' metacognitive awareness and RFN understanding are very limited. Although RFN studies are broad in scope in terms of curriculum (Cheung, 2020; Park *et al*., 2020) and textbook analysis (McDonald, 2017; Yang *et al*., 2020), preservice (Erduran *et al*., 2020), university students (Akgun & Kaya, 2020) and in service teachers (Aksoz, 2019; Azninda & Sunarti, 2021), middle schoolers' RFN understanding are very limitedly examined. This deficiency also exists for the relationship between RFN understanding and metacognitive awareness.

When these all advantages of RFN framework especially its contributions in educational perspectives have been considered, it outweighs the other approaches. This theoretical framework needs to be transformed into research practice which gives empirical data on students' RFN understanding and introduces new construct in RFN teaching with examining the relationship between students' RFN understanding and their metacognitive awareness.

1.1. Purpose of the Study

This study aims to (a) investigate the middle school students' RFN understanding (b) investigate the middle school students' metacognitive awareness level (c) investigate the relationship between students' metacognitive awareness and their RFN understanding (d) examine the middle school students' perceptions of RFN e) examine the middle school students' self-reported metacognitive awareness.

1.2. Research Questions

For the scope of the study the following research questions and null hypotheses were directed as follows.

1. What are the middle school students' RFN understanding?

The sub-questions

1a) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students' RFN understanding?

1b) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students in terms of their understanding of aims and values of science?

1c) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students in terms of their understanding of scientific practices?

1d) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students in terms of their understanding of methods and methodological rules of science?

1e) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students in terms of their understanding of scientific knowledge?

1f) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students in terms of their understanding of social institutional systems of science?

2. What are the middle school students' metacognitive awareness level?

The sub-questions

2a) Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th}, 8^{th}) middle school students' metacognitive awareness?

3. Is there a statistically significant relationship between middle school students' RFN understanding and their metacognitive awareness?

The sub-questions

3a) Is there a statistically significant relationship between 5^{th} grade middle school students' RFN understanding and their metacognitive awareness scores?

3b) Is there a statistically significant relationship between 6^{th} grade middle school students' RFN understanding and their metacognitive awareness scores?

3c) Is there a statistically significant relationship between 7th grade middle school students' RFN understanding and their metacognitive awareness scores?

3d) Is there a statistically significant relationship between 8th grade middle school students' RFN understanding and their metacognitive awareness scores?

3e) Can students' metacognitive awareness significantly predict RFN understanding?

4. What are the middle school students' RFN perceptions?

The sub-questions

4a) What are 5th grade level students' RFN perception?
4b) What are 6th grade level students' RFN perception?
4c) What are 7th grade level students' RFN perception?
4d) What are 8th grade level students' RFN perception?

5. What are the middle school students' self-reported metacognitive awareness?

The sub-questions

5a) What are 5th grade middle school students' self-reported metacognitive awareness?
5b) What are 6th grade middle school students' self-reported metacognitive awareness?
5c) What are 7th grade middle school students' self-reported metacognitive awareness?
5d) What are 8th grade middle school students' self-reported metacognitive awareness?

1.3. Significance of the Study

This study contributes to science education literature in many distinct ways. Firstly, it is significant for students to understand the categories of science, the relationship, cooperation of aspects of science and how those categories contribute to making and doing of science (Duschl & Grandy, 2012; Erduran & Dagher, 2014). Hence, one of the aims of this study is to examine middle school students' NOS understanding where theoretical framework is based on RFN. There are empirical studies with RFN framework with respect to preservice teacher education (Cullinane, 2018; Erduran & Kaya, 2018; Kaya *et al*., 2019) university students (Akgun, 2018; Akgun & Kaya, 2020) , teacher education (Aksoz, 2019; Azninda & Sunarti, 2021), curriculum policy (Erduran & Dagher, 2014a; Kaya & Erduran, 2016, 2016a; Park *et al*., 2020; Yeh *et al*., 2019) and textbook analysis studies (BaouJaoude *et al*., 2018; McDonald, 2017; Yang *et al*., 2020).When school science context was considered, few studies concentrate on middle school students (Akbayrak & Kaya, 2020; Cilekrenkli, 2019; Karabas, 2017). However, these studies focused on the experimental design with investigation of the effect of RFN enriched lessons on 5th grade students' RFN understanding. In brief, there was still need of research for examining each grade level students' RFN understanding. Thus, there is gap in the literature that examines middle school students' RFN understanding holistically in addition to examining differences between different grade levels.

The research also shows that there is linked and related, influencing cognitive factor in students' development, and understanding process of NOS. If students are aware of their learning and conceptualizing process, they become intentional learners with having metacognitive awareness (Beeth & Hewson, 1999; Davis, 2003; Jaleel & Premachandran, 2016). It is significant to understand students' metacognitive awareness, how students develop and conceptualize science and its categories in their minds whether with aware of their own thinking process in concepts and ability to regulating their learning or not (Akerson & Donnelly, 2008; Peters, 2007). Hence another aim of the study is to examine students' metacognitive awareness and its relationship with RFN understanding. Although there are plenty of research which examines students' metacognitive awareness (Jaleel & Premachandran, 2016; Karakelle & Saraç, 2007; Sperling *et al*., 2002) and NOS understanding as separately, there are very limited studies that examine relationship between metacognitive awareness and NOS understanding together (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Gulsuyu, 2019; Sukaesih *et al*., 2020). However, scope of these studies is generally on preservice science teachers and limited with consensus view of nature of science. Thus, there is big gap in the literature that examines the relationship between middle school students' RFN understanding and metacognitive awareness.

Secondly, the use of questionnaires and interviews as multiple data source helped to get more reliable results and therefore significant for measuring metacognitive awareness and students' RFN understanding. As mentioned in the literature although questionnaires are easy to administer and bring large sample which reduce sampling error, depending on only one method for measurements can threat the validity of the results (Harrison & Vallin, 2018). Thus, the use of other possible measures such as interviews, coded observations, think-aloud protocols, performance ratings are more appropriate (Guskey, 2007; Dinsmore *et al*., 2008; Sarac & Karakelle, 2012). One of these frequent used methods is verbal reports which is directly asking students' what they know and what they do. The interviews allow in-depth investigation of students' ideas which give students opportunity to expand on their answers within mutual interaction process. The basic drawback of this method is the loss of time which can be compensated partially with auxiliary techniques of interview process (Baker, & Cerro, 2000; Scott, 2008). Thus, great emphasis has been put for reliable measurement of students' understanding and students' metacognitive awareness. Otherwise, the study would depend on only one method of measurement which would cause the questionable results (Guskey, 2007; Van Driel *et al*., 2012).

Thirdly, the correlational study itself provides advantages as a contribution of this study. Its design is straightforward to use, and it gives useful starting point for researcher who discover and understand the phenomena firstly. Before carrying out causal studies, examining the relationship between variables of experimental or causal comparative research give researcher insight about variables (Polit & Beck 2012). Moreover, the results of relationship studies can provide hypothesis testing for experimental research and can inform for further research to be conducted. Thus, in the current study the investigation of the relationship between students' RFN understanding and metacognitive awareness opens up the way for experimental research on metacognitive studies in the nature of science teaching that based on the recent theoretical approach. Although the correlational research does not provide causation, this disadvantage does not overshadow its significance and contribution to research field (Curtis *et al.*, 2016).

In overall, this study contributes the literature in terms of NOS instruction and NOS learning with eliciting students' RFN understanding and specially bringing new perspective and the term that is metacognitive awareness in NOS education. Revealing students' understanding gives understanding of students' ideas, thoughts and knowledge about NOS which can inform NOS instruction in a way to enhance or develop learners' ideas. It can contribute to consider implications of NOS in science lessons, revision, and inclusion of more cognitive strategies in the NOS teaching. Last but not least, the study shows the need of metacognition in NOS teaching and considering students' metacognitive awareness level in science classes. After understanding students' metacognitive awareness and its relationship with NOS, its importance and use of metacognitive strategies in NOS teaching can be advocated with more research in addition to looking for the ways to increase students' metacognitive awareness for practices in the nature of science education.

1.4. Operational Definitions of the Key Terms

- The Nature of science (NOS): It is defined differently and broadly by researchers with association in scientific knowledge or inquiry within predefined tenets, as features of science (mathematization, experimentation, idealisation, models, technology, realism, world-wide beliefs, explanations, and values), reliability, epistemic aspects and scientific literacy (Abd-El-Khalick *et al.*, 1998; Allchin, 2011; Matthews, 2012). In this study it is defined as comprehensive term that encompasses historical, philosophical, cognitive-epistemic and social-institutional aspects of science (Erduran & Dagher, 2014; Irzik & Nola, 2014).
- Reconceptualized Family Resemblance Approach to Nature of Science (RFN): RFN is coined term that was constructed for the Reconceptualized Family Resemblance Approach to NOS framework defined by Erduran and Dagher (2014) and named by Kaya and Erduran (2016). It reflects NOS as epistemic, cognitive and social system, its categories and educational applications for science education (Erduran & Dagher, 2014; Kaya & Erduran, 2016).

- RFN Understanding: It is operationally defined in this study. Individuals RFN understanding and its categories which is based on the recent framework of NOS.
- RFN Perception: It is operationally defined in this study. Individuals own ideas, thoughts, views on descriptions of RFN and its categories.
- Aims and Values of science (AV): One of the categories of science that explains aims and values of science such as objectivity, novelty, accuracy, value of simplicity within epistemic, cognitive and social aims and values (Erduran & Dagher, 2014).
- Scientific Practice (SP): Category of science that includes 6 components such as real world, explanation, model, prediction, activities and data to produce scientific knowledge with social processes of science (Erduran & Dagher, 2014).
- Methods and methodological rules of science (M): Diversity of methods that scientist used in their works that lead explanatory consilience such as evidence-based reasoning, experiments, observations, manipulative and non-manipulative methods, hypothesis testing, direct or indirect evidence (Erduran & Dagher, 2014).
- Scientific knowledge (SK): The work and coherence of theories, laws and models (TLM) for validation of knowledge and yield explanations for facts or principles (Erduran & Dagher, 2014).
- Social-Institutional systems of science (SI): The social aspects of science such as scientists' interaction with each other or values, ethics that they consider in their works in addition to professional activities, social certification and dissemination, scientific ethos, social organizations and interactions, political power structures, and financial systems of science (Erduran & Dagher, 2014).
- Metacognition: Ones' knowledge about cognition and regulation of cognition. Ones' control of own skills, learning activities, knowledge on how to learn and which kind of strategies or procedures are most effective for themselves (Brown, 1987; Flavell, 1976).
- Metacognitive Awareness Level: It refers to awareness of ones' own thinking and strategies that used, ability to control ones' own learning process (Brown, 1987; Schraw & Dennison, 1994).

2. LITERATURE REVIEW

This chapter focuses on the review of related literature about short review in history of nature of science (NOS), different accounts of NOS, “Reconceptualised Family Resemblance Approach to NOS”, the middle school students’ NOS understanding, metacognitive awareness in science education and metacognition and nature of science. In each section there are subsections to elaborate and broadly review each section.

2.1. Short Review of History of NOS in Science Education

In last decade, the nature of science (NOS) has become widely studied and researched are in science education literature (Conant, 1947; Jaffe, 1938; Pearson, 1900). Until today, many philosophers, historians and science educators has been defined what the nature of science is and its role in science education. The research on the nature of science (NOS) has increased in 1960s after Sputnik era, however, before then the nature of science has been characterized and used in the literature.

At the beginning of nineteens, the sense of NOS and its role in education can be found. For example, scientific method and scientific knowledge have been defined and explained by Karl Pearson (1900) with discussing the classification of facts, discovery of laws, systematic unit inquiry, benchmark of validity for minds, self-criticizing, and exactness of the mind. In the classrooms, these help students to be observer and careful investigator in his/her field to reach all citizens. On the other hand, in 1940s Jaffe (1938) advocates the use of nature of science skills, the importance of the scientific method, scientific research and scientific trainings on understanding of how the nature works. Unfortunately, in science classes, students are away from those issues and require life skills and activities. According to him scientists’ works, methods, humility intellectual integrity and growth of scientific knowledge (abandoning theory) should be the objectives of science education. The importance of history of science in education has also emphasized with research (Conant,1947). Students must acquire the strategies and tactics of science that help them to get deeper understanding of the scientific phenomena. These are the among earliest notions about the use and integration of NOS for science education and its relationship with the scientific literacy, scientific knowledge, and history of science.

In 1960s, the importance of NOS like other areas in science education has increased and gained importance after the Sputnik era, the launch of Sputnik in 1957 (Cotham & Smith, 1981; Klopfer, 1969; Kimball, 1968; Ruba & Anderson, 1978; Schwab, 1964). Then it has been mainly associated with the scientific knowledge and scientific enterprise which was the purpose of the science education and was stated in National Society for the Study of Education. It has been stressed that the students should not learn solely pure knowledge but to learn how knowledge is constructed, used, and developed (Hurd, 1960).

According to Klopfer (1969) development and accumulation of scientific knowledge and ideas, using instruments in the scientific research and interaction with science and society can be the insights of nature of science and process of scientific inquiry. These help students to relate the methods of scientific inquiry with scientists' work. Students who understand and adopt them become scientific literate person and have awareness in personal life. Moreover, as a teaching strategy the history of science should be taught to students with giving historical case studies such as development of scientific knowledge in history.

Another researcher (Kimball, 1968) developed the nature of science model as a result broad review of literature. This model consists of 8 ideas that reflect science and its features such as process orientation, curiosity, scientific method, relationship of science with gender, religion, politic power, reproducibility, and tentativeness of science. Another characterization of NOS has been modelled by Ruba and Anderson (1978). The scientific knowledge which is essential element of NOS was represented to reflect NOS. A 6-factor model that is "The Nature of Scientific Knowledge Model" was formed. According to this model, science is amoral, creative, developmental, parsimonious, testable, and unified. It is the product of human imagination and essence of scientific inquiry, and never absolute provable with interacting the theories, laws and concept. Cotham and Smith (1981) defined NOS with encompassing more characteristics such as tentativeness, making revisions, theory testing, generation of theories, theory choice and scientific hypotheses which are considered as important elements of characteristics of NOS. These components constitute crucial aims of science education since it entails public understanding and scientific enterprise. In brief, it can be seen that until today the nature of science has been defined and linked with scientific literacy, scientific knowledge, history of science, epistemic characteristics and scientific inquiry in the literature.

Around 2000s two adjacent terms of NOS which are the scientific knowledge and scientific inquiry were dominant in the literature. However, they have been differentiated from NOS in some research (Flick & Lederman, 2006; Lederman, 2004). Although Lederman (2004) stated that the inquiry and NOS are two different constructs, in literature two concepts are considered as interrelated and linked (Grandy & Duschl, 2007; Irzik& Nola, 2011). He advocated that "NOS refers to epistemology of inquiry activities and properties of scientific knowledge" (Lederman 2004, p. 308). Then later he proposed the term "nature of scientific knowledge" for NOS (Lederman, 2007). He considered nature of inquiry, scientific knowledge and NOS as a different connotation and proposed different term for NOS. However, some authors (Grandy & Duschl, 2007; Irzik& Nola, 2011) has criticized the essence of this term. According to Irzik and Nola (2011) omission of fundamental part of the science from NOS which are forming hypothesis, analysis of data, making conclusions, etc are artificial since they make what science is. Grandy and Duschl (2007) objected that epistemic frameworks and social aspects are the parts of scientific inquiry that cannot be disregarded. In these sense, scientific knowledge and NOS has also been seen and treated as same constructs while it has been seen as separated terms by some authors (Carey & Smith, 1993; Lederman, 2007; Driver *et al*., 1996).

Driver *et al*. (1996) made a distinction between the scientific knowledge and knowledge about science. The scientific knowledge is expressed as objects or phenomena of the real world. Knowledge about science is objects of science as theory, observation, law, and so on. It is meta language. Understanding the NOS is broad term that students understand ideas about science, scientific knowledge, social organization, practices of science and science content deeply and it is integral part of public understanding. Ryder *et al*. (1999) defined the knowledge of nature of science as knowledge about scientists' works, their decisions, how they conduct their research, collect data and develop the scientific knowledge. Three features of NOS were considered as key elements: understanding of the purposes of scientific work, the nature and status of scientific knowledge and science as a social enterprise. Students should also know scientific enquiry, distinction between data, explanation, laws and theories, consistency and accuracy of data, simplicity and fruitfulness of enquiry.

As it is seen from the literature the importance and research on NOS in science education has increased after Sputnik Era and it has been defined differently from 1960s to 2000s when it was associated with scientific literacy, history of science, scientific knowledge and scientific inquiry mainly. After 2000s, NOS has been broadly characterized and reflected as well. However, it has been changed and developed from those periods to today. To make clarification and better understanding for the scope and evolution of NOS contemporary accounts of NOS in the literature were reflected in the next section.

2.2. Contemporary Views and Trends of NOS in Science Education

In the recent literature on the nature of science (NOS), many different approaches and accounts has been proposed (Abd-El-Khalick *et al.*, 1998; Allchin, 2011; Erduran & Dagher, 2014; Irzik & Nola, 2011; Matthews, 2012) with defining and explaining the NOS and its role in science education. According to McCommas (1998) NOS combines various disciplines such as philosophy, history and psychology to explain what science is, what scientists do and how society reacts to scientific outputs. For science education it comes to play when different disciplines address and impact the science teaching and learning.

The most popular view in NOS literature is consensus view by Abd-El-Khalick *et al.* (1998). In later papers, the framework of this consensus view was explained with seven tenets that are stated with,

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

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

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

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

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

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

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

These 7 tenets explain what NOS is and features of it where it has been become mostly studied account of NOS in the literature (Abd-El-Khalick & Lederman, 2000; Lederman, 2007; Chen, 2006; Lederman *et al*., 2002; McComas *et al*., 1998; Schwartz *et al*., 2004). However, there are lots of studies that criticize and opponents of this approach (Allchin, 2011; Duschl & Grandy, 2012; Erduran &Dagher, 2014; Hodson &Wong, 2017; Irzik & Nola, 2011; Matthews, 2012; Osborne, 2017; Rudolph, 2000). Because of the critiques and oppositions to consensus view, thus, there is still no consensus on the specific definition of NOS among philosophers, science educators and historians of science.

One of these critiques is by Allchin (2017). According to him consensus view is outdated and outmoded. There are ambiguities and limited explanations of the consensus view. Teaching NOS should not be restricted within a limited list and focus should not only to teach NOS concepts but also NOS analysis. This means that students should ask questions by themselves and question the reliability of works. The broadening view of science is needed, and this is "Whole Science" (Allchin, 2011). This approach gives importance to the reliability, trustworthiness of knowledge and potential errors in studies such as poor measurement, lack of controls, misconduct the results, researcher bias, governmental effects and conflicts in science. The shift will be from the declarative knowledge to functional analysis of scientific literacy. Developing skills such as interpretation results, explanations, judgments that scientists manage are required skills to be taught in school science. Preparing scientifically literate citizens that will function in the society should be focus of the science education (Allchin, 2011). Like author said, “Students should develop a broad understanding of how science works to interpret the reliability of scientific claims personal and public decision making” (Allchin, 2013, p.4). We should let students have skills and practices that continue and go beyond the NOS classrooms. Learning the fraud, pseudoscience, misconducted research, political and commercial issues are points to be learned by students. This also informs the epistemic aspects of science and analytical skills such as scientific practices. According to researcher “Whole Science” is more systematic and include scientific literacy as opposed to consensus view (Allchin, 2011; 2017).

From Matthews’s (2012) view defining the NOS with explicit tenets do not reflect the scientific enterprise, historical, philosophical, epistemic, and psychological aspects of science which are limited and ambiguous in the consensus view. Science is portrayed as too general with missing its complex structure (Hodson &Wong, 2017). For example, while defining the empirical base of science, the ontological aspect in entities and role of abstraction are neglected. The debate between realist, instrumentalist, and empiricist in the history of science was omitted. Subjectivity of science brings discussion about the objectivity of science and gives little understanding about philosophical or psychological subjectivity. Although scientific knowledge is subjective, science is oriented by scientific works which has objectivity in nature. Cultural embeddedness of science in consensus view which means the science is culturally dependent neglect the effect of Nazism, Hinduism or etc on scientific works. Irzik and Nola (2014) also criticized this tenet of consensus view. They criticized the cultural embeddedness of science since scientific knowledge is valid and belong the across nation. Thus, science cannot be justified as good or bad. These 7 tenets encompass only scientific knowledge without other components of science (Erduran & Dagher, 2014; Irzik & Nola, 2011, 2014; Matthews, 2012). Furthermore, deficiencies in the methods of science such as limited focus of variety of methods and investigations in science shows the main deficiencies and lack of representation of NOS (Osborne, 2017; Irzik & Nola, 2011).

Rather than these tenets Matthews added features of science (FOS) to NOS literature. New features that were added are experimentation, idealisation, models, technology, realism, world-wide beliefs, explanations, and values. These are the subtle, relaxed, contextual FOS to nature of science research. Epistemological aspects of science, role of inference in scientific process are required to consider while defining the NOS. He suggested slow and step by step process for embedding philosophical aspects of science for the educational application. However, there are critical aspects such as cognitive and social aspects of science that are not directed in this approach. Mainly some certain aspects of science such as sociocultural, socio-scientific aspects and scientific literacy are advocated and defended to define and explain NOS and NOS teaching.

2.2.1. The Idea of Family Resemblance and Family Resemblance Approach to NOS

Another contemporary account is “The Family Resemblance Approach to NOS” by Irzik and Nola (2011) with framing the philosophical view of family resemblance idea (Wittgenstein, 1958) to nature of science. This family resemblance idea comes from philosopher Wittgenstein (1958) about making definitions of terms. According to Wittgenstein, complex terms can be defined with broad cluster of linked ideas or terms rather than defining in explicit and certain way. For example, the triangle can be explicitly defined with three edges and lines in closed shape geometric figure. However, for definition of game, there is no certain circumstance or exact way to define the game explicitly since each game types have different nature and characteristics such as mind games, video games, ball games, board games, etc. However, the family resemblance idea can define complex terms such as the term of science. The family resemblance idea reflects the family analogy where members of the family share similar or dissimilar characteristics somehow. To define concept (e.g., family) one should consider the common traits (e.g., eye, hair colour, etc) and overlapping characteristics of that concept. Then, for making definition of the term science one need to know similar and dissimilar traits of science disciplines to understand and define it (Hacking, 1996; Wittgenstein,1958).

Then basing upon Wittgenstein's (1958) this idea, "The Family Resemblance Approach to NOS" (Irzik & Nola, 2011) can be explained in detailed way. From the idea of family resemblance, the observations and making inferences can be common in different disciplines of science such as in astronomy, earthquake, organic chemistry, microbiology, or zoology, etc. For instance, astronomy can be successful at making prediction of locations of celestial bodies while earthquake science does not. On the other hand, using manipulative or hypothesis testing can be hard for some of branches. If these are put in systematic way, the eight categories of science give us understanding about what the NOS is. These eight categories are process of inquiry, aims and values, methods and methodological rules, scientific knowledge as epistemic- cognitive epistemic system and social institutional system with subcategories such as professional activities, social certification and dissemination, scientific ethos, and social values (Irzik & Nola, 2014). Although they have investigated some of those categories in their previous work, they framed and broadened these categories in more systematic way later (Irzik &Nola, 2014). According to Irzik & Nola (2014) social part of science has been less examined in science education research as opposed to epistemic cognitive system, researchers preferred to consider social institutional system as new category with its subcategories. These subcategories are social certification and dissemination, scientific ethos, social values, and professional activities that scientists engage. These are the social aspects of science that scientists consider in their works and interactions. Additionally, although this approach has also taken perspective for educational application of NOS for teachers, these suggestions are limited in terms of how to apply and facilitate each category from curriculum perspective. Thus, in the literature there is still need of comprehensive, systematic expression for defining and teaching NOS for inclusion of educational and pedagogical perspective.

Although FRA to NOS by Irzik and Nola (2014) seem systematically encompassing all aspects of science, the more extended discussion is needed to elaborate and broaden explanations of components and educational applications which were limited in the "FRA to NOS" approach. Although science consists of epistemic-cognitive social institutional system, political-financial-institutional aspects are needed to be reflected in social system. The proposed philosophical models for NOS need to be translated into functional model to facilitate application by science teachers and learners. The linguistic account that was represented in FRA is required to be represented in visual collective, dynamic way (Erduran & Dagher, 2014).

2.3. Reconceptualized Family Resemblance Approach to Nature of Science (RFN)

Within the light of these critical issues in the "Family Resemblance Approach to Nature of Science (FRA to NOS)" (Irzik &Nola, 2014), this framework has been reconceptualized by Erduran and Dagher (2014) with additional categories of science (epistemic, cognitive, and social institutional aspects holistically) as a recent holistic approach to NOS literature. These categories are complementary and in mutual interaction with comprehensive epistemic cognitive social system. This "Reconceptualized Family Resemblance Approach to NOS" (RFN) framework extends FRA with additional categories (scientific practices, political power structures, financial systems, social organizations and interactions in social institutional system), educational applications,

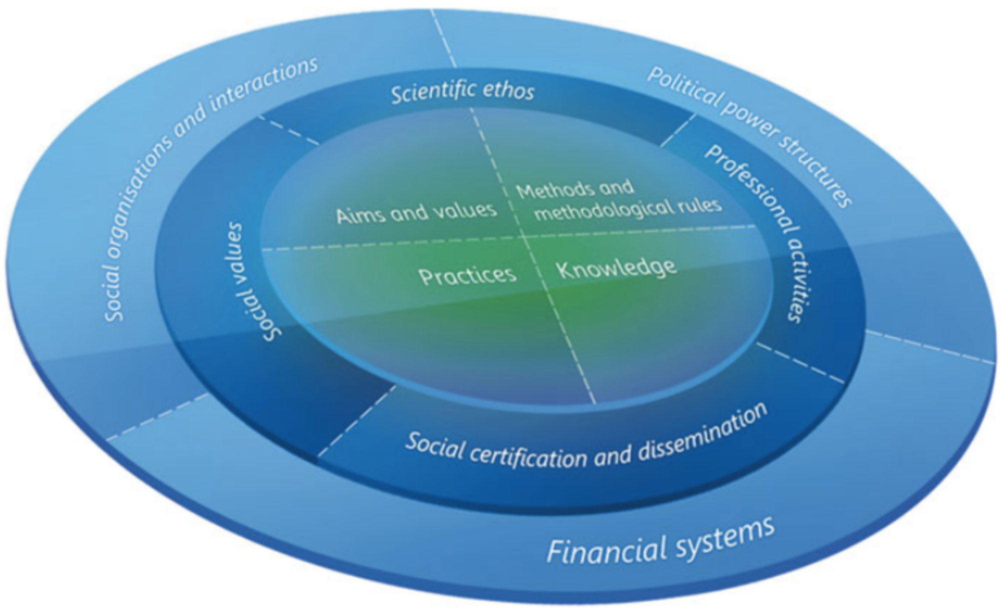

Figure 2. 1. FRA wheel: science as a cognitive- epistemic and social institutional system. Source: [Erduran & Dagher, 2014, p28]

visual representations that help teachers to elaborate and practice them in science lessons. It represents curricular and pedagogical perspectives in science education. Then the coined term of RFN for the "Reconceptualized Family Resemblance Approach to Nature of

Science" (Erduran & Dagher, 2014; Kaya & Erduran, 2016) is mainly used and referred in the literature for empirical studies and educational importance of this framework. In this framework science consists of 5 main categories which are aims and values, scientific practices, methods and methodological rule, scientific knowledge, and social institutional system. The components of science are systematically and visually constructed with figures and representations by Erduran and Dagher (2014). One of these visual figures is "FRA Wheel" (Figure 2.1) model that represents all cognitive, epistemic, and social-institutional components of science holistically. This concentric circle model extends 8 categories which was in textual format in Irzik and Nola' s framework (2014) into visual, comprehensive format with 3 new additional categories that place in outer circle. As it is seen borders between categories have hollows that shows the flexibility or fluidness between categories. These porous parts show the interaction between categories rather than distinction between them. Each of these categories were explained detailly in the remaining sub sections.

2.3.1. Aims and Values

This category encompasses epistemic, cognitive, and social aims and values of science. There has been long debate on aims and values of science such as objectivity and subjectivity of the science where the stress appears between facts and values (Abd-El-Khalick *et al*., 1998; Matthews, 2012). Aims and values of science are so intertwined and interrelated with each other that it is hard to distinguish them. Epistemic values are accuracy (Popper 1963, 1975), testability, empirical adequacy (van Fraassen 1980) and novelty that help scientists to make judgements on scientific works (Longino, 1995). On the other hand, social values as a complementary component of social dimensions of science mean critical values of science that scientists experience. These aims and values intertwined with other components of science. For instance, novel predictions, the explanatory power and value of simplicity can also affect and be a criterion in choosing the method and methodological rules (Irzik & Nola, 2011). For example, when there are two competing rival theories (other factors equal), one can select the one which is more explanatory and simpler in nature. Thus, this can be rule for researcher while in explaining or selecting methods that will be followed. Furthermore, the other aims of science are consistency, simplicity, fruitfulness and broad scope (Kuhn, 1977) in cognitive system. Then to reflect these epistemic, cognitive and social aspects of science Erduran and Dagher (2014) used triangle figure (Figure 2.2) where each boundary represents these aspects continuously. Additionally, moral and ethics were also part of these aims and values. However, its place and role were linked in social political cultural context and detailed in social institutional system by Erduran and Dagher (2014).

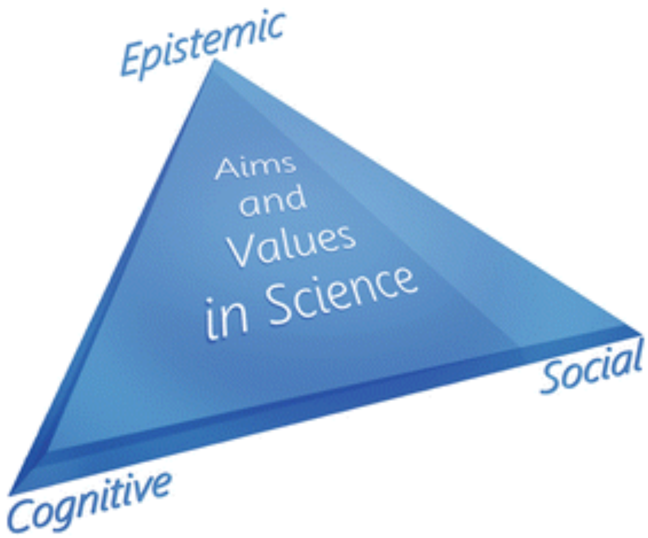

Figure 2. 2. Aims and values of science.
Source: [Erduran & Dagher, 2014, p. 49]

In educational sense, promoting these essential aims and values of science in classrooms are needed due to 3 important reasons. 1) aims and values of science guide and give coherent way of understanding the formation and development of scientific knowledge and practices. 2) deeper understanding of science concepts and topics 3) students get the idea that the bias that come from values can affect the scientific works or transmission of knowledge (Erduran & Dagher, 2014). Critical aspects such as meaning of accurate data, defending arguments and constructing powerful and explanatory theories or explanations are required students for understanding aims and values that shape development of scientific knowledge. Students can experience the value of science with choosing most explanatory and simple theories. Practicing these values in science lessons also help to develop students' cognitive abilities (Allchin, 1999; Erduran &Dagher, 2014).

2.3.2. Scientific Practices

This category of science mainly related with activities that scientists perform. Three main activities which are observation, experimentation and classification are pointed out in terms of their contribution to development of scientific knowledge and science products. Observation is the main activity that can be practiced in many branches of science. While some disciplines require direct observation, some can require calibrated equipment such as telescopes or spectrographs. However, observation becomes scientific practice when it was included in theories or promoted with other practices (Irzik & Nola, 2011, 2014; Erduran & Dagher, 2014). Classification on the other hand is used effectively in many sciences such as classification of species classification of elements within the periodic table. It has also hierarchical structure that can help to organize and evaluate concepts with linking higher level concepts and examples. This is especially useful in school science to generate ideas and concepts, making relationship between them with categorical representation (Davies, 1989; Kwasnik, 1999). In experimentation, scientists deal with various controlled tests and communicate the results with peer review process. Intervention and reproducibility are the key elements of experiments (Radder, 2009). Intervention means that scientists need to manipulate variables or intervene the process to reach conclusion. Reproducibility is the production in new substance or elements. It is also theory free that can be reinforced with other practices. In sum these epistemic activities are not separated or distorted rather they are interrelated that incorporate for development and generation of knowledge (Erduran & Dagher, 2014; Mayo, 1996).

Although these practices have considerable place in the science curricula, they are represented in very limited and distorted way. This cause students to have inadequacy for understanding and experiencing these scientific practices before graduating the middle or high school (Cheung, 2020; Kaya & Erduran, 2016). In school science context, the offered benzene heuristic (Figure 2.3) that represents epistemic cognitive and social aspects of scientific practices with benzene ring analogy can be an effective tool (Erduran & Dagher, 2014). The benzene ring reflects each scientific practice such as real world, prediction, explanation, model, data, and activities as epistemic cognitive dimensions with making analogy of six-carbon hexagonal ring with double bonds. Besides, social aspects are also interviewed with those epistemic and cognitive scientific practices. They are so dynamic that can incorporate and change their position with each other. The circle bonds are moving around with each practice which means that these social components can interact with

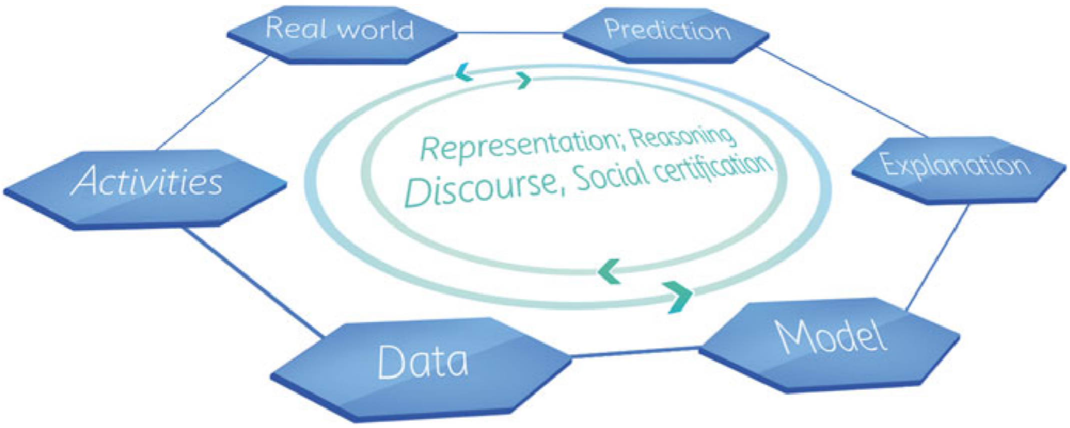

Figure 2. 3. "Benzene Ring" heuristic of scientific practices.
Source: [Erduran & Dagher, 2014, p. 82]

epistemic cognitive practices inclusively. These are representation, reasoning, discourse, and social certification in which two-way arrows incorporate. This means that they are like fluid and can be refined within the process. These are central in science learning where students experience and practice scientists' work. Thus, this heuristic offers two main aims. 1) It shows the scientific practices in systematic and comprehensive way. 2) It can help educators to practice them in school science context (Erduran & Dagher, 2014).

2.3.4. Methods and Methodological Rules

In a comprehensive way, the scientific method has been defined by philosophers, science educators and dictionaries with different notions. In Merriam-Webster (n.d.) it was defined as collecting data with observations, experiments, carrying out procedures and forming hypotheses. In the philosophical perspective, Irzik and Nola (2014) discuss that there are methodological rules of science that direct the scientific method process. These rules are the forming hypothesis, choosing explanatory theories, performing experiments, using blinded processes etc. These rules help scientists to follow the way of generation of scientific knowledge (Grandy & Duschl, 2007). On the other hand, in school science there is a disagreement between historians, philosophers and science educators in terms of the scope of scientific method. According to philosophers and historians the algorithmic representation in school context is not possible since science is more complex for students to experience (Halwes, 2000). However, the educators advocate that simple and basic version of scientific method can be practiced by students in schools. In this process teachers should use disciplined inquiry rather than standard or lock step method of science. Recipe like cookbook procedures do not help students to understand the how scientists work and get reliable knowledge (Radder, 2009).

The notion that there is no one way of doing science is mostly used to explain scientific method which is also one of tenets of consensus view (Abd-El-Khalick *et al*., 1998). It is obviously true that there is no one way of doing science. However, in science there are diversity of methods and no explicit certain process or procedures to follow. For example, scientists can use evidence-based reasoning, experiments, observations, manipulative and non-manipulative methods, hypothesis testing, direct or indirect evidence in their works. When different diverse methods emerge, explanatory consilience help to form or explain the phenomena (Wilson, 1998). Furthermore, Erduran and Dagher (2014) constructed the gears image (Figure 2.4) to represents these diverse methods and their complementary function which yield explanations of complex phenomena. These methods are represented as gears and lead the way of explanatory consilience with functioning together. Thus, this figure can be used as a visual tool to represent working principle of methods and methodological rules of science in school science.

How these methods and methodological rules can be practiced in school science is another important point of concern. The lock step where certain, same methods are used can distort the way of making science (Radder, 2009). For example, many students try to explain evolution theory with direct evidence such as looking for experiments and observations (Dagher & BouJaoude, 2005). However, in evolution theory there are historical evidence (from palaeontology) and manipulation techniques such as gene alterations. To make sense

Figure 2. 4. The 'gears' image illustrating how evidence from variety of methods work synergistically contributes to explanatory consilience.
Source: [Erduran & Dagher, 2014, p.101]

for other methods such as observation, cultural and historical evidence, descriptive, manipulative/non-manipulative methods, and hypothesis/no hypothesis testing teachers should use and practice them. When students realize these diversities of methods used in science, they will get the understanding and way of doing science (Dagher & BouJaoude, 2005; Erduran & Dagher, 2014).

2.3.5. Scientific Knowledge

Scientific knowledge is related with the development, emergence and growth of theories, laws and models (TLM) (Erduran & Dagher, 2014). These are the basic forms of scientific knowledge with having the dynamic connection and interaction rather than being as separate entities. The work of these forms of knowledge where explanations bind them together generate scientific enterprise and knowledge. For example, for understanding and explaining the concept of biological traits the genetic theory, law of inheritance and gene models all contribute to explanation of this scientific phenomena (Kuhn, 1970). Furthermore, these theories, laws and models all have different function and forms of classification as separately (Dutch, 1982). These functions and classifications can be explained with the domain specificity which dictates the differences between the branches of science such as chemistry, astronomy, etc. For example, while laws in physics such as the law of gravity can have quantitative, algebraic or predictive nature, periodic law in chemistry rather than in mathematical terms it has predictive nature with its regularities (Scerri, 2000). This shows the function of laws in different disciplines can serve for different explanations (Lakatos, 1978). In school science, students generally think that laws are verifiable and become hypothesis which they consider as an end point (McComas, 1998). The classification and relationship between these tree components of scientific knowledge are important to practice in science lessons. In simplistic version domain specificity can be promoted in school science with discussing the claims that explain similar and different functions of laws, theories, and models. In this way, students can get the meaning of domain specificity in these forms of scientific knowledge. Although, in school science these are not represented, and work of the forms of knowledge are not explained, teachers can create learning environment for work and coherence between theories, laws and models (Duschl *et al*., 2006). For this

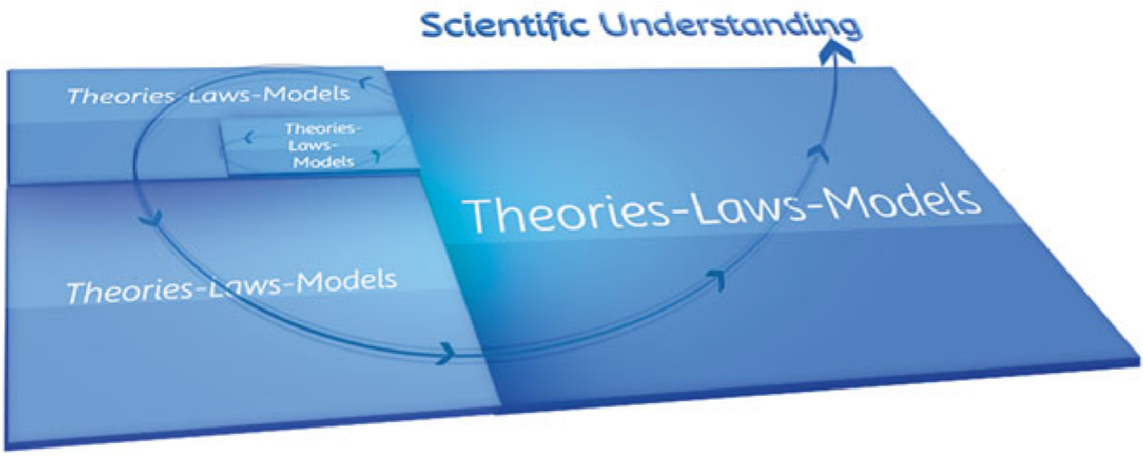

Figure 2. 5. TLM, growth of scientific knowledge and scientific understanding.
Source: [Erduran & Dagher, 2014, p.115]

purpose, the visual tool that was proposed by Erduran and Dagher (2014) can be efficient tool to emphasize how the work of TLM support for the development of scientific knowledge and understanding. This visual tool (Figure 2.5) represents scientific knowledge and its growth as a pedagogical tool as well for teachers and students. It is dynamic and coherent representation that can help learners to visualize the work of TLM (Erduran & Dagher, 2014). These issues such as domain specificity, explanatory pluralism, work of TLM are the main stones that contribute epistemological conceptual learning aspects of students.

2.3.6. Science as a Social Institutional System

Science as a social institutional system relates to social aspects of science such as scientists' interaction or social utility, integrity, enterprise of science. This system has its subcategories which are scientific ethos, social certification and dissemination, social values and professional activities that was defined by Irzik and Nola (2014). However, since there were deficient social categories of science in this categorization, Erduran and Dagher (2014) extended this categorization with adding political power structure, financial systems and social organizations and institutions categories. There is also the visual representation of this category constructed by Erduran and Dagher (2014). They elaborated all 7 categories of social institutional system with concentric model. They centred 4 categories that are professional activities, social values, social certification and dissemination and scientific ethos at the inner part. Then other remaining newly added 3 categories are political power structures, financial systems and social certification and dissemination at the outer part with this holistic visual representation of this category (Erduran & Dagher, 2014). These all subcategories represent social aspects of science such as scientists' interactions, values, ethics, etc. For example, professional activities mean scientists' activities, presenting findings, attending conferences, writing papers, etc as professional (Irzik &Nola, 2014). Social values are freedom, respect for the animals and environment and social utility. Social certification and dissemination are evaluating and reviewing articles, publishing in journals, peer review process, endeavours in the scientific community (Kitcher, 2011). Scientific ethos refers to scientists' interactions and behaviours that adopt and display while in their scientific works and human interactions. This scientific ethos is also known as 'Mertonian norms' (Merton, 1973) which are universalism, organised scepticism, disinterestedness, communalism. However, the scientific ethos is not restricted with these norms rather there are also Resnik' norms (Resnik, 2007) such as intellectual honesty, respect for research subjects, respect the environment, freedom, openness.

In the outer circle the one of the elaborated categories is social organizations and interactions. This refers to scientific organizations and institutions that represents scientists work environment and their interactions such as universities, research centres and institutions. The example of these institutions can be TUBITAK, CERN, NASA, etc. where researchers work on projects and articles together. The other new category is political power structures which is related with the effect of political system on science and scientific studies. The gender, race, use of science as ideology and other factors have connection with the political power structures such as feminist philosophers who strive for inclusion of women in characterization of science. The relation or role of government on science and the ideological power of science are critical in scientific studies. The last category is financial system which refers economic issues that scientists deal with in their works. For example, scientists can need to find grant or finance their research with the help of economic authorities. Thus, promoting these in science lessons will help students to be scientifically literate person and understanding comprehensively of how scientific knowledge is produced. Teachers have important role in promoting and practicing these NOS aspects in science lessons (Erduran & Dagher, 2014). Furthermore, for practice of these categories in science lessons, pedagogical methods such as evidence-based reasoning, argumentation, searching data archives, discussing scientific papers, attending scientific olympiads can be provided within logical context. In schools these social aspects of science also needed to be practiced to sense holistic picture of NOS.

In overall, this framework put emphasis on epistemic cognitive and social aspects of science together with integrating domain specificity, evidence-based argument, and educational application of NOS in science education literature. It broadens FRA in holistic, systematic, and visual way which also connected with metacognitive dimension in terms of domain specificity perspectives. How NOS can be integrated to classroom level, curriculum policy and instruction are represented in this framework with examples and discussions on critical issues. Then later, for making clarification on the term used for ‘‘Reconceptualized FRA-to-NOS’’ framework, Kaya and Erduran (2016) constructed the term RFN. This coined term was mainly used in many studies whose framework was based on RFN framework (Erduran & Kaya, 2018; Kaya & Erduran, 2016; 2016a; Kaya *et al*., 2018; 2019). The aim was to teach NOS in holistic way, examining curricular policy and coin comprehensive term for this framework. The holistic picture of science are the interrelations among categories of science are core elements to teach NOS (Erduran & Dagher, 2014).

RFN framework also have metacognitive dimension. It allows for the facilitation of metacognitive awareness of the domain-specific aspects of science (Erduran & Dagher, 2014). When different branches of science have been thought and tried to be reflected in terms of domain specificity, it helps to organize thinking around the different methods in science. This metacognitive dimension has effect in scientific knowledge as well which domain specificity play a major role in explanation of this aspect (Irzik & Nola, 2011; Erduran & Dagher, 2014; Wittgenstein, 1958). It stimulates students' thinking and regulation of ideas, learning while thinking around different concepts. Thus, students' learning, problem solving and understanding of NOS concepts are related with their metacognitive process in thinking and constructing concepts (Schizas & Psillos, 2019; Zohar & Dori, 2012). Although metacognition has not been emphasized in RFN studies, there are many studies that show use of metacognition and metacognitive awareness in NOS which theoretical basis rely on consensus view (Abd-El-Khalick & Akerson, 2009; Akerson & Donnelly, 2008; Cetinkaya, 2012; Cetinkaya-Aydın & Cakıroglu, 2017; Peters & Kitsantas, 2010; Ozgelen, 2012). However, for clear expression, RFN studies at first and metacognitive studies in NOS were reflected in successive sections.

2.4. RFN Studies in Science Education

In the literature, studies that based on RFN framework are broad in number (Akgun & Kaya, 2020; Aksoz, 2019; Akbayrak & Kaya, 2020; Alayoglu; 2018; Cullinane, 2018; Cilekrenkli, 2019; Dagher & Erduran, 2016; Erduran & Dagher, 2014, 2014a; Erduran & Kaya, 2018; Kaya & Erduran, 2016, 2016a; McDonald, 2017; Sarıbas *et al*., 2019). In some of these RFN based studies, representations of RFN approach in science curriculum (Cheung, 2020; Erduran & Dagher, 2014a; Kaya & Erduran, 2016, 2016a; Park, et al., 2020; Yeh *et al*., 2019) and textbooks (BouJaoude *et al*., 2018; McDonald, 2017; Yang *et al*., 2020) were examined. Some of these studies investigated preservice or university students' NOS understanding (Akgun, 2018; Akgun & Kaya, 2020; Cullinane, 2018; Erduran & Kaya, 2018; Erduran *et al*., 2020; Kaya & Erduran, 2016; Kaya *et al*., 2019) while some of studies focused on teachers' RFN understanding (Aksoz, 2019) and the effect of RFN based instruction on middle school students (Akbayrak & Kaya, 2020; Cilekrenkli, 2019; Karabas, 2017).

The studies that focus on middle school students rely on experimental design and 5th grade level students as study group (Akbayrak & Kaya, 2018; Cilekrenkli, 2019; Karabas, 2017). For instance, Akbayrak & Kaya (2020) examined the effect of teaching social institutional category of RFN on 5th grade students' attitudes and understanding of social category of science. Students' scores on social institutional aspect of science were in the range of the 64% and 72%. In addition, their perceptions in the social institutional system were more prevalent in professional activities and social certification and dissemination. Emerging ideas from students' interviews were attending conferences, making presentations on findings, publishing articles, reviewing their work, making congress, and meetings, social organizations that scientists work, effect of politics on science. However, scientific ethos and social values were less emphasized by students (Akbayrak & Kaya, 2020).

Similarly, Cilekrenkli (2019) investigated the effect of instruction on 5th grade students for all RFN categories to examine students' RFN understanding and their perceptions. Students' pre-test RFN scores were corresponding to 66 % of scores. In the pre-interview results students' initial perspectives on science and its categories showed diversity. Students' thoughts in aims and values of science were on social utility such as informing public, making inventios, serving for humanity, doing no harm. In scientific practices, she found that most 5th graders were expressing experimentations, observations and classification before intervention, but students' expressions on other practices such as social certification and real world were less dominant. For method and methodological rules experimental tools, having presuppositions and activities such as drawing diagrams and excavations were students' ideas while in scientific knowledge tentative nature of science, governmental laws and propositions for theories were their initial ideas. On the social system of science governmental control, funding, reporting the study results, social utility, protecting the subjects, informing public were general appearing notions in the pre interview results. However, the scope of these RFN based studies was limited to conclude about students' RFN understanding and perceptions because of their experimental nature of design. Thus, more detailed research is needed to see all middle school students' RFN understanding.

In sum, although there are empirical RFN framework-based research on middle school students, these studies focus on specific aspect of RFN such as students' social institutional or scientific practices category (Akbayrak & Kaya, 2020; Karabas, 2017) and mainly rely on experimental design research and 5th graders (Akbayrak & Kaya, 2020; Cilekrenkli, 2019; Karabas, 2017). Furthermore, when metacognitive perspective has been examined, it is seen that limited research focuses on the relationship between students' RFN understanding and their metacognitive awareness in this scope.

2.5. Middle School Students' Understanding and Views of NOS

One of the important and main goal of science education is to develop students' understanding of NOS in constructive way which make them scientific literate person and have them basic skills and content knowledge (American Association for the Advancement of Science [AAAS], 1993; Bell *et al*., 2011; Osborne *et al*., 2003). Developing students' NOS understanding improves the quality of science education which allow students to have ability for reaching full richness of NOS, applying it in daily life and practicing as lifelong ability. Considering and revealing students' NOS understanding inform curriculum studies and teacher education programs for broadening NOS inclusion in school science (Meichtry, 1993). Although there are lots of studies (BouJaoude, 1996; Celikdemir, 2006; Demir & Akarsu, 2013; Sadler *et al*., 2004; Suzuri-Hernandez, 2010; Tao, 2003; Yalaki *et al*., 2019) that examine students' NOS understanding and their views, few of them were summarized in this section.

Tao (2003) investigated 150 middle school students' understandings and arguments for NOS, students' reactions to NOS stories and effect of small group working on NOS understanding. The results showed that many students have inadequate understanding in terms of aim of experiments, scientific knowledge and scientific method. 95% of students did not realize the function of hypothesis and scientists' expectations in the experiments while for scientific knowledge 48% of them thought that theories are the explanations for phenomena and facts that are proven. Only 4% considered making prediction for explanation of theories. Many students (75%) consider that models such as solid, liquid, gas particles are proved through experiments by scientists. Just 12% thought that their imaginary representations. These results show the students' limited perspective on scientific methods and scientific knowledge in science.

Cofré *et al*. (2019) reviewed 52 studies on students' views of NOS and mostly studied aspects of NOS are found as tentativeness, observation and inference, creativity, and the empirical basis of science. In the empirical basis of science many students have adequate views while for subjectivity of science many of them have naïve views. Half of studies that examine students' views based on experimental studies and commonly used instrument is 'Views of Nature of Science Questionnaire' (VNOS-D). Limited aspects (relative, empirical, provisional, inferential, subjective and social cultural perspective) of NOS have been investigated. Researchers indicated that students' learning in the tentative nature of science, theory and law concepts, social and cultural embeddedness properties of science are harder than learning empirical basis of science, observation, inference, and creativity aspects of science for students.

Celikdemir (2006) examined middle school students' NOS understanding with 10-item questionnaire and semi-structured interviews. 1026 6^{th} and 923 8^{th} grade students attended to quantitative part while 12 students were interviewed in the qualitative part of her study. As a result of data analysis in terms of tenets of NOS she concluded that students have traditional views on NOS. Most students were limited in viewing theories and laws while for methods of science they were believing scientific method myth that is pursuit of one scientific method in scientific studies. 8^{th} graders had more realistic views on the tentative and subjective features of science compared to 6^{th} graders. A similar study (Kang *et al*., 2004) examined 6^{th}-8^{th} and 10^{th} grade students' views of NOS with attendance of 1702 students to survey. They concluded that majority of students had absolutist/empiricist views on NOS. Students were viewing scientific theories and models as proven knowledge. They reported that students consider science as making useful productions for human. Most students had contemporarily accepted the nature of models. In addition, researchers also founded no differences between 6^{th}-8^{th} and 10^{th} grade students

The studies (Akerson *et al*., 2000; Khishfe & Abd-El-Khalick, 2002) were also pointing that NOS as a cognitive instructional outcome develops the chance of achievement for students' NOS views. As a cognitive learning outcome teaching NOS explicitly with reflective, discussion led environments, explaining purpose of actions allow students to map their actions. These reflective explicit lessons aim increasing students' awareness in NOS concepts. For instance, Khishfe and Abd-El-Khalick (2002) investigated the effect of these explicit teaching on 6th grade students' NOS understanding. With completing the 2.5 months of intervention, researchers founded that the students who had uninformed views of NOS before the intervention developed more informed views at the end of the intervention. They suggested that in NOS lessons students' awareness of their NOS views is needed with inclusion reflective NOS teaching.

From the literature it has been seen that many students hold inadequate or naïve views and understanding of NOS. Furthermore, these studies were mainly depending on consensus view (Celikdemir, 2006; Cofré *et al*., 2019; Kang *et al*., 2004; Tao, 2003). However, realizing students deeper thinking process in NOS, considering, and understanding students' own cognitive process and their strategies to learn NOS are also crucial for NOS teaching. If teachers can understand the students' own learning process, instruction can also be promoted in way of enhancing students' regulation, control of their thinking and making them familiar and more aware of thinking about their own thinking process in NOS (Chiu & Duit, 2011; Choi *et al*., 2011).

The recent research indicates that students' understanding, and their concept development has been related with their regulation of cognitive process such as their reflection in NOS and metacognitive abilities. (Schwartz *et al*., 2004; Tsai, 2006). Students' learning, problem solving and understanding of concepts depend on their cognitive process such as thinking and constructing concepts (Astawa *et al*., 2018). While they develop and form their concepts and try to understand NOS, the cognitive factors such as metacognition has an enormous impact on students' thinking and learning process with interfering cognitive construction of individuals. Use of strategies as a teaching method promote teaching NOS effectively as well as learning NOS. It allows students to regulate their thinking with aware of NOS learning process. Thus, it is important to consider metacognition and its components such as metacognitive awareness in which students get aware of their learning process in school science context (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Ozgelen, 2012; Yenice *et al*., 2017).

2.6. Metacognitive Awareness in Science Education

The term metacognition has been firstly introduced by Flavell (1976) and Brown (1987) with referring it to the knowledge about cognition and regulation of cognition. The knowledge of cognition (KC or KoC) refers to our knowledge about how we learn, which kind of strategies or procedures are most effective and beneficial for us. It is about the knowledge of skills, strategic knowledge, one's self-knowledge on learning strategies and abilities. It includes the declarative, procedural and conditional knowledge. The declarative knowledge is awareness of one's own strategies and capabilities. The procedural knowledge related with awareness and knowing how to apply those strategies and lastly conditional knowledge is the knowing the exact time to apply those and reason of use of those strategies. On the other hand, the regulation of cognition (RC or RoC) refers to control of ones' own skills of learning activities such as planning, management, monitoring, debugging and evaluation. Putting aims, making organization, evaluating ones' learning process or actions, improvement and realizing errors, rescheduling, making revisions and analysis of strategies are strategies for the regulation of cognition. (Brown, 1987; Schraw & Dennison, 1994; Schraw & Moshman, 1995).

With the help of metacognition students realize their own capacities to learn and their abilities with monitoring their learning process (Brown, 1994). It has main role not only in self-regulating but also creative and critical thinking in which students realize their own performances and strategies in science. It gives a way for effective and long-term learning for students (Memnun & Akkaya, 2009). For example, Akyol *et al*. (2010) investigated the relationship between use of metacognitive strategies and 7th grade students' science achievement. They found that use of metacognitive self-regulation strategy is significant predictor for students' science achievement. For instance, Schraw *et al*. (2012) investigated the relationship between knowledge of metacognition and field-based science program in 4th and 5th grade students. It was found that students' cognition and regulation of knowledge are correlated. Additionally, their metacognitive knowledge was also correlated with their attitudes. On the other hand, metacognitive awareness also brings positive outcomes in classrooms in terms of achievement, performance and critical thinking, abilities. Many researches showed that metacognitive awareness and achievement are related in which metacognitive awareness helps to increase students' success, improve their performance, and make them to become more strategic (Wilkins, 1997). Thus, being metacognitively aware help individuals' learning in abstract concepts, thinking creatively and increase their achievement in science classes. (Thomas *et al*., 2008).

Within years, the terms and components of metacognition are coined in the literature. Metacognitive awareness, metacognitive strategies, skills, metacognitive experiences and metamemory are few of them which are related and underlined with the term of metacognition (Brown, 1987; Schraw, 1998). Metacognitive awareness, on the other hand, refers awareness of ones' thinking and use of strategies. It is one of the aspects of metacognition and helps for individuals' behavioural control. Awareness of knowledge, thinking and using strategies are all kinds of metacognitive awareness which includes knowing ones' own and others' knowledge, knowing requirements for accomplishing the task and realizing learning strategies and approaches (Jacobs & Paris, 1987; Veenman *et al*., 2004).

Moreover, measuring metacognitive awareness is critical concern in the literature. Since the metacognition is complex construct to define and measure, there have been many discussions on how to measure it (Fleming & Lau, 2014; Lai, 2011). There are online vs offline measures of metacognition or metacognitive related constructs. The online methods refer measuring concurrent task performance such as thinking aloud, eye movement registration, observations, etc. In these methods individuals are required to perform specific actions and need to describe their behaviours or thoughts concurrently (Sarac & Karakelle, 2012; Veenman, 2011). However, these methods can have limitations. For instance, think aloud protocols can be intrusive and may disrupt the induvial' task processing since participants are required to express their actions and thoughts at the same time. Task should be difficult and new for performing and showing metacognitive skills. In addition, its scoring is controversy (Baker & Cerro, 2000; Scott, 2008). Other online measures such as observations and log file registrations measure overt behaviours.

Offline measures, on the other hand, can be used before or after the task. They are questionnaires and interviews that learners describe or express the strategies that they used or actions that they performed under specific conditions. However, although this method has advantages in administering large groups, participant can be reluctant or have tendency to provide socially desirable answers as main disadvantage. Nonetheless, there is a still consensus that verbal reports are valid and reliable sources (Baker & Cerro, 2000; Schraw, 2009) and widely used in the literature as a primary basis for data collection (Belmont & Borkowski, 1988). Use of multiple data sources is key to discover underlying metacognitive process and increase trustworthiness of findings (Azevedo, 2009; Janesick, 1994).

Metacognitive awareness is very critical for all learners from different ages (Linn & Bat-Sheva, 2006). Learners get the sense of independent learning since it promotes self-reflection. They built their own understanding and learning with using proper strategies that are most effective for themselves. If they have metacognitively higher level of thinking ability, they become intentional learners. Understanding students' metacognitive awareness help teachers to understand their students' reasoning and thinking process in way of integrating those effective strategies for students to acquire (Jaleel & Premachandran, 2016). It can be enhanced in classroom environment by letting students reflect what they learn, think, and progress their duties through the actions which help them to control their learning process. After adapting these strategies students by themselves have the metacognitive awareness, strategies without their intention and it becomes part of their lives. Thus, promoting and helping students to be aware of their learning process in science classes is one of crucial aims of science education (Hartman, 2001). If the aim is making students acquire these skills, their metacognitive awareness should be investigated. In this regard some studies (Jaleel & Premachandran, 2016; Karakelle & Saraç, 2007; Sperling et al., 2002) has been conducted to understand students' metacognitive awareness to improve and understand students' awareness level.

In these perspectives studies that examines students' metacognitive awareness can be reflected since these studies reveal many affirmative outcomes. In the recent literature Jaleel and Premachandran (2016) investigated middle school students' metacognitive awareness level and gender differences. In the results they founded that %40 of students had very low, %29.3 average and %36.6 of them had very high awareness level among the 180-middle school students. In terms of gender no significant difference was found in students' metacognitive awareness level. In another research (Karakelle & Saraç, 2007), primary, middle- and first-year high school students' metacognitive awareness level were investigated. In the results, students' scores in these different groups showed nearly same results. 3rd (30.94 score), 4th (31.47) and 5th (31,14) graders get higher scores respectively out of 36. On the other hand, 6th (73.92), 7th (68.99), 8th (70.59) and 9th (69.58) grade students' scores were showing difference with having 70.8 mean out of 90. This shows that students' metacognitive awareness scores can show differences between different grade levels. Moreover, lower grade (3rd, 4th and 5th) students' metacognitive awareness level was found higher than other grades (6th, 7th, 8th and 9th). The similar study (Calgıcı, 2018) in which 5th, 6th, 7th and 8th grade level students' metacognitive awareness were examined also revealed that students' metacognitive awareness scores were in the moderate level. 5th (69.83), 6th (69.82), 7th (68.37) and 8th (68.54) graders had nearly similar scores.

As it is seen from the literature students' metacognitive awareness level can show difference across grade levels (Hartman, 2001; Schraw *et al*., 2012). Furthermore, metacognitive awareness is related and connected closely with understanding science concepts. Students with high metacognitive awareness have better achievement in science compared to lower ones, become critical scientific thinker and have better understanding in science concepts (Akben, 2018; Kuiper, 2002; Memnun & Akkaya, 2009). Many studies (Emrahoğlu & Öztürk, 2010; Kuiper, 2002; Swanson, 1990; Young & Fry, 2008) pointed that the students with higher level of metacognitive awareness are more strategic in solving science problems and have higher science achievement. For instance, Swanson (1990) indicated that metacognitively aware 6th grade students are more strategic and get better results in pendulum problems than students who have low metacognitive awareness. Being metacognitively aware help students to solve problems better. Kuiper (2002) indicates that if learners have metacognitively high level of self -regulation and strategy, they show better understanding in concepts. It promotes reflective thinking, ability to make reasonable decisions with critical thinking strategies. These all show the influence of metacognition and metacognitive awareness in science education.

Although, metacognition and metacognitive awareness are broadly focused in many areas of science education such as STEM education (Anwari *et al*., 2015; Dori *et al*., 2018), socio scientific issues (Hsu & Lin, 2017; Ozturk, 2011), argumentation (Bowen *et al*., 2018; Kuhn *et al*., 2013), its place in NOS is very restricted in terms of investigating middle schoolers (Yenice *et al*., 2017). In NOS instruction it has many benefits for students' understanding science, scientists' works and how nature works (Peters, 2007; Peters &

Kitsantas, 2010). Students thinking and organization of these ideas which are related with NOS are affected with metacognitive strategies in positive way. For example, students who have high metacognitive awareness level get higher scores from views of NOS scale (Cetinkaya-Aydın & Cakıroglu, 2017). In these perspectives understanding students' metacognitive awareness and its link with NOS is very important since it has a special contribution in NOS education.

2.7. Metacognition and NOS

In science classrooms science has been taught as a solid content knowledge with traditional methods which shapes students' ideas and understanding process accordingly (Driver *et al*., 2000; Van Driel *et al*., 2001). However, students need to rationale their ideas and get the epistemology behind their understanding. To promote students' learning in NOS metacognitive methods and instructional techniques are essential rather than traditional teaching methods (Abd-El-Khalick, & Akerson, 2009; Davis, 2003; Morrison *et al*., 2009). Understanding how students develop scientific ideas, how they control these learning process, and their thinking strategy are all important for constructing of students' metacognitive awareness and cognitive demand (Beeth & Hewson, 1999). These can be practiced through metacognition, metacognitive strategies or understanding of students' metacognitive awareness. In this sense, NOS aspects are beneficial for learners to consider and think on their thinking (Peters, 2007). One of the ways to promote and enhance students' metacognitive awareness is explicit reflective teaching (Duschl *et al*., 1992; Peters, 2007; Peters-Burton & Burton, 2020). For example, use of metacognitive prompts or strategies broaden students' nature of science knowledge with making them aware on disciplines of science, how science and scientists works. Thus, these metacognitive prompts or strategies develop students' metacognitive awareness level and especially beneficial for naïve learners of NOS. In this way students can have ability to control their learning process and self-regulated learning with cognitive understanding of NOS (Akerson & Donnelly, 2008; Peters, 2007). Thus, as seen from the literature investigating students' metacognitive awareness is crucial for enhancement in their NOS concept development, their learning process and understanding in science.

There have been many studies that based on different accounts of NOS as reviewed in the literature. However when to examine metacogniton and NOS research together, there has been very limited research (Abd-El-Khalick & Akerson, 2009; Akerson & Donnelly, 2008; Baraz, 2012; Cetinkaya-Aydın & Cakıroglu, 2017; Peters, 2007; Peters & Kitsantas, 2010). In the review research paper of Zohar and Barzilai (2013) it has been seen that among examined 178 articles the only 5.6% of papers related with the nature of science and metacognition. Many of these studies rely mainly on metacognitive strategies as an intervention (Abd-El-Khalick & Akerson, 2009; Baraz, 2012; Peters, 2007; Peters & Kitsantas, 2010) while some of them are related with learners' characteristics such as metacognitive awareness level, self-efficacy beliefs, attitudes and NOS (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Ozgelen, 2012). For example, Abd-El-Khalick and Akerson (2009) investigated the influence of metacognitive strategies on NOS teaching. The instruments that were used are "Views of Nature of Science Questionnaire (VNOS-C)" (Lederman *et al.*, 2002) and "Metacognitive Awareness Inventory (MAI)" (Schraw & Dennison, 1994) for adults. As a result, the MAI questionnaire scores of preservice science teachers were high compared to control group. Additionally, NOS understanding of preservice teachers at experimental group in which NOS instruction was taught with metacognitive strategies were more informed than control group. This shows the positive effect of metacognitive prompts on NOS instruction with promoting preservice teachers NOS understanding. These metacognitive strategies coupled with NOS instruction increased preservice teachers' metacognitive awareness. Additionally, it was found that the developed NOS understanding is related with metacognitive awareness.

Baraz (2012) examined the effect of metacognitive strategies on NOS understanding with utilizing case studies, reflections, discussions, and concept maps strategies. The similar results appeared that use of metacognitive strategies in NOS teaching which was practiced in the experimental group improved students' both NOS understanding and metacognitive awareness. On the other hand, in the control group students' NOS understanding is improved only. This shows that utilizing metacognitive prompts in NOS teaching enhances students' NOS understanding and their metacognitive awareness. Thus, these studies (Abd-El-Khalick & Akerson, 2009; Baraz, 2012) show that metacognitive strategies in NOS lessons can be effective instructional technique for NOS learning.

The related literature has been also on the middle school science context. Peters (2007) implied metacognitive strategies for inquiry science content of 8th graders with NOS instruction where 7 tenets of consensus view were practiced with. Students' self-regulatory efficacy, content knowledge and nature of scientific knowledge were examined in both groups. It was found that students in experimental group which received metacognitive strategies had significant gains in content and nature of scientific knowledge. On the other hand, both groups had raised steadily in self-regulatory efficacy. This shows embedding metacognitive prompts in NOS teaching increase middle school students' NOS understanding and content knowledge.

Furthermore, other studies focused on the relationship between understanding or views of NOS and learners' characteristics. Akerson and Donnelly (2008) investigated 21 preservice science teachers (PSTs)' views of NOS and the relationship between NOS views, metacognitive awareness, scientific inquiry views, self-efficacy, cultural values and attitudes toward science teaching of PSTs. According to the students' "Metacognitive Awareness Inventory (MAI)" (Schraw & Dennison, 1994) scores, they founded that there were no PSTs who have low level of metacognitive awareness. Furthermore, PSTs who had inadequate views of NOS had higher scores on knowledge of cognition than PSTs who had adequate views. Their mean scores (211.2) were higher than another group (189.4). Additionally, no relationship found between regulation of cognition and NOS views of participants. Another similar study (Cetinkaya-Aydın & Cakıroglu, 2017) investigated the relationship between preservice teachers' NOS understanding and nature of scientific inquiry understanding, self-efficacy believes of teaching science, metacognitive awareness, and faith/worldview schemas. When two components which are knowledge and regulation of cognition of metacognitive awareness were examined, they founded that PSTs had higher scores for both components which shows high metacognitive awareness. Furthermore, students who had high informed views of NOS had higher scores in the regulation of cognition (KoC) and the regulation of cognition (RoC) scores in MAI scale. The students in adequate and inadequate views were differing in their KoC and RoC scores. This shows that PSTs who had informed view has high metacognitive awareness in terms of both components of metacognitive awareness.

In middle school science context, Yenice *et al.* (2017) investigated 5th, 6th, 7th and 8th grade students' NOS perceptions and metacognitive awareness scores in terms of gender and academic achievement. The data were collected through "Nature of Science Instrument" (Hacıeminoglu *et al*., 2012) and "Junior Metacognitive Awareness Inventory" (Yılmaz-Tuzun & Topcu, 2007) from students. It was found that for academic achievement students who have high academic achievement get higher scores in metacognitive awareness scale. However, since their study has not focused on the relationship between NOS and metacognitive awareness, they investigated the male and female students' scores in these two forms. Then, they founded that girls' scores in metacognitive awareness and nature of science were higher than boys' scores. In another similar study, Gulsuyu (2019) examined the relationship between students' metacognitive awareness and their NOS understanding with quantitative measures. Researcher also investigated the gender, achievement, grade level variables in term of students' differences in NOS and metacognitive awareness scores. Researcher founded the significant positive relationship between these two constructs and correlation coefficient value was found as .306. Thus, the study (Gulsuyu, 2019) shows that metacognitive awareness and NOS can be related constructs. However, the scope of her study is on different account of NOS (consensus view) and restrictive with quantitative measures.

From the literature it is seen that metacognitive awareness and NOS can be related constructs (Akerson & Donnelly, 2008; Gulsuyu, 2019). In addition, the use of metacognitive prompts enhances students' NOS understanding, views and the science content knowledge (Abd-El-Khalick & Akerson, 2009; Baraz, 2012; Peters, 2007; Peters & Kitsantas, 2010). Although these studies show the importance of metacognition and link of metacognitive awareness with NOS education, the focus is generally on preservice science teachers and previous accounts of NOS (Abd-El-Khalick & Akerson, 2009; Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Peters & Kitsantas, 2010; Gulsuyu, 2019). Studies that focus on middle school were limited (Gulsuyu, 2019; Yenice *et al*., 2017) and scope of these studies were on consensus view of NOS. Thus, the research in this area is still scarce and limited research considers the relationship between holistic account of the nature of science and metacognitive awareness in middle schoolers. Then, there is need to examine the relationship between middle school students' RFN understanding as a recent, holistic framework on NOS and metacognitive awareness.

2.8. Summary of the Literature Review

This chapter has focused on NOS in science education with zooming in short review of NOS and recent accounts in NOS in which emphasis was on "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN). This framework has been highlighted mainly since it is also theoretical framework of this study. The chapter has been traced with students' NOS understanding with emphasizing students' thinking process and importance of their awareness in NOS ideas. Then, in metacognition and NOS subsection, the need, place and studies of metacognition and metacognitive awareness in NOS has been focused.

In the first section short review of NOS in science education from the nineteens to two thousands period has been reflected. Researches on NOS highly increased and conducted after sputnik era with investments of governments on science education. It has been mainly characterized with scientific literacy, scientific knowledge, history of science, epistemic characteristics, and scientific inquiry. It is possible to trace the development of NOS from these periods to today. When compared with today, it has been changed and placed differently in its meaning and scope.

In the second section recent accounts of NOS has been explained where "consensus view", "whole science", "features of science" and "family resemblance approach to NOS" has been elaborated (Abd-El-Khalick *et al*., 1998; Allchin, 2011; Irzik & Nola, 2014; Matthews, 2012). In these accounts, consensus view has been studied widely within many years. The main critiques of consensus view were summarized. This approach was focusing mainly on scientific knowledge, had limited explanations in method and methodological rules of science, ambiguity on the subjective vs objectivity nature of science, deficiency in domain specificity perspectives in disciplines, deficiency in epistemic- cognitive, social aspects of science.

The third and fourth sections describes the theoretical framework of this study and effectiveness of this framework with empirical studies. Contributions of this approach to NOS literature and educational applications in curricular policy with epistemic-cognitive social system of science differentiate this approach from other accounts of NOS. Afterwards, the current research conducted with theoretical base of RFN, and their scope were emphasized. The studies have been highlighted curriculum (Cheung, 2020; Erduran & Dagher, 2014a; Kaya & Erduran, 2016, 2016a; Park, *et al*., 2020; Yeh, *et al*., 2019) and textbook analysis (BouJaoude, *et al*., 2018; McDonald, 2017; Yang, *et al*., 2020), preservice or university students' RFN understanding (Akgun, 2018; Akgun & Kaya, 2020; Cullinane, 2018; Erduran & Kaya, 2018; Kaya *et al*., 2017; 2019). However, middle school students' RFN understanding has limitedly examined (Akbayrak & Kaya, 2020; Cilekrenkli, 2019; Karabas, 2017) and these studies were based on the experimental designs and 5th grade level students.

In the fifth section, the relevant literature which focused on students' NOS understanding showed that many students have inadequate views and understanding of NOS (Celikdemir, 2006; Cofré *et al*., 2019; Tao, 2003). Many students fail to recognize hypothesis, scientific knowledge, and methods (Tao, 2003). The aim is to contribute NOS teaching in a way of enhancing or developing students' difficulty in learning NOS. Importance of NOS learning and understanding their thinking process and helping them to realize these processes were some of points in this section. Although these studies were relying on the different framework of NOS and reflected in that perspective, they were giving clues of students' awareness in NOS learning ideas.

Lastly in the sixth and seventh sections metacognition which is crucial element and main stone for revealing students' NOS perspectives and their understanding has been reflected. Since it refers to students' thinking process and their ability to manage their learning in these concepts, teachers can consider their students' metacognitive awareness and its relationship with NOS in their instruction. Understanding students' metacognitive awareness not only give insight for teachers but also curriculum developers and educators for improvement of NOS education. Although metacognition is very important for deeper understanding of students' perspectives and understanding of their science concepts, there has been very limited research examine students' NOS understanding and metacognitive awareness together with relating these two constructs (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Gulsuyu, 2019; Ozgelen, 2012). Furthermore, the scope these studies were restricted with preservice science teachers (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017) and limited studies were on middle school students as a study group (Gulsuyu, 2019). Thus, gap in the literature remains for the relationship between students' NOS understanding within holistic account and their metacognitive awareness with limited focus on RFN approach.

To sum up NOS has been developed and has been changed since 1960s. As a recent and holistic approach RFN framework remain in the literature. Its contribution in an educational sense and curricular policy makes valuable contributions to NOS literature. NOS is within association of many cognitive constructs such as epistemology, metacognition, concept development, etc (Cetinkaya & Karısan, 2012; Peters-Burton & Burton, 2020; Peters-Burton *et al*., 2019; Murphy, 2017). Among them as a broad area metacognition has both impact on teaching strategies and learning NOS (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Yenice *et al*., 2017; Ozgelen, 2012). In this regard, investigations on the metacognitive perspective, students' RFN understanding are the main stones of this research that contributes NOS literature.

3. METHODOLOGY

In this chapter, the methodology of the study was explained with a research design, participants, data sources, data collection, data analysis and ethical considerations sections. The chapter starts with the research design and participants. Information about the explanatory sequential mixed method design was given and discussed at research design section while information about participants such as their age, grade level and their schools were provided at the participants' section. In the data sources section, data collection tools which were "RFN Student Questionnaire" (Cilekrenkli, 2019), "The Metacognitive Awareness Inventory for Children" (Karakelle & Saraç, 2007) and interviews were explained. The data collection, data analysis and ethical considerations were provided at the remaining sections respectively.

3.1. Research Design

In this study both quantitative and qualitative data were used to interpret the results of two data sources. The researcher collected quantitative data first and qualitative data subsequently. The design of this study is based on the explanatory sequential mixed methods design (two-phase model; Creswell *et al.*, 2007). In this design, researcher provides a priority to the quantitative data and collect this data in first phase. Qualitative data, on the other hand, are used for the refinement of the results from quantitative data. The rationale of this design is the understanding general picture of the research problem with the refinement and extension of an additional data source such as the qualitative one (Creswell, 2014). This design has advantage for both readers and researchers since it has clearly explained quantitative and qualitative parts (Creswell, 2012). In this study design, researcher collected both quantitative and qualitative data through two phases in which one form of data inform and support the other. The quantitative data were supported with qualitative data to answer and get deeper understanding of the research problem.

3.1.1. Quantitative Design of the Study

In this explanatory sequential mixed methods design, the surveys were used as quantitative data source to understand middle school students' RFN understanding and their metacognitive awareness. The quantitative data provided researcher large amounts of data about students' RFN understanding and its categories such as aims and values, scientific practices, methods and methodological rules, scientific knowledge, and social institutional systems of science in addition to students' metacognitive awareness levels.

As another part of the study, a correlational study design was followed to investigate the relationship between middle school students' RFN understanding and their metacognitive awareness. This design is especially useful in education and social sciences since it allows the measurement of variables and their relationship (Cohen *et al*., 1994). In correlational design the aim is measuring the degree of relationship between variables or set of scores. Two variables covary together which means that knowledge about ones' score of one variable can relate or change with the score of another variable. There are two types of correlational design which are explanatory and prediction designs. In the explanatory design researcher correlate at least two variables at single point of time with considering that all individuals are single group and using statistical test analysis. On the other hand, the prediction design is used for using one variable to forecast and predict the outcome (also called criterion variable) (Creswell, 2014). In this study, the relationship between students' RFN understanding and their metacognitive awareness scores were investigated with making correlation and examining students' perceptions at each construct. Thus, the focus of the study was on the explanatory correlational design to examine the relationship between two variables (students' RFN understanding and their metacognitive awareness). Although the predictor ability of metacognitive awareness on students' RFN understanding was also investigated, the prediction design has not demanding role in this study.

In this study the "RFN Student Questionnaire" (Appendix A) and "The Metacognitive Awareness Inventory for Children" (Appendix B and C) were used to investigate and explore students' RFN understanding, its categories, and students' metacognitive awareness level.

3.1.2. Qualitative Design of the Study

In the second phase of the study through the refinement of the results from quantitative data for deeper examination of the individuals' RFN understanding and their metacognitive awareness, interviews with students were carried out for examining these constructs separately. It has been achieved through using the follow-up in addition to in depth interviews. The reason of using qualitative design in this research is to support quantitative data and make comparisons for holistic understanding on the relationship between students' RFN understanding and their metacognitive awareness. In addition, in the literature the use of additional source of measurement has been suggested for measuring students' ideas (Harrison & Vallin, 2018). In the next section the participants of the study were reflected with explaining participant selection steps for both quantitative and qualitative part of the study.

3.2. Participants

The participants of this study were 701 5th, 6th, 7th and 8th grade students that take formal education at public Turkish middle schools located at Istanbul. Instead of selecting students, schools were selected as a first step. The schools were selected on the base of convenience sampling method which is commonly used in educational research and participants who are easily available to researcher as non-probability sampling method (Gorard, 2001). The schools where data were collected were located at different districts of Istanbul, Turkey such as from Anatolia and European Sides. In Istanbul, totally 238.005 students take formal education and there are 3.937 schools (MEB, 2019).

3.2.1. Participant Selection

The sampling of participants was followed within two steps. Firstly, students were sampled for quantitative data process. In this process, three different schools that were convenient to the researcher were selected. After selecting schools, the classrooms from each grade levels were sampled. Totally 701 students from 5th, 6th, 7th and 8th grade levels were participated in the quantitative part of the study. The Table 3.1 provides information about participants' age and their grade level, the number and percentage of students that attended to the quantitative part of the study. The age of the participants was varying between 10 and 14 with having 11.52 mean. 180 students from 5th grade (25.7%), 167 students from 6th (23.8%), 170 students from 7th grade (24.3%) and 184 students from 8th grade (26.2%) participated to the study.

Table 3.1. Participants' frequency distribution of grade levels.

Level	Age means	Schools	Number of Students	Total	%
5th Grade	10	School 1	143	180	25.7
		School 2	37		
6th Grade	11	School 1	102	167	23.8
		School 2	50		
		School 3	15		
7th Grade	12	School 1	90	170	24.3
		School 2	58		
		School 3	22		
8th Grade	13	School 1	130	184	26.2
		School 2	25		
		School 3	29		
Total	11.52			701	100

As a second step of the sampling method, students were selected for interview process. For this part, students' scores from "RFN Student Questionnaire" and "The Metacognitive Awareness Inventory for Children" were divided into high, moderate and low level of RFN understanding and metacognitive awareness separately for each scale. Afterwards, students who got high, moderate and low score from both scale were determined and reflected in the Table 3.2. As it is seen from the table, students who got low scores from both scale were relatively limited in number compared to moderate and high-level students. The percentage shows the proportion degree of total number of students in each grade level which was rather low. Thus, 1 student from every grade level who place at low, moderate or high were randomly selected. In this way, three 5th grade three 6th grade, three 7th grade and three 8th grade students who comes from low, moderate and high levels were sampled.

Table 3. 2. Number of students from high, moderate, and low levels from RFN understanding and metacognitive awareness.

Grade Levels	RFN Understanding Level	Metacognitive Awareness Level	Number of Students (n)	Percentage (%)
5th Grade	Low	Low	1	0.5
	Moderate	Moderate	8	4.4
	High	High	51	28.3
6th Grade	Low	Low	4	2.3
	Moderate	Moderate	36	21.5
	High	High	39	23.3
7th Grade	Low	Low	3	1.7
	Moderate	Moderate	66	38.8
	High	High	32	18.8
8th Grade	Low	Low	3	1.6
	Moderate	Moderate	79	42.93
	High	High	27	14.6

Totally 12 students were interviewed for both RFN and metacognitive awareness process. The reason of selecting both high, moderate and low-level students from these two forms was for the representation of equal number of students from different levels for interview procedure. Since interviews consist of two parts including RFN based and metacognitive awareness questions, to reflect representative sample who have different scores or levels and to form relationship between different level students' RFN understanding and their metacognitive awareness level this process has been followed.

3.3. Data Sources

Both quantitative and qualitative data sources were used in this explanatory sequential mixed methods design. As a quantitative data source two different surveys were used, and as a qualitative data source interviews were carried out. Both quantitative and qualitative data sources were preferred since these data sources helped to get broader data for revealing the relationship between students' RFN understanding and their metacognitive awareness. In subsequent subsections these quantitative and qualitative data sources were explained respectively.

3.3.1. Quantitative Data Sources

The quantitative data sources that have been used in this study are "RFN Student Questionnaire" (Cilekrenkli, 2019) and "The Metacognitive Awareness Inventory for Children Form A and Form B" (Karakelle & Saraç, 2007). The first subsection provides the detailed explanation of "RFN Student Questionnaire" (Cilekrenkli, 2019) which was used to measure 5^{th}, 6^{th}, 7^{th} and 8^{th} grade students' RFN understanding. The following section describes "The Metacognitive Awareness Inventory for Children" which has been Form A and Form B versions. Form A administered to 5^{th} grade while Form B has been administered to 6^{th},7^{th} and 8^{th} graders.

<u>3.3.1.1. RFN Student Questionnaire.</u> "RFN Student Questionnaire" that was used in this study was adapted by Cilekrenkli (2019) with the aim of measuring 5^{th}, 6^{th}, 7^{th} and 8^{th} grade students' RFN understanding. The original "RFN Questionnaire" was designed by Kaya *et al*. (2019) to measure preservice teachers' RFN understanding with consisting of five main categories of science. It has been designed by researchers on the base of ''Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) (Erduran & Dagher, 2014; Kaya & Erduran, 2016). The items were prepared by authors were structured on three criteria. 1) Firstly, Kaya *et al*. (2019) prepared each item with considering all RFN categories. In other words, all questions were representing each category of science. 2) Another criterion was key themes appeared from RFN that was addressed by Erduran and Dagher (2014) for each category of science. For example, scientific knowledge includes theories, laws, models and items that represent this category include these themes as well. 3) Educational application of RFN categories was also embedded to questionnaire by authors since their aim was also for understanding teachers views on educational applications of RFN (Kaya *et al*., 2019). Then Cilekrenkli (2019) adapted this "RFN Questionnaire" for middle school students' level to measure students' RFN understanding. The characteristics of the questionnaire such as the positive and negative item numbers, item distributions were based on categories, and percentage correspondence of them were given at the Table 3.3. The RFN categories and the number of items that were included to the questionnaire were

as follows; four items in aims and values, eight items in scientific practices, four items in methods and methodological rules, seven items in scientific knowledge, fourteen items in social and institutional systems of science. It is 5-point Likert type scale including 37 questions and options were strongly disagree, disagree, neutral, agree and strongly agree.

The adaptation process of the questionnaire has been achieved by Cilekrenkli (2019). She piloted it two times for this process. The content validity was done by consulting the experts' opinions from science education department and researcher teacher. The researchers checked the appropriateness and applicability of the questions. The pedagogical orientation and linguistic adaptation were done by Cilekrenkli (2019). She implemented the questionnaire firstly to 32 5th grade students to get feedbacks and make revisions. The Cronbach Alpha (α) value was found as .731 (Cilekrenkli, 2019) as a result of this pilot implementation. Based on coming feedbacks and agreements from piloted test, author made final versions and revisions of the questionnaire. Then, she piloted with 376 students from 5th to 8th grade for the last time. In this time, the Cronbach Alpha value was found as .733.

Table 3.3. The categories of RFN Student Questionnaire, number of items and item numbers with percentages.
Adapted from: [Cilekrenkli, 2019, p50]

RFN Categories	Item Numbers		Number of Items	Percentage
	Positive	Negative		
Aims and Values (AV)	17, 19	23, 29	4	10.8%
Scientific Practices (SP)	3, 9, 12,13,16, 21	26	8	21.6%
Methods and Methodological Rules (M)	14, 31, 35	5, 37	4	10.8%
Scientific Knowledge (SK)	7, 25, 28, 33	1, 10, 34	7	18.9%
Socio-Institutional System (SI)	2, 4, 6, 8, 15, 20, 22, 24, 27, 32, 30, 36	11, 18	14	37.8%
Total	24	10	37	100%

In this study after implementing the questionnaire to 701 students the Cronbach Alpha value was found as .706 which is acceptable level for reliability of scale (Pallant, 2010) and close value with previous study (Cilekrenkli, 2019). For the evaluation of the questionnaire suggested point system of the researcher were used. The evaluation was based on giving points to each true answer according to students' answers to strongly disagree, disagree, neutral, agree and strongly agree options. For example, a student who choose strongly agree option which is one of positive items got five points. The scores of other options as follows; four for agree option , three for neutral option, two for disagree option, one point for strongly disagree option. The maximum score that can be get from the sclae is 185 while minumum point is 37.

The questionnaire consists of not only positive items but also negative items. The author (Cilekrenkli, 2019) used negative items for the reason of reducing the acquiescence bias. This bias is participants' agreements to all items without considering the content of questions (Podsakoff *et al*., 2003). The evaluation process of these items was managed with reversing the positive items and scores. The number and distribution of these items can be followed from the table 3.3. Thus, in this study the "RFN Student Questionnaire" that was adapted by Cilekrenkli (2019) was used as one of the instruments to measure 5th, 6th, 7th, 8th grade students' RFN understanding and its categories.

3.3.1.2. The Metacognitive Awareness Inventory for Children (Jr. MAI). The Turkish version of "The Metacognitive Awareness Inventory for Children (Jr. MAI)" has been adapted by Karakelle and Saraç (2007). There are two forms of this inventory (Form A and Form B) which were prepared for different age groups. In this study these two forms have been used to measure 5th, 6th, 7th and 8th grade students' metacognitive awareness.

The original "Metacognitive Awareness Inventory for Children (Jr. MAI)" was constructed by Sperling *et al*. (2002) to measure students' metacognitive awareness. Sperling *et al*. (2002) stated that they aimed to develop a new and easy administered scale to monitor students for potential metacognitive and cognitive strategy intervention. There are subdimensions of the scale which are the knowledge of cognition and regulation of cognition. The knowledge of cognition encompasses the declarative, conditional and procedural knowledge. The regulation of condition consists of subcategories such as planning, monitoring, information management, evaluation, debugging. Both Form A and B consists of these categories. However, the number of the items covered in each form changes. While Form A was designed for lower grade levels (3^{rd},4^{th} and 5^{th}) with including 12 questions, Form B measures 6^{th}, 7^{th},8^{th} an 9^{th} grade levels including 18 questions. Thus, because of these differences in characteristics of forms Form A has been administered to measure 5^{th} grade level students' metacognitive awareness while Form B has been administered to 6^{th},7^{th} and 8^{th} graders. The detailed information about different versions of these forms were given in the following sub-sections.

3.3.1.2.1. The Metacognitive Awareness Inventory for Children (Jr. MAI) Form A. Form A was developed by Sperling *et al* (2002) to measure 3^{rd}, 4^{th} and 5^{th} grade students' metacognitive awareness level with covering totally 12 questions. It is three choice Likert scale with always, sometimes, and never options. The authors constructed the knowledge of cognition and regulation of cognition factors with having subcategories that are the declarative, conditional, and procedural knowledge, planning, monitoring and evaluation. There are six items related with the knowledge of cognition while remaining six measures the regulation of cognition. In addition to that Sperling *et al* (2002) consulted teachers to check the appropriateness of the scale according to students' levels and pedagogical language. They calculated factor loadings for each item. From five factor solution, one factor accounts for the regulation of cognition, two factors related with the conditional and procedural knowledge and remaining two factors include items from both the regulation and knowledge (Sperling *et al*., 2002).

The instrument that was used in this study was adapted by Karakelle and Saraç (2007) to Turkish with attendance of 194 students from 3^{rd} grade, 183 from 4^{th}, 188 from 5^{th} grade levels. For adaptation process they implemented the scale to totally 565 students from 3^{rd} to 5^{th} grades. For the reliability of the scale Karakelle and Saraç (2007) used test-retest method and found internal consistency as .76. They found item total correlation for the validity of the scale. From the results, threshold value for all correlations was found above the 0.3 value which means that questions have high separation index. For another measure of the validity, after authors checked the appropriateness of factor analysis, with implementing Bartlett test and found KMO values. They found four factors from varimax variation results. Thus, in this study to measure 5^{th} grade students' metacognitive awareness "The Metacognitive

Awareness Inventory for Children Form A" (Appendix B) was used. Form A has been applied to 180 5th grade students to understand their metacognitive awareness level. When Cronbach Alpha value of this scale has been investigated, it was found as .701 which is very close value to Karakelle and Saraç' (2007) findings.

3.3.1.2.2. The Metacognitive Awareness Inventory for Children (Jr. MAI) Form B. Sperling *et al* (2002) developed form B for measuring 6th, 7th, 8th and 9th grade students' metacognitive awareness level. Form B includes 18 questions, and they implemented the scale to 736 6th, 7th, 8th and 9th grade students. The Form B includes same questions with Form A. However, there are 6 additional questions in Form B with 5-point Likert type. In this study the Turkish version of "The Metacognitive Awareness Inventory for Children Form B" which has been adapted by Karakelle and Saraç (2007) was used. They used 5-point Likert scale for Forms B with having always, often, sometimes, rarely, and never options. This scale also has subdimensions of the knowledge and regulation of cognition. The Table 3.4 provides the distribution of each item for these sub dimensions. These general subdimensions were forming around the broader theoretical framework of Brown (1978). However, although Sperling *et al* (2002) provide subdimensions and factor structure of these scale, Karakelle and Saraç (2007) suggest the use of single factor structure rather than separation into its sub dimensions. Thus, the scale has been evaluated as one single factor rather than its subfactors. However, these subfactors provided guide and basis for interview procedure with detailed examination.

For adaption to Turkish language Karakelle and Saraç (2007) consulted three different researchers for the translation of original scale to Turkish simultaneously. Experts such as psychologist, English teacher, linguist, educational sciences researcher and English language literature experts were consulted for the final version of scale and the content validity of the test. They piloted the scale with 750 6th, 7th, 8th and 9th grade students. For the reliability of the scale researchers (Karakalle & Saraç, 2007; Sperling *et al.*,2002) used test-retest method and this correlation value was found as .82 ($N = 373$, $p < .01$). In addition, they founded the Cronbach alpha value as .80 (Karakelle & Saraç, 2007). In this study, as a result of reliability analysis Cronbach alpha has been investigated and found as .838 which is closer value to previous studies. Thus, in this study, "The Metacognitive Awareness

Table 3.4. Factors and corresponding Jr. MAI Items of Form B.

Factors	Subfactors	Item
Knowledge of Cognition	Declarative Knowledge	1. “Bir şeyi anlayıp anlamadığımı bilirim”.
		4. “Öğretmenin neyi öğrenmemi istediğini bilirim”.
		12. “İlgimi çeken konuları daha iyi öğrenirim”.
	Conditional Knowledge	2. “İhtiyacım olduğunda kendi kendime öğrenebilirim”.
		5. “Konu hakkında daha önceden bir şeyler biliyorsam daha iyi öğrenirim”.
		13. “Öğrenirken zayıf yönlerimin üstesinden gelmek için güçlü yönlerimi kullanırım”.
		14. “Çalıştığım konuya bağlı olarak farklı öğrenme yöntemlerini kullanırım”.
	Procedural Knowledge	16. “Bazen öğrenme stratejilerini otomatik olarak kullanırım”.
		3. “Daha önce işime yaramış olan çalışma yollarını kullanmaya gayret ederim”.

Table 3.4. Factors and corresponding Jr. MAI Items of Form B (cont.). Adapted from: [Sperling et al., 2002, p58-59].

Regulation of Cognition	Planning	9. "Çalışmaya başlamadan önce ne öğrenmem gerektiğini düşünürüm".
		18. "Bir işe başlamadan önce nelerin yapılması gerektiğine karar veririm".
	Monitoring	8. "Bir problemi çözmek için birçok yol düşünür, aralarından en iyi olanını seçerim".
		10. "Yeni bir şey öğrenirken kendi kendime ne kadar öğrenebildiğimi sorarım".
		15. "Ara sıra durup öğretmenin verdiği görevi zamanında bitirip bitiremeyeceğimi kontrol ederim".
	Evaluation	7. "Çalışmam sona erdiğinde kendime öğrenmek istediğim konuyu öğrenip öğrenemediğimi sorarım".
		17. "Öğretmenin verdiği bir işi bitirdikten sonra kendime, bu işi yapmanın daha kolay bir yolu olup olmadığını sorarım".
	Information Management Skill	6. "Şekil ve resimler çizmek bir konuyu daha iyi anlamamı sağlar".
		11. "Önemli bilgileri çok dikkatli dinlerim".

Inventory for Children Form B" (Appendix C) were used to measure 6^{th}, 7^{th} and 8^{th} grade students' metacognitive awareness level.

3.3.2. Qualitative Data Sources

As qualitative data sources semi-structured interviews were held for deeper investigation of students' RFN understanding and their metacognitive awareness levels. The aim of admitting to qualitative data source is for getting multiple data source for investigating these two constructs which were expected to support and consolidate the quantitative data results.

3.3.2.1. Interviews. Semi structured interviews were carried out with middle school students as a qualitative data source (see Appendix D and E). With the aim of having deeper understanding of middle school students' perceptions about RFN and their metacognitive awareness 12 students were interviewed. The interview process consists of two main parts. Firstly, RFN interview questions have been directed to students which were designed to reveal students' understanding of science and its categories. Afterwards, metacognitive awareness questions were asked to participants to examine their metacognitive actions, skills or behaviours. There were totally 27 interview questions with including both RFN related and metacognitive awareness questions. The interview questions that have been used for examining students' RFN understanding have been adapted from Cilekrenkli's (2019), Akbayrak and Kaya's (2020) studies. The equal distribution of number of questions for each RFN categories and components of metacognitive awareness have been considered. On the other hand, the metacognitive awareness questions have been adapted from Peters' (2007), Kapucu and Oksuz's (2016) studies.

The English and Turkish version of interview questions were given at Appendix D and E, respectively. To clarify dimensions of interview questions they were separated as general, RFN based and metacognitive awareness questions. The flow of the interview was starting from introductory questions, RFN based and metacognitive awareness questions respectively (see Appendix D). In order to understand the appropriateness and clarity of the questions, questions were piloted with three middle school students from different grades.

After the pilot study some questions has been changed and reorganized. Interviews approximately took one hour for each participant.

For the face validity of interview questions, one expert from science education department whose expertise is on this approach and two researchers at middle school science education department revised for relatedness and appropriateness and clarity of the questions. Moreover, for reliability of the interviews interrater reliability has been achieved through coding and agreement of two independent coders. These two coders independently coded both RFN and metacognitive awareness interviews with open coding. After revisions and agreement of researchers on codes, it was found that researchers agree on 91.5% of all codes for RFN interviews. The same process has been followed for metacognitive awareness interviews. This agreement was corresponding to 82% for these interviews. These interviews were expected to get deeper understanding about students' RFN understanding and support the quantitative data that came from "RFN Student Questionnaire" (Cilekrenkli, 2019) and "Metacognitive Awareness Inventory for Children" (Karakelle & Saraç, 2007).

3.4. Data Collection

In this section both the quantitative and qualitative data collection processes were explained. The sequence that was followed, the scope of interviews, how quantitative and qualitative data were collected were the focus of this section.

3.4.1. Quantitative Data Collection

The quantitative data collection from the surveys ("RFN Student Questionnaire" and "Metacognitive Awareness Inventory for Children") was carried out in 2020-2021 academic term in online classes. Data collection process for three different schools were in different time frame with having two- or three-day gap between different schools. In total data collection process lasted two–three-week period. Permissions from science teachers in those schools were taken and information about the study was provided. Ethical considerations and MEB permissions were provided to school administration. After that, for ensuring ethical permissions consent forms for parents were provided through online links in groups.

Since some students were selected for the interview process, students' ID numbers were collected for anonymity and easiness in participant selection.

The quantitative data collection was followed in online science lessons through providing online survey links to students. Students who were at online lessons answered the surveys. This was for ensuring attendance of students to survey and let them ask their questions during implementation. Students were told that those scale will not be graded and will not affect their science grades. Students provided their school ID numbers, grade level and age as a demographic data. None of their personal information that identifies students' individuality was collected. After giving information about the study, both "RFN Student Questionnaire" and "The Metacognitive Awareness Inventory for Children" were sent to students concurrently through one link. The importance of honesty and sincerity in answers were emphasized. These same procedures were completed in other three schools as well.

3.4.2. Qualitative Data Collection

After completing quantitative data, as a second phase of the research qualitative data was collected through semi structured interviews. Since students' answers were divided into high, moderate and low levels as described in participant selection process, three students from every grade level who were from low, moderate and high level in both scale were identified through their school ID numbers. None of this information has been provided and shared with third party for data privacy. After this categorization and determination of participants, students were interviewed through online communication platform. Before directly starting to interview, to make participants comfortable and relax in interview procedure, little conservation was held. In the interview process, firstly, RFN based, and afterwards metacognitive awareness questions have been directed to students. In total 27 questions were directed and interviews which took nearly one hour were audio taped. In the interview process, ethical considerations were explained to participants that their names were kept anonymous, and their personal information were not asked and shared in anywhere. Since students were under the age of 18, their parents' permissions through verbal and consent forms were also gathered before the interview process. The importance of the ethical perspective of the study was also emphasized in the ethical considerations section as well.

3.5. Data Analysis

In this section, the quantitative and qualitative data analysis procedures were explained detailly. The quantitative data analysis presents the analysis of data from "RFN Student Questionnaire" and "The Metacognitive Awareness Inventory for Children". The qualitative data analysis presents the analysis of interviews which were based on RFN and metacognitive awareness questions.

3.5.1. Quantitative Data Analysis

To analyse students' scores from "RFN Student Questionnaire" and "The Metacognitive Awareness Inventory for Children" scale SPSS 25.0 statistics program was used to conduct descriptive and inferential statistics. Before implementing the statistical tests, assumptions including normality, homogeneity of variances, linearity, standardized residuals were checked. Since the assumptions were held for parametric tests, one-way ANOVA, Pearson r correlation and simple linear regression were conducted.

As an answer to first research question students' total RFN scores were analysed through descriptive analysis to investigate middle level school students' RFN understanding. This analysis helped to examine the total scores, mean, standard deviation, skewness and kurtosis, minimum and maximum scores. It provided general idea about students' RFN understanding and their initial perspectives before researcher analysed the qualitative results. According to students' scores low, moderate, or high levels were formed with dividing scores into equal intervals within their group.

For the first sub research questions RFN categorical scores of all middle school students and different grade level students' RFN total scores were analysed. In order to see whether there is a statistically significant difference among 5th, 6th, 7th and 8th grade students' RFN understanding, one way between groups ANOVA statistical test was used. This test was also used for looking differences in middle school students scores in each RFN category. After this test, since significance differences appeared between groups, Tukey post-hoc test was applied to understand which groups or categories differ.

For the second research question, students' scores from "The Metacognitive Awareness Inventory for Children" were analysed with examining descriptive statistics such as total scores, mean, standard deviation, skewness and kurtosis, minimum and maximum scores. However, this was not only the data that helped to investigate students' metacognitive awareness. Qualitative part brought more perspectives on this examination. Additionally, students were divided into high, moderate and low levels according to their scores with the similar analysis procedure of RFN levels.

As an analysis of the sub second research question differences between 5th, 6th, 7th and 8th grade level students' metacognitive awareness were analysed through statistical analysis of comparing different grade level students' metacognitive awareness scores. The one-way ANOVA was used for this process.

For the third research question, to examine relationship between middle school students' RFN understanding, and their metacognitive awareness level Pearson r correlation was applied according to the results of assumption checks. Since the normality, homogeneity of variances and linearity assumptions were satisfied, to understand whether significant relationship exist between these variables Pearson r correlation was used. For showing the strengthen of the relationship between these variables Pearson Product-Moment Correlation Coefficient was calculated. Moreover, this process has been achieved for examining the relationship between each grade level students' RFN understanding and metacognitive awareness separately as well. The assumptions were again checked for each grade level (5th,6th,7th and 8th) students separately. Thus, the sub research question three has been analysed in this way.

Lastly, to understand whether students' metacognitive awareness can significantly predict their RFN understanding the simple linear regression was used. The predictive variable is metacognitive awareness and criterion variable is students' RFN understanding.

To understand how much change in dependent variable can be explained by change in independent variable shared variance was calculated. This gave researcher to understand tendency in overlapping variables and the predictor ability of metacognitive awareness on RFN understanding.

3.5.2. Qualitative Data Analysis

The interview data strengthened the quantitative data in terms of students' RFN understanding, its categories and metacognitive awareness. After completing the interview procedure, all audiotapes of 12 interviews were transcribed. For the analysis of this procedure thematic analysis was used. This technique is especially used and beneficial for analysis of participants' views, knowledge, or experiences. Codes and themes are generally produced with conceptualizing key elements in the texts (Braun *et al*., 2019). The analysis of students' interviews was achieved with coding procedure and producing themes. The main framework that was followed during coding process was Erduran and Dagher's (2014) framework that is "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) (Kaya & Erduran, 2016). The coding procedure of previous similar studies on RFN were followed while forming key and related words about categories of science. At the end for clarity the main codes and themes were tabulated through each category of science.

For metacognitive awareness interviews students' verbal expressions on specific situations in which they are required to imagine and remember, their reports on how they handle problems, what they do and think in certain situations were some of focuses of interviews to elicit students' thoughts. This allowed researcher to gain depth investigation of students' ideas and experiences. Thus, students' ability to express their mental process pointed the level of their metacognitive awareness (Georghiades, 2004). The discourse analysis of data reveals diverse emerging themes such as the declarative, procedural and conditional knowledge, planning, monitoring and evaluation. Each theme and codes have been formed within the light of general framework of Brown' metacognitive awareness framework.

In both interviews the meaning that has been emerge from students' excerpts has been analyzed in addition to direct vocabulary. Since the interviews were conducted with Turkish language, students' quotes were translated to English. However, the coding process and themes were formed in English. In some quotations sample quotes the brackets were provided and some of original Turkish quotations were given at the Appendix F.

Moreover, the relationship between students' RFN understanding and their metacognitive awareness was also examined with qualitative perspective. After examining students' RFN and metacognitive awareness interviews separately, all students' answers to RFN interviews were interpreted in terms of the emergence and existence of metacognitive skills. The metacognitive aspects that have been mentioned so far (the declarative, procedural, conditional knowledge, monitoring, planning, evaluation) were examined in students' RFN expressions. In addition to this, the same level students' answers to RFN and metacognitive awareness questions have been matched. For instance, it was investigated whether high RFN level students who explain science and its categories in structured way was also at high level according to their answers to metacognitive awareness interviews. For this analysis process students' answers to both interviews have been compared and examined in terms of their RFN and metacognitive awareness level. This has been performed for each high, moderate, and low-level students' expressions.

3.6. Ethical Considerations

To conduct this study officially, the permissions from Ministry of Education and The Institutional Review Board for Research with Human Subjects (INAREK) of Boğaziçi University was taken. After this approval at first, since students were under the age of 18, their legal guardians such as their parents or relatives' permissions have been taken by the consent form (see Appendix G). No potential harm of the study, interview and anonymity issues were emphasized in the consent forms. This information about the tests that was implemented to students were provided to parents as well. After permissions were taken from parents, students' verbal permissions were also taken. For the demographic data students were required to provide their school ID number, age, and grade level for easiness in the interview selection process. Their personal data was not used in none of the step of the research. While providing quotations students' names or any data were not disclosed. Their grade, RFN and metacognitive awareness levels were dictated.

4. RESULTS

This chapter represents the results of the quantitative and qualitative data analyses. The first section reflects the results of quantitative data analysis with descriptive and inferential statistics results of students' RFN understanding and metacognitive awareness scores separately. The second section includes the qualitative results for students' responses to interviews which are based on RFN framework and metacognitive awareness questions. It covers the main themes, codes of RFN categories and sub dimensions of metacognitive awareness. Additionally, the converge of quantitative and qualitative data have been examined and interpreted holistically. At the end of the second section the relationship between RFN understanding and metacognitive awareness have been examined. In each section students' grade levels and group divisions (high-moderate-low) have been considered to make comparisons.

4.1. Quantitative Data Results

In this section the quantitative data results were reflected with descriptive and inferential statistics for both RFN and metacognitive awareness scores respectively. The results have been explained in accordance with answering main and sub research questions. The amount of data coming from quantitative data helped to explain students' RFN understanding and their metacognitive awareness level.

4.1.1. Descriptive Statistics Results

In the descriptive results minimum, maximum scores, mean, standard deviation, skewness and kurtosis values of students' scores were examined and reflected for RFN understanding and metacognitive awareness as separately. Students' RFN and metacognitive awareness levels (high-moderate-low) have been investigated as a determinant process of participant selection.

<u>4.1.1.1. Descriptive Statistics Results of RFN Scores.</u> For answering the main research question 1 (What are the middle school students' RFN understanding?), both quantitative and qualitative data were utilized to investigate students' RFN understanding. As a quantitative data, middle school students' RFN levels and their descriptive scores helped to infer general trend in students' scores. The Table 4.1 provides mean scores (M), its percentage correspondence (%), minimum (min), maximum(max) scores, standard deviation (SD), skewness and kurtosis values that students get from "RFN Student Questionnaire". From the Table 4.1 it can be seen that minimum and maximum scores are 92 and 170 respectively (SD=12.001) with having 134.91 (72.92%) mean for total RFN score. In aims and values category scores range from 4 to 20 (SD=2.248) with having mean of 13.00 (%65). In scientific practices category minimum and maximum scores are 15 and 40 (SD=3.906) respectively with having mean of 30.05 (75.12%). In method and methodological rules category minimum score is 6 and maximum is 20 with having 14.18 mean (70.90%) and

Table 4.1. Descriptive statistics analysis for total and category based RFN Student Questionnaire.

Category	Number of Items	Min	Max	Mean	Percentage of Mean	SD	Skewness	Kurtosis
Total RFN Score	37	92	170	134.91	72.92%	12.001	-.414	.450
Aims and Values (AV)	4	4.00	20.00	13.00	65.00%	2.248	.113	.637
Scientific Practices (SP)	8	15.00	40.00	30.05	75.12%	3.906	-.572	.668
Method and Methodological Rules (M)	4	6.00	20.00	14.18	70.90%	2.352	-.054	.171
Scientific Knowledge (SK)	7	14.00	34.00	24.78	72.88%	3.297	.116	.134
Social Institutional System (SI)	14	28.00	68.00	52.90	77.79%	6.088	-.454	.426

SD=2.352. In last two categories while students' mean scores in scientific knowledge category are 24.78 (72.88%) and scores' range varied from 14 to 34, in social institutional system this score is 52.90 (77.79 %) with having minimum and maximum score 28.00 and 68.00 respectively. Scores from these categories showed that students' social institutional system (SI) and mean scores percentage (77.92%) were higher than other categories. On the other hand, the skewness and kurtosis values were -.414 and .450. For RFN categories these values were .113 and .637 (aims and values), -.572 and. 668 (scientific practices), -.054 and .171 (method and methodological rules), .116 and .134 (scientific knowledge), -.454 and .426 (social institutional system). These values showed that scores were normally distributed according to Tabachnick and Fidell' (2007) normality assumption.

As another aim of the study, each grade level students' descriptive total RFN scores has been investigated seperately. The Table 4.2 provides descriptive scores of these students' total RFN scores. It can be seen from the table that minumum score that all students get was nearly similar with each grade level students except 5th graders. The maximum score

Table 4.2. Each grade level students' descriptive scores of total RFN.

Score	Grade Levels	Min	Max	Mean	Percentage of Mean	SD	Skewness	Kurtosis
Total RFN	5th	103	154	133.89	72.37%	10.73	-.356	-.069
	6th	92	161	133.10	71.94%	12.91	-.567	.390
	7th	93	163	136.81	73.95%	12.13	-.365	.482
	8th	92	170	135.80	73.40%	11.95	-.358	.621

that students had was changing from 154 to 170. Students' mean scores were varying for 5th (M=133.89 SD=10.73), 6th (M=133.10 SD=12.91), 7th (M=136.81 SD=12.13) and 8th (M=135.80 SD= 11.95) graders. When skewness and kurtosis values were evaluated, it can be concluded that each grade level students' scores were normally distributed according to the normality range (Tabachnick & Fidell, 2013).

In addition, to select participants for follow up interviews, students' minimum, and maximum scores of "RFN Student Questionnaire" have been determined. Afterwards, these scores were divided into equal score points. It has been found that 175 students were in the high (24.96%) with 92-117 score range, 471 students were in the moderate (67.19 %) with scores between 118-143 and 55 students (7.85%) were in the low level with range of scores of 144-170. This process has been calculated to determine students' RFN score intervals and their RFN correspondence level.

4.1.1.2. Descriptive Results of Metacognitive Awareness Scores. This section provides the descriptive results of 5th grade and other grade level students' (6th ,7th and 8th) metacognitive awareness scores separately. This separate examination is because of the differences in the score distribution of two scale. The questionnaire that has been administered to 5th graders was "The Metacognitive Awareness Inventory for Children Form A". The maximum score that can be get from this form is 36 and 12 for minimum. On the other hand, the maximum score of "The Metacognitive Awareness Inventory for Children Form B" which has been administrated to 6th,7th and 8th graders is 90 and 18 for minimum. Thus, because of these differences in two scale 5th grade and other grade level (6th,7th and 8th) students' scores were analysed separately and have been reflected in the following subsections. The following first subsection examines the descriptive scores of 5th grade students' metacognitive awareness, and the second subsection reflects 6th, 7th and 8th graders' comprehensively.

4.1.1.2.1 Descriptive Results of 5th Grade Students' Metacognitive Awareness Scores.

Along with the analysis of main research question 2 (What are the middle school students' metacognitive awareness level?), 5th grade students' metacognitive awareness descriptive scores were tabulated. From the Table 4.3 students' mean scores were corresponding to 30.73 (SD= 3.277) with having minimum score of 16 and maximum of 36.

Table 4.3. Descriptive scores of 5th grade students.

Scale	Number of Items	Min	Max	Mean	Percentage of Mean	SD	Skewness	Kurtosis
Jr. MAI Form A	12	16	36	30.73	85.36%	3.277	-.844	1.519

When the skewness and kurtosis values were examined, it can be seen that this range was between -.844 and 1.519. Then, it was seen these values were in the between the suggested range of normal distribution. According to George, D., & Mallery, M. (2010) skewness and kurtosis values can be between -2.0 and +2.0 applicable for normal distribution.

Furthermore, besides descriptive statistics students' metacognitive awareness level has been examined as well. When 5th grade students' metacognitive awareness scores were divided into three groups as low, moderate, and high, it has been founded that the scores between 16-23 corresponds to low, 24-29 to moderate and 30-36 high level. However, to select students for interview process their both RFN and metacognitive awareness scores have been investigated. This have been achieved for each grade levels separately. Thus, from the Table 4.4, it can be seen that one student was in low level, eight students were in moderate, and 51 students were in high level at both scale. The percentage values were

Table 4.4. 5th Grade students' metacognitive awareness and RFN understanding level, score ranges and percentage correspondence.

Grade Level	Metacognitive Awareness Level-Score Range	RFN Understanding Level- Score Range	Number of Students (n)	Percentage
5th Grade	Low 16-23	Low 92-117	1	0.5%
	Moderate 24-29	Moderate 118- 143	8	4.4%
	High 30-36	High 144-170	51	28.3%

representing the correspondence of the total number of 5th grade students. According to this division 28.3% of students were at the high level in both scale. While 4.4% of students was in the moderate and 0.5% was in the low level.

4.1.1.2.2. Descriptive Results of 6th, 7th, 8th Grade Students' Metacognitive Awareness Scores.

For the analysis of main research question 2 (What are the middle school students' metacognitive awareness level?), the Table 4.5 that has been formed shows the mean, variance, minimum, maximum scores, skewness and kurtosis values for each grade level and 6th,7th,8th graders. The mean score of all students was 72.03 out of 90 with having minimum

36 and maximum 90. The skewness (-.588) and kurtosis values (.536) were between +1.5 and -1.5 which were satisfying the normal distribution according to Tabachnick and Fidell

Table 4.5. Descriptive statistics of 6th, 7th, 8th grade students' metacognitive awareness scores.

Grade Level	Min	Max	Mean	Percentage of Mean	SD	Skewness	Kurtosis
6th-7th-8th Grade	36	90	72.03	80.03%	9.517	-.588	.536
6th Grade	36	90	71.52	79.46%	10.776	-.642	.425
7th Grade	46	90	71.94	79.93%	8.665	-.514	.389
8th Grade	42	90	72.59	80.65%	9.061	-.495	.383

(2013). From the table 4.5 it can be seen that mean scores of 6th (M=71.52 SD=10.776), 7th (M=71.94 SD= 8.665) and 8th (M= 72.59 SD= 9.061) graders were nearly similar. While minimum scores that students get was slightly varying for 6th graders. It was nearly same for each grade level students. As it can be seen that skewness and kurtosis values were within the range of +1.5 and -1.5 with having acceptable value for the normal distribution (Tabachnick & Fidell, 2013).

Table 4.6. 6th, 7th, 8th Grade students' metacognitive awareness level, score range and percentages.

Grade Level	Metacognitive Awareness Level-Score Range	RFN Understanding Level-Score Range	Number of Students (n)	Percentage
6th,7th and 8th Grade	Low 36-53	Low 92-117	10	1.9%
	Moderate 54-71	Moderate 118- 143	189	36.2%
	High 72-90	High 144-170	149	28.5%

Additionally, 6th, 7th and 8th grade students' metacognitive awareness and RFN understanding scores were divided in three equal interval points and reflected at Table 4.6. It can be said that 149 students (28.5%) were in the high, 189 (36.2%) in the moderate and10 (1.9 %) students were in the low level. The metacognitive awareness score range were72-90 for high, 54-71 for the moderate and 36-53 for the low-level student. On the other hand, this division in RFN was 144-170 for the high, 118- 143 for the moderate and 92-117 for the low-level students.

4.1.2. Inferential Statistics Results

In this section the assumptions of inferential statistics, the analysis of the research questions in conjunction with the statistical tests such as one-way ANOVA, Pearson r and simple linear regression were reflected. For this process "The Statistical Program for Social Science" (SPSS) Version 25 has been used with .05 significance level.

4.1.2.1. Assumption Checks. Starting with the assumptions of parametric tests general assumptions in the literature are as follows, a) level of measurement b) random sampling c) independence of observations d) normal distribution and e) homogeneity of variances (Pallant, 2016). In addition to these assumptions f) linearity g) homoscedasticity, and h) normality of error distributions ı) independence of errors (Morgan *et al.*, 2019) were also checked for the regression analysis.

Firstly, the level of measurement was ratio level, and this assumption has been satisfied with having continuous scores from the scale which has been used for examining students' RFN understanding and their metacognitive awareness. Secondly, students have been sampled randomly although schools were conveniently selected. Students were independent groups according to their level and classrooms were assigned randomly. Thirdly, according to Stevens (1996) observations or measurements should not been affected from each other or from other measurement of observation. Then, in this study, the groups were intact groups, and two measurements were independent from each other and other levels.

4.1.2.1.1. Normality

This assumption has been satisfied for RFN scores, its categories and each grade level and all students' metacognitive awareness scores as whole. As it has been discussed (see Table 4.1 and Table 4.5), the skewness and kurtosis values of students' RFN scores, its categories and metacognitive awareness scores were between -1.5 to +1.5 which were appropriate range for satisfying normal distribution according to Tabachnick and Fidell (2007; 2013). This has been achieved for each grade level students' RFN and metacognitive scores separately and their skewness and kurtosis values were found within this range as reflected at Table 4.2 and 4.5. However, 5^{th} graders' skewness and kurtosis values were between -2.0 and +2.0 (see Table 4.3) which also satisfy the normality assumption according to George & Mallery (2010).

4.1.2.1.2. Homogeneity of Variances

For checking the assumption of homogeneity of variances, Levene's test has been conducted for parametric tests. After conducting the Levene's test for students' RFN and metacognitive awareness scores the results have been tabulated at Table 4.7 and 4.8. Then from the Table 4.7 it has been interpreted that p values of total RFN (df1=3 df2=697 p= .204), scientific practices (df1=3 df2=697 p= .577), method and methodological rules (df1=3 df2=697 p= .527) and social institutional system (df1=3 df2=697 p= .100) categories were greater than significance level ($p > .05$) and not violated the homogeneity of variances

Table 4.7. Levene's test of homogeneity of variances for RFN scores and its categories.

	Levene Statistics	df1	df2	Sig.(p)
Total RFN	1.536	3	697	.204
Aims and Values (AV)	3.406	3	697	.017
Scientific Practices (SP)	.660	3	697	.577
Method and Methodological Rules (M)	.743	3	697	.527
Scientific Knowledge (SK)	6.472	3	697	.000
Social Institutional System (SI)	2.088	3	697	.100

of assumption. However, for aims and values (df1=3 df2=697 p= .017) and scientific knowledge (df1=3 df2=697 p= .100) p values were less than significance level (*p*< .05) which violate the homogeneity of variance assumption. However, although these categories violate this assumption, group size can be determinant factor for the robustness. For example, violation of this assumption can be conditionally robust when group sizes are reasonably near or similar (Pallant, 2010). According to Pituch and Stevens (2016) this assumption can robust when the proportion of large group size to smaller one is lesser than 1.5. Then, when this criterion has been checked for the group sizes, the larger group was 8^{th}

Table 4.8. Levene's test of homogeneity of variances for metacognitive awareness.

		Levene Statistics	df1	df2	Sig.
Total Metacognitive Awareness Score	Based on Mean	4.651	2	518	.010
	Based on Median	4.006	2	518	.019
	Based on Median and with adjusted df	4.006	2	498.111	.019

graders (n=184) and smaller one was from 6^{th} graders (n=164). Then this proportion was corresponding to 1.12 which was smaller than suggested value. Thus, this assumption has not been violated with conditionally robust.

In similar way, the result of Levene's test for 6^{th}, 7^{th} and 8^{th} grade students' metacognitive awareness scores were reflected at the Table 4.8. In the table, p values were lower than significance level (p= .010 p< .05) with violating the homogeneity of variances. However, robustness of this assumption was possible according to Pituch and Stevens (2016) with having conditionally robustness. The proportion of larger group size to smaller one was found as 1.12 which was smaller than the accepted range of 1.50.

4.1.2.1.3. Linearity

Another assumption of Pearson r correlation and simple linear regression is the linearity assumption. The scatterplot which shows the relationship between dependent and independent variables need to be linear straight-line not curvilinear in order to meet with this assumption (Fox, 2015). Thus, the examination of scatter plot of RFN understanding (dependent variable) and metacognitive awareness scores (independent variable) were

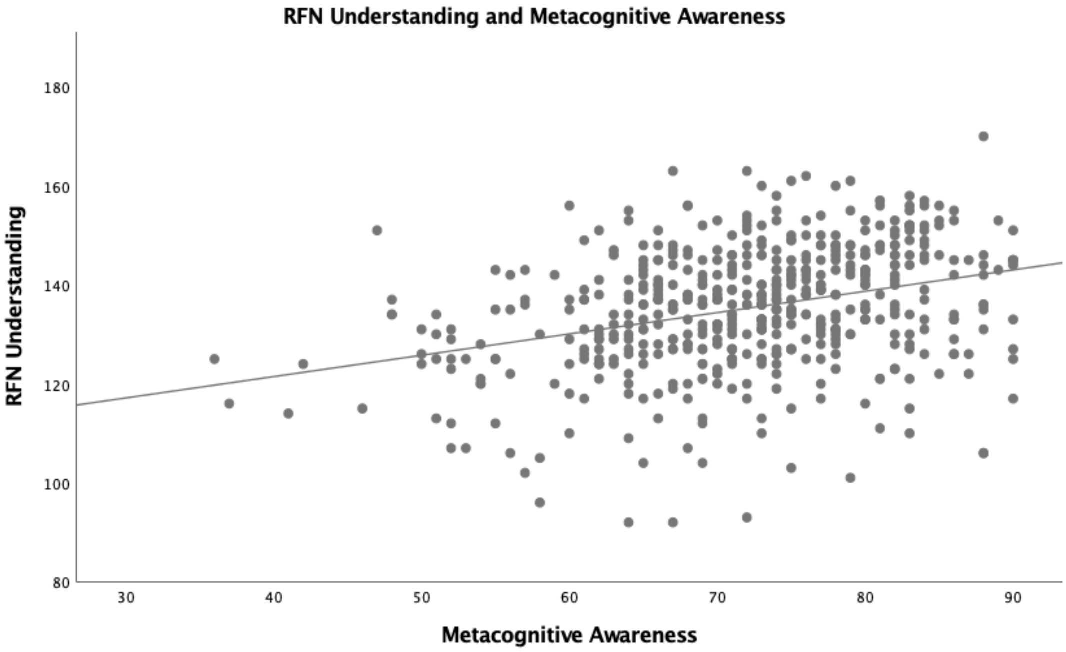

Figure 4. 1. The scatter plot of RFN understanding and metacognitive awareness.

reflected at the Figure 4.1 and indicates straight-line with meeting the linearity assumption. This linearity assumption check has been carried out for 5th, 6th, 7th and 8th graders' scatterplots of RFN understanding and metacognitive awareness scores in order to analyse the sub research question 3a, 3b, 3c and 3d. Then it was found that the scatter plots of every grade level were linear with having the straight line.

4.1.2.1.4. Homoscedasticity

For checking homoscedasticity, scatter plot of residuals has been analysed (Figure 4.2). According to figure there are few outliers which are standardized residuals with having value more than 3.3 and less than -3.3. However, a few of scores can exceed this range without taking necessary action (Pituch & Stevens, 2016; Tabachnick & Fidell, 2013). This homoscedasticity assumption has been checked for 5th, 6th, 7th and 8th grade students' scores separately for analysis of sub research question 3a, 3b, 3c and 3d. Then standardized residuals were within the range of 3.3 and -3.3 with meeting this assumption.

4.1.2.1.5. Independence of Errors

Another assumption of the simple linear regression is the independence of errors in which residuals should be independent from another and errors need to be not correlated

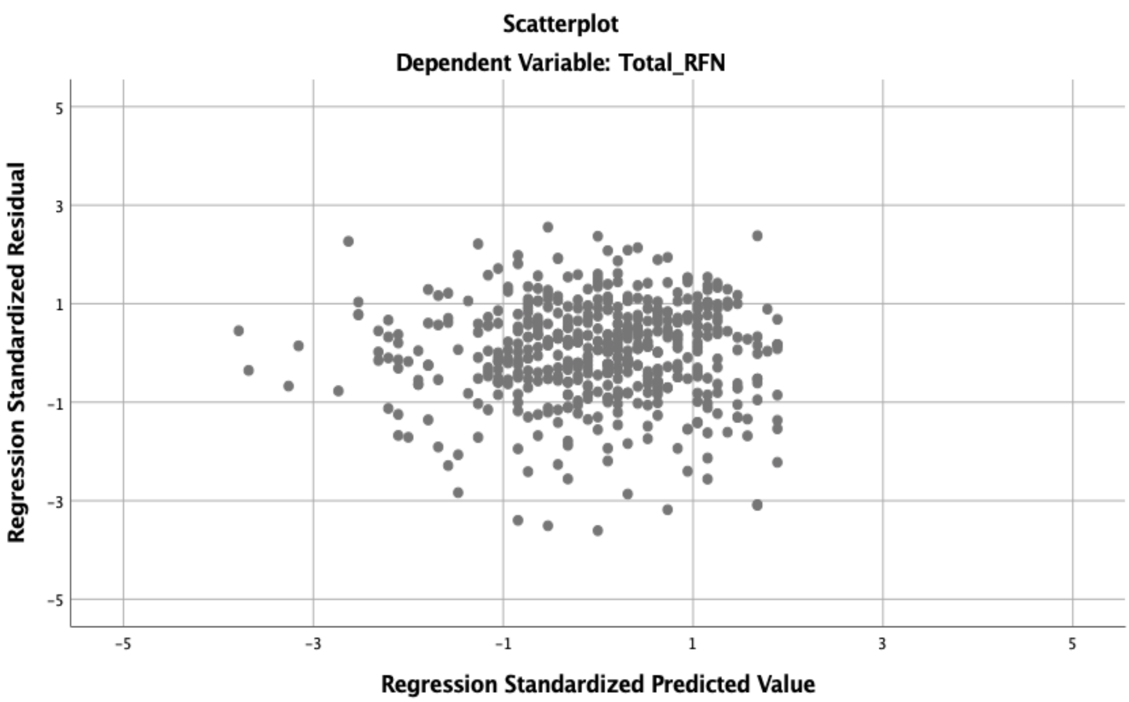

Figure 4. 2. The scatterplot of distribution of residuals.

(Pituch & Stevens, 2016). Thus, for testing this assumption residuals vs fits plot has been examined and randomly scattered graph showed that values were symmetrically distributed around zero with no violation of this assumption. Additionally, Durbin-Watson test has been applied for serial correlation procedure. According to this test, the values between 0 and 4 are suitable for not violation of this assumption. Values equal to 2 indicate least autocorrelation (error) (Huitema & Laraway, 2006). Thus, the value that appear from Durbin-Watson test was 1.756. Thus, this assumption has not been violated according to suggested value range.

4.1.2.1.6. Normality of Error Distribution

For satisfying this assumption the residuals need to be normally distributed. Then, histogram and normal probability plot (P-P) of standardized residuals were checked. According to Figure 4.3 histogram of standardized residuals in which RFN understanding is dependent variable show normal distribution. According to Field (2009) the line of The Normal Probability Plot in which scores are distributed should be linear for normal

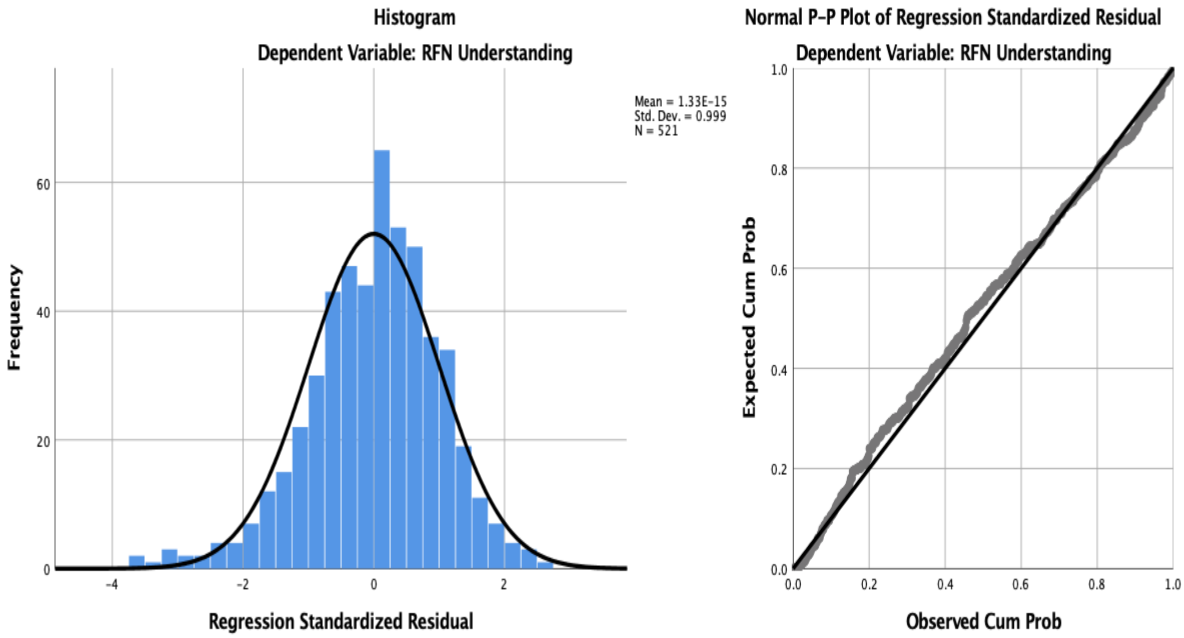

Figure 4. 3. Histogram and normal P-P Plot of standardized residuals.

distribution. This assumption has been met in which P-P plot shows nearly perfect line around scores.

<u>4.1.2.2. The Sub Research Questions of Main Research Question 1 (Group Differences in RFN Scores and RFN Categories).</u> In accordance with answering the sub research questions of main research question 1 (1a,1b,1c,1d,1e,1f), one-way ANOVA test was conducted for comparing different grade level students' total RFN scores and its categories in which assumptions of parametric tests were satisfied. Then, the one-way ANOVA test was conducted, and the results were reflected at Table 4.9.

Table 4. 9. ANOVA summary table for RFN scores and its categories.

		SS	df	MS	F	Sig.
Total RFN	Between Groups	1497.30	3	499.099	3.503	.015
	Within Groups	99320.395	697	142.497		
	Total	100817.692	700			
Aims and Values (AV)	Between Groups	9.836	3	3.279	.648	.585
	Within Groups	3528.142	697	5.062		
	Total	3537.977	700			
Scientific Practice (SP)	Between Groups	88.983	3	29.661	1.952	.120
	Within Groups	10592.064	697	15.197		
	Total	10681.047	700			
Method and Methodological Rules (M)	Between Groups	101.648	3	33.883	6.258	.000
	Within Groups	3773.705	697	5.414		
	Total	3875.352	700			
Scientific Knowledge (SK)	Between Groups	311.201	3	103.734	9.909	.000
	Within Groups	7296.637	697	10.469		
	Total	7607.837	700			
Social Institutional System (SI)	Between Groups	397.762	3	132.587	3.616	.013
	Within Groups	25554.047	697	36.663		
	Total	25951.809	700			

Starting with the answering of the first sub research question (1a) of "Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students' RFN understanding?" the Table 4.9 indicated that there was a statistically significant difference between 5^{th}, 6^{th}, 7^{th} and 8^{th} grade students in terms of their total RFN scores ($F(3,697) = 3.503$ $p < .05$).

On this occasion, to understand which groups significantly differ Tukey's post hoc test has been carried out for multiple comparisons. This test is commonly used test for making multiple comparisons between groups for identifying differing groups (Pallant, 2016; Tabachnick & Fidell, 2013). Thus, the results of RFN Understanding scores of Tukey Post Hoc tests have been reflected at Table 4.10. The table shows that mean difference values which were statistically significant and labelled as Asterix. The test indicated that the mean difference between 6th and 7th grade students significantly differs with having 3.716 mean difference (SE= 1.301 p= .023). In here 7th graders' mean scores (M=136.81) were higher than 6th graders (M= 133.10).

Table 4.10. Comparison of RFN understanding among different grades.

	Grade	Grade	MD	SE	p
RFN Understanding	5th Grade	6th Grade	.799	1.283	.925
		7th Grade	-2.917	1.277	.102
		8th Grade	-1.910	1.251	.422
	6th Grade	5th Grade	-.799	1.283	.925
		7th Grade	-3.716*	1.301	.023
		8th Grade	-2.709	1.276	.147
	7th Grade	5th Grade	2.917	1.277	.102
		6th Grade	3.716*	1.301	.023
		8th Grade	1.007	1.270	.858
	8th Grade	5th Grade	1.910	1.251	.422
		6th Grade	2.709	1.276	.147
		7th Grade	-1.007	1.270	.858

*The mean difference is significant at the 0.05 level.

Another the sub research question (1b) is "Are there any statistically significant differences among different grade (5th, 6th, 7th and 8th) middle school students in terms of their understanding of aims and values of science?". From the Table 4.9 the significance value of this category equals to .547 ($F(3,697) = 0.648$ $p > .05$) with showing that there was no statistically significant difference between groups.

For the analysis of the sub research question of 1c that was "Are there any statistically significant differences among different grade (5th, 6th, 7th and 8th) middle school students in terms of their understanding of scientific practices?" the one-way ANOVA test was conducted. From the Table 4.9 it was seen that the p value was non-significant (F (3,697) =

1.952 p>.05). Thus, there was no statistically significant difference between 5^{th},6^{th},7^{th} and 8^{th} grade students' scientific practices scores.

In accordance with answering the sub research question 1d (Are there any statistically significant differences among different grade (5^{th}, 6^{th}, 7^{th} and 8^{th}) middle school students in terms of their understanding methods and methodological rules of science?) the Table 4.9 showed that students' scores in methods and methodological rules of science significantly differ with having p value of .000 which was less than significant value ($p < .05$). Then, there was a statistically significant difference between 5^{th}, 6^{th}, 7^{th} and 8^{th} grade students' method methodological rules scores ($F(3,697) = 6.258$ $p < .05$). When students' scores in the methods and methodological rules of science category were compared, from Table 4.11, Tukey post hoc multiple comparisons test showed that there was a statistically

Table 4.11.Tukey post hoc test of multiple comparisons of method and methodological rules scores among grade levels.

Category	Grade	Grade	MD	SE	p
Method and Methodological Rules	5^{th} Grade	6^{th} Grade	-.32908	.25000	.553
		7^{th} Grade	-.59346	.24885	.081
		8^{th} Grade	-1.02307*	.24393	.000
	6^{th} Grade	5^{th} Grade	.32908	.25000	.553
		7^{th} Grade	-.26439	.25351	.724
		8^{th} Grade	-.69399*	.24869	.028
	7^{th} Grade	5^{th} Grade	.59346	.24885	.081
		6^{th} Grade	.26439	.25351	.724
		8^{th} Grade	-.42960	.24753	.306
	8^{th} Grade	5^{th} Grade	1.02307*	.24393	.000
		6^{th} Grade	.69399*	.24869	.028
		7^{th} Grade	.42960	.24753	.306

*. The mean difference is significant at the 0.05 level

significant difference between 8^{th} and 5^{th} grade students' scores. The significance value was .000 and less than significance value (MD=1.02307 SE= .24393 $p < .05$). 8^{th} graders' mean score (M= 14.716 SD= 2.444) was greater than 5th graders (M= 13.688 SD= 2.146). In addition, there was also significant difference between 8th and 6th grade students' means scores (M= .6939 SD=.24869 $p < .05$). 8th graders' mean score (M= 14.716 SD= 2.444) was greater than 6th graders (M=14.016 SD=2.479).

Another the sub research question (1e) is "Are there any statistically significant differences among different grade (5th, 6th, 7th and 8th) middle school students in terms of their understanding scientific knowledge?". The Table 4.9 indicated the significant difference between 5th, 6th, 7th and 8th grade level students ($p <.05$). Afterwards, to understand which group differs the Tukey post hoc test has been carried out and tabulated at the Table 4.12 According to this table 8th grade students' scores significantly differed from 5th grades (MD= 1.54746* SE= .30032 p= <.05). 8th graders' scores (M =25.364 SD=3.092) were higher than 5th graders (M= 23.816 SD= 2.622). From the table, it can also be seen that

Table 4.12. Tukey post hoc test of multiple comparisons of scientific knowledge scores among grade levels.

Category	Grade	Grade	MD	SE	p
Scientific Knowledge	5th Grade	6th Grade	-.69232	.35597	.212
		7th Grade	-1.60098*	.32092	.000
		8th Grade	-1.54746*	.30032	.000
	6th Grade	5th Grade	.69232	.35597	.212
		7th Grade	-.90867	.39154	.095
		8th Grade	-.85515	.37484	.105
	7th Grade	5th Grade	1.60098*	.32092	.000
		6th Grade	.90867	.39154	.095
		8th Grade	.05352	.34173	.999
	8th Grade	5th Grade	1.54746*	.30032	.000
		6th Grade	.85515	.37484	.105
		7th Grade	-.05352	.34173	.999

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

statistical differences were also between 5th and 7th grade students (MD= 1.60098 SE= .32092 p<.05). 7th graders' mean scores (M =25.417 SD=3.318) were higher than 5th graders (M= 23.816 SD= 2.622).

Lastly, the research question 1f was "Are there any statistically significant differences among different grade (5th, 6th, 7th and 8th) middle school students in terms of their understanding social institutional systems of science?". As a result of interpretation of the Table 4.9 there was a statistically significant difference between students' social institutional system scores ($F(3,697) = 3.616$ $p < .05$), Afterwards, Tukey post hoc test results (Table 4.13) showed that there was a statistically significant difference between 6th and 7th grade students' social institutional system scores (M= -1.78394* SE= .65970 p=.035 <.05). 7th graders' mean score (M= 53.697 SD= 5.772) was greater than 6th graders (M= 51.910 SD= 6.695).

Table 4.13. Tukey post hoc test of multiple comparisons of social institutional system scores among grade levels.

Category	Grade	Grade	MD	SE	p
Social Institutional System	5th Grade	6th Grade	1.66204	.65055	.053
		7th Grade	-.12190	.64757	.998
		8th Grade	-.12190	.64757	.998
	6th Grade	5th Grade	-1.66204	.65055	.053
		7th Grade	-1.78394*	.65970	.035
		8th Grade	-.49199	.64714	.872
	7th Grade	5th Grade	.12190	.64757	.998
		6th Grade	1.78394*	.65970	.035
		8th Grade	1.29194	.64414	.187
	8th Grade	5th Grade	-1.17005	.63477	.254
		6th Grade	.49199	.64714	.872
		7th Grade	-1.29194	.64414	.187

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

To sum up the first research question, descriptive scores of RFN understanding showed that students' mean scores were 134.91 (72.92%) out of 185. For the sub research questions it has been seen that significant difference was between 7th and 6th graders' RFN understanding scores. In the categories of science there was no statistically significant difference among middle schoolers in terms of aim and values and scientific practices scores. In the method and methodological rules category, differences were between 8th and 5th grade students as well as differences between 8th and 6th graders. For the scientific knowledge category, 7th graders significantly differed from 5th graders while in the social institutional system 7th graders significantly differed from 6th graders. However, interviews helped to understand and consolidate this data for deep examination of the students' RFN understanding.

4.1.2.3. The Sub Research Question 2 (Group Differences in Metacognitive Awareness Scores). The sub research question of main research question 2 was "Are there any statistically significant differences among different grade (6th, 7th, 8th) middle school students' metacognitive awareness". For analysis of this question, the one-way ANOVA test was used with satisfying assumptions.

Table 4.14. The one-way ANOVA for middle school students' metacognitive awareness scores.

Category	Source	SS	df	MS	F	Sig.
Metacognitive Awareness Scores	Between Groups	102.984	2	51.492	.568	.567
	Within Groups	46990.394	518	90.715		
	Total	47093.378	520			

According to the Table 4.14, the significance value was greater than significance level ($F(2,518) = .568$ $p = .567$) and there were no statistically significant differences between 6th, 7th and 8th grade students' metacognitive awareness scores.

4.1.2.4. The Main Research Question 3 and Its Sub Questions (The Relationship Between Students' RFN Understanding and Their Metacognitive Awareness). The third main question of "Is there a relationship between middle school students' RFN understanding and their metacognitive awareness scores?" and the sub questions (3a, 3b, 3c, 3d) were analysed through Pearson correlation. The aim was to understand whether students' RFN understanding and metacognitive awareness were related constructs and revealing predictor ability of metacognitive awareness scores on students' RFN understanding. In this sense, the correlation matrix at the Table 4.15 provides correlation coefficient between students' RFN understanding (M= 135.26 SD=12.399) and their metacognitive awareness (M=72.03 SD=9.517) scores. According to Cohen (1988) r value shows the strength of relationship between two variables. Correlation coefficient values were between .10 and .29 (small), .30 and .49 (medium), .50 and 1.0 (large) indicate degree of relationship (Cohen, 1988; Gravetter & Wallnau, 2014). Thus, the Table 4.15 showed that there was a significant positive relationship between middle school students' (6^{th},7^{th}, 8^{th} grade) RFN understanding and their metacognitive awareness (r (521) = .331, $p< .01$). The degree of relationship was medium with values between .30 and .49.

Table 4.15. Pearson correlation, mean and standard deviation of RFN understanding and metacognitive awareness.

		M	SD	1	2
1.	Metacognitive Awareness	72.03	9.517	_	
2.	RFN Understanding	135.26	12.399	.331**	_

** $p< .001$ (2-tailed)

Moreover, the sub research questions have been analysed with Pearson correlation since assumptions have been satisfied (see the section 4.1.3.1). For the analysis of the sub research question 3a, "Is there a relationship between 5^{th} grade middle school students' RFN understanding and their metacognitive awareness scores?", the Table 4.16 was tabulated. It has seen that there was a significant positive relationship between 5^{th} grade students' RFN understanding and their metacognitive awareness (r (180) = .292, $p< .01$). The strength of relationship was low since it was between the .10 and .29 values (Cohen, 1988).

Another the sub research question (3b) was "Is there a relationship between 6^{th} grade middle school students' RFN understanding and their metacognitive awareness scores?". Then the Table 4.16 reflects the correlation coefficients, and it was found that there was a significant positive relationship between 6^{th} grade students' RFN understanding and their metacognitive awareness (r (167) = .317 p< .01). The strength of the relationship was medium and in the positive way.

With the same analysis procedure, the sub question of 3c “Is there a relationship between 7th grade middle school students’ RFN understanding and their metacognitive awareness scores?” was answered. The Table 4.16 showed that correlation coefficient was in the moderate level with having medium corelation coefficient. Thus, there was a significant positive relationship between 7th grade students’ RFN understanding and their metacognitive awareness (r (170) = .332 p< .01).

Table 4.16. Correlation matrix of RFN understanding and metacognitive awareness for grade levels.

Grade Level		1	2
5th Grade	1. RFN Understanding	-	.292**
	2. Metacognitive Awareness		-
6th Grade	1. RFN Understanding	-	.317**
	2. Metacognitive Awareness		-
7th Grade	1. RFN Understanding	-	.332**
	2. Metacognitive Awareness		-
8th Grade	1. RFN Understanding	-	.347**
	2. Metacognitive Awareness		-

** p< .001 (2-tailed)

Lastly, the sub question 3d was “Is there a relationship between 8th grade middle school students’ RFN understanding and their metacognitive awareness scores?”. The value of correlation coefficient was in the moderate level and there was a significant positive relationship between 8th grade level students’ RFN understanding and their metacognitive awareness (r (184) = .347 p< .01). However, to examine shared variance of these two variables and whether metacognitive awareness can be predictor variable for students’ RFN understanding the simple linear regression test was conducted.

In correlational studies, prediction is one of common uses that has been investigated (Pallant, 2010). Although RFN understanding and metacognitive awareness seem correlated statistically, for getting accuracy in prediction squared correlation (r^2) which is called coefficient determination was used. This is the tendency of two variables to vary together (Pituch & Stevens, 2016). Thus, to answer the sub research question (3e) "Can metacognitive awareness significantly predict RFN understanding?" the simple linear regression analysis was conducted. The results of regression analysis showed that model explained the 11.0% of variance and it was significant ($F (1, 519) = 63.819$, $p < .001$). Thus, it was found that metacognitive awareness significantly predicted RFN understanding ($\beta_1 = .43$, $p < .001$). This means that students who have relatively high metacognitive awareness level were likely to have high RFN understanding. The final predictive model was: Proportion of RFN Understanding = 104.20 + (.43 * Metacognitive Awareness). In brief, metacognitive awareness have predictive ability on RFN understanding but change in 11% of RFN understanding can be explained by the metacognitive awareness.

To sum up this section, according to the results, it was found that metacognitive awareness and RFN understanding are related constructs and metacognitive awareness had predictive ability on RFN understanding. The relationship between students' RFN understanding and their metacognitive awareness exists among each grade level students and all middle school students. In students' RFN scores, the descriptive statistics showed that 7^{th} graders' and 8^{th} graders' mean scores were higher than 5^{th} and 6^{th} graders. However, the inferential analysis pointed the significant differences between 7^{th} grade and 6^{th} grade students' RFN understanding. In categories of science, the significant difference between students' scores was found in methods and methodological rules, scientific knowledge, and social institutional system categories. In these categories generally 7^{th} and 8^{th} graders' superiority in scores were evident. Students' scores in metacognitive awareness didn't differ between each grade level.

4.2. Qualitative Data Results

This section covers the qualitative data results from 12 semi structured interviews which consist of RFN based and metacognitive awareness questions respectively. The sub section (4.2.1) starts with representation of students' perceptions of RFN through each category of science which are aims and values, scientific practices, methods and methodological rules, scientific knowledge, social-institutional systems of science and the following section (4.2.2) reflects students' metacognitive awareness including their metacognitive knowledge (the declarative, conditional, procedural knowledge) and the regulation of their cognition (monitoring, planning, evaluation).

In the RFN interview subsection students' perceptions of each category of science have been examined through RFN based interview questions. Since students were selected from high-moderate-low RFN and metacognitive awareness level, these students' RFN based interview results were reflected at the corresponding subsection. Each grade level students' perceptions and general trend have been reflected in addition to comparisons of students from different RFN level. In the metacognitive awareness subsection, the results of students' metacognitive awareness interviews were reflected with including subcomponents of metacognitive awareness and considering students' metacognitive actions, skills, and knowledge. With the similar aim, the general results and students' metacognitive awareness have been examined with making comparisons among each grade level students and high-moderate-low metacognitive awareness level students.

In each subsection, sample quotations were provided to display students' perceptions and explanations. Students' grade, RFN and metacognitive awareness level (high-moderate-low) have been provided at the end of these quotations. For instance [5^{th}-M] imply that response was provided by 5^{th} grade moderate RFN and metacognitive awareness level student. In addition, in the last subsection [RFN] and [MAI] abbreviations were also used at the end of quotations. While [RFN] was standing for students' answer to RFN questions, [MAI] meant students' answer to metacognitive awareness questions. In each interview, in addition to direct vocabulary and words, the meaning that has been extracted from students' answers has been analysed and represented accordingly.

4.2.1. RFN Interview Results

For this section, the main research question that has been explored is "What are middle school students' RFN perception?". This was the main research question 4 and students' perceptions were focused. Additionally, the sub research questions (4a, 4b, 4c, 4d) were specifically for different grade levels. These are "What are 5th grade level students' RFN perception?", "What are 6th grade level students' RFN perception?", "What are 7th grade level students' RFN perception?" and lastly, "What are 8th grade level students' RFN perception?". To clearly represent all students' RFN perceptions appearing themes and codes from each category of science have been clarified with the tables and explained with giving sample quotes from students' answers. Each grade level students' ideas in the categories of science have been reflected through each subsection. However, their holistic image of RFN has been summarized at the last section (4.2.1.6).

The abbreviations and one of the sample table that has been referred for explaining students' RFN understanding has been provided at Figure 4.4. The figure provides emerging

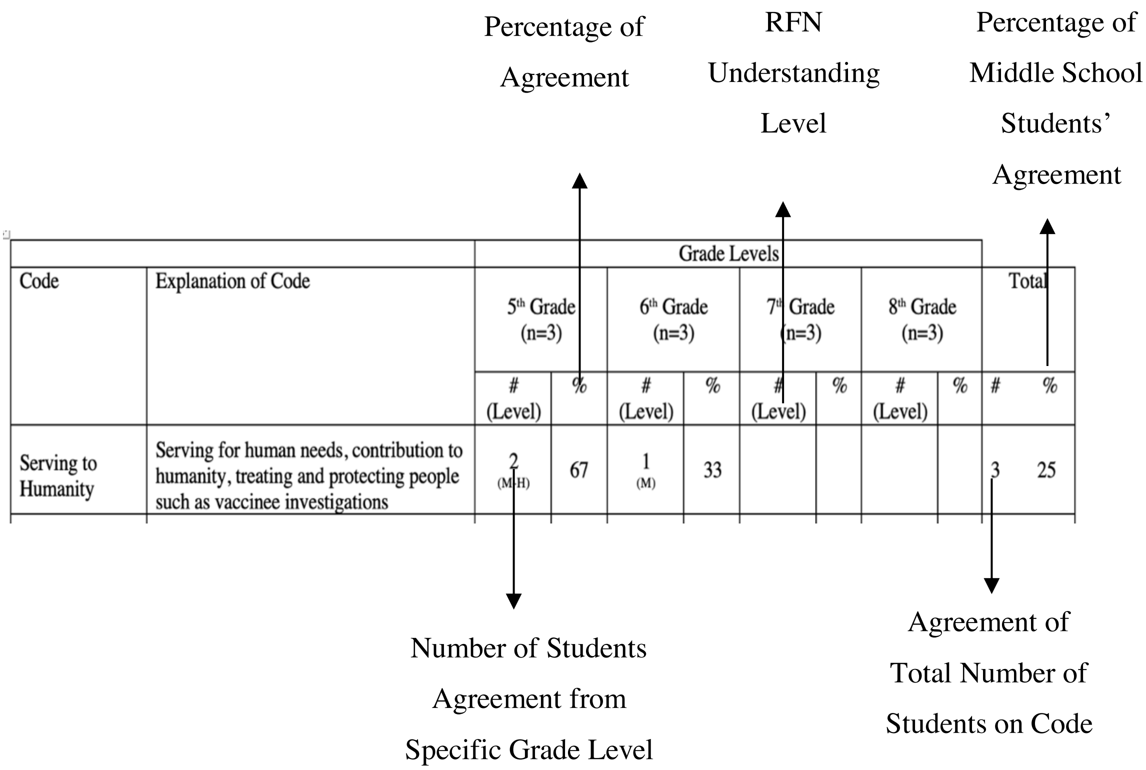

Figure 4. 4. Explanation of tables that has been used for each category science.

codes in each category of science and definitions that has been formed according to students' explanations. The table also reflects the frequency of for each grade and all middle school students' agreement, the prevalent codes of each category of science and students' RFN levels (high-moderate-low) holistically. For instance, one can trace the 5^{th},6^{th},7^{th}, and 8^{th} grade level students' agreement, their RFN levels (high-moderate-low) and all middle school students' agreement on the code. It serves as a general summary of qualitative notions and provide clear vision for middle students' perceptions of RFN. Additionally, another aim of the tables is bounding coherence between the quantitative and qualitative results with following students' responses from different grade and RFN level. Lastly, in the tables the sign that was used through is (**) sign. It was used to represent students' limited expressions such as non- scientific, unrelated explanation or naïve ideas. It helps to identify students who provided that notion and students' limited expressions at corresponding category. In overall, the design of the tables that has been referred and formed to represents students' RFN ideas and codes have been inspired from Cilekrenkli's (2019) study which expressed the 5^{th} grade level students' RFN perceptions. In addition, while forming related themes and codes, similar codes that appeared in the previous studies of RFN (Akbayrak & Kaya, 2020; Akgun & Kaya, 2020; Cilekrenkli, 2019) has been utilized or rearranged for this study as well.

4.2.1.1. Middle School Students' Perceptions of Aims and Values of Science. Middle school students' perceptions of aims and values of science have been gained through asking questions to students on scientists' aims in conducting scientific studies, values of scientists that follow, etc (see appendix D). After the data analysis process, emerging codes were given at the Table 4.17.

Firstly, from the Table 4.17, it can be interpreted that the middle schoolers mainly thought that informing people, serving to humanity making the daily life easier, making developments and curiosity are the aims of science. These means that informing people on scientific studies, providing solutions for daily life, protecting to humankind, and making developments for science and country are the aims of science according to students. For example, one of student explained that

> Their aims are informing people. For instance, if scientists thought that meteor will hit the Earth according to their study studies and research, they inform the people so that people can take precautions. They protect us. [6^{th}-M] (Appendix F, line 1)

Table 4.17. Emerging codes from students' perceptions of aims and values of science.

Code	Explanation of Code	Grade Levels: 5th Grade (n=3) # (Level)	%	6th Grade (n=3) # (Level)	%	7th Grade (n=3) # (Level)	%	8th Grade (n=3) # (Level)	%	Total #	Total %
Serving to Humanity	Serving for human needs, contribution to humanity, treating and protecting people	2 (H-M)	67	1 (M)	33					3	25
Informing People	Transferring the knowledge accumulation to the public	2 (M-L)	67	1 (M)	33	1 (H)	33			4	33
Proving as an aim of science	Proving ideas and knowledge through evidence-based ideas and investigations			2 (H-L)	67					2	17
Curiosity	Fulfilling a strong desire to learn and curiosity			1 (H)	33	1 (M)	33	1 (H)	33	3	25
Developments	Making developments for the world, country and scientists' own professional capacity					1 (H)	33	2 (H-M)	67	3	25
Making the daily life easier	Producing solutions to people's daily life problems and contributing daily life needs					1 (L)	33	2 (M-L)	67	3	25
Ethics (*Value)*	Care for living beings in scientific experiments, protecting their rights	1 (H)	33	2 (M-L)	67	1 (H)	33	3 (H-M)	100	7	58
Novelty *(Value)*	Revealing and learning new knowledge, explanations			1 (H)	33			1 (H)	33	2	17
Empirical Base *(Value)*	Empirically adequate evidence with making investigations, collecting data, testing					1 (H)	33			1	8
Accuracy *(Value)*	Reaching and getting accurate knowledge after making investigations and experiments	1 (H)	33							1	8

This student thought informing people as an aim of science to protect or serving humankind. This code was most the prevalent code among middle school students (33%). Related with this code another dominant code was social perspectives such as serving to humanity, making daily life easier and making developments. For instance, 7th grade student explained that

> While making scientific investigations, scientists try to contribute on something. For example, scientific experiments…. umm…, for instance, for making daily life easy they can produce something. They can make inventions and make medicines for providing benefits to people. For making people' life easy they make those inventions like that. [7th-L] (Appendix F, line2)

This student considers making progression in medicine and country to provide better future for human being with focusing generally on making daily life easier code. Besides, some students (25%) were also thinking that aim of science is to fulfil curiosity and enhancing development of country. It was evident that students from each grade and diverse levels (high-moderate-low) have recognized mostly the social utility of science as opposed to epistemic, cognitive aims of science. Dominance of this social aspect were also obvious from number of codes (16 out of 18) as well.

When students' perceptions of values of science were examined, it was seen that accurate knowledge, ethics, novelty, and empirical evidence were the values of science which were obviously less in number than aims of science. Agreement on ethics (58 %) and novelty (17%) were relatively high among middle schoolers. They were thinking that respecting animals and humans are crucial in scientific studies and scientists have to consider these values. In addition to this, novel studies such as discovering something new, getting an accurate result and conducting empirical based studies have been valued in scientific studies according to students' views. It can be said that students not only view social but also epistemic cognitive values as well.

As another purpose of interviews, each grade level students' RFN understanding have been explored. In this scope, it has been seen that most 5th graders' ideas (67%) were relying on serving to humanity and informing people as aims of science. For instance, students stated that scientists aim to produce beneficial results for helping people in treatments and inform public. In addition, the values of science have been elaborated with accuracy of knowledge and ethics only by high level student. These shows that 5th grade students' views were generally on social aspects and social utility as aims and values of science. Furthermore, from 6th grade students' ideas it was evident that most students (33%) consider proving as an aim of science. For instance, low RFN level student stated that

> Some people can make false or misleading claims with lies. Scientists can try to prove truth and for achieving this they make investigations and research on that. After that, they prove whether claim is true or not. [6th-L]

This student thought that science aims to prove ideas and knowledge through evidence-based ideas and investigations to find truth against misinformation. Thus, it was evident that more structured ideas appeared from higher grade levels as aims of science. Surprisingly, student with low RFN level provided more structured explanations in this category compared to other low RFN level students. Moreover, in addition to students' aims, 6th graders had a perception on novelty as values of science which means the learning and revealing new knowledge in science. This showed that 6th grade students' ideas were also on epistemic-cognitive dimensions of values of science.

7th grade students' some ideas were same with 6th and 5th graders explanations. As a difference, inventions and explanations were evident among 7th graders. For instance, one of students stated that aim of science is to explain and understand the specific concept. Another 7th grade student was thinking that scientists aim to make inventions. Although some similar codes with lower grade level students appeared. 7th graders also connected these codes to explain aims of science. For instance, while explaining developments in country they also mentioned the importance of informing public and evidence-based arguments. As values of science, students explained the ethics and empirical evidence generally. Only high RFN level student mentioned that science should value for respecting animal and human rights and empirical evidence. It has seen that 7th graders' ideas on aims and values of science were more diverse and spread over various codes.

8th graders' agreement on making the daily life easy (67%), developments (67%) and ethics (100%) were dominant for aims and values of science. For example, while students explained the importance of making developments and contributions in science for the world and country, other students viewed that scientific studies need to ease people' daily life. As values of science students viewed the ethical perspectives generally and novel studies such as revealing the new knowledge and reaching undiscovered results. However, these ideas were similar with 7th graders' explanations but elaborated when compared with 5th and 6th graders.

Lastly, low, moderate and high-level students' responses can be compared from the Table 4.17. It can be seen that number of codes provided by moderate and high-level students were more than low level students. Not surprisingly, most codes on epistemic and cognitive values came from high RFN level students. Students' explanations for these codes were more structured and organized than low level students. For instance, it can be seen from the table that the most low-level students perceive aims of science as making daily life easier and no expression for values of science. Some of their excerpts can also be traced from the previous quotations that has been provided in each grade level students' expressions.

In sum, the middle school students perceive informing people, serving to humanity, making daily life easier, making developments as aims of science while ethics and novelty as values of science in general. The grade level examination showed that students from all grades consider social aspects of aims and values of science. In the quantitative results there were no statistically significant differences between students' understanding of aims and values of science and this result was nearly similar with the qualitative results of this category. The frequency of codes between different grade levels were also nearly same and students' expressions were revolving around similar ideas. However, higher grade level students provided epistemic-cognitive perspectives for aims and values in more clear and structured way.

4.2.1.2. Middle School Students' Perceptions of Scientific Practices. This section reflects students' perceptions on scientific practices in science. Questions related with how scientists conduct their studies, the meaning of scientific practices, the terms such as observation, classification and experimentation have been asked to them. From the Table 4.18, highly agreed codes among students were direct observation, investigations, scientific categorization of classification and testing.

Table 4.18. Middle school students' perceptions of scientific practices.

		Grade Levels								Total	
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)			
		Level (#)	%	Level (#)	%	Level (#)	%	Level (#)	%	#	%
Constructing Theories	Constructing and putting theories forward			1 (H)	33					1	8
Investigations	Planning and conducting scientific studies, examining the concept, making observations and experiments, reaching findings	2 (H-M)	67	2 (H-M)	67	3 (H-M-L)	100	3 (H-M-L)	100	10	83
Observation											
Direct Observation	Watching and tracing changes, examining, observing planets, moon, plants, animals, effects of vaccines on people	2 (H-M)	67	3 (H-M-L)	100	3 (H-M-L)	100	3 (H-M-L)	100	11	92
Experimentation											
Use of Materials	Making mixtures with adding materials, using test tubes, calibrating experimental tools such as telescopes, microscopes	2 (H-M)	67			3 (H-M-L)	100	1 (H)	33	6	50
Testing	The way of trying and testing, making trial and error	1 (M)	67	3 (H-M-L)	100	2 (H-M)	67	3 (H-M-L)	100	9	75
Classification											
Scientific categorization	A systematic categorization or clustering of scientific phenomenon such as species, plants,	3 (H-M-L)	100	3 (H-M-L)	100	2 (H-M)	67	2 (H-M)	67	10	83
Activity**	The act of separation or grouping according to characteristics or common criteria such as classification of activities, materials and tools					1 (L)	67	1 (L)	33	2	17

Table 4.18. Middle school students' perceptions of scientific practices (cont.).

Code	Explanation of Code	Grade Levels								Total	
		5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)			
		Level (#)	%	Level (#)	%	Level (#)	%	Level (#)	%	#	%
Data	Scientists collect data from natural environment and take people' perspectives with surveys, interviews, observations	2 (H-M)	67	1 (H)	33					3	25
Diverse activities	Filming videos for their studies, taking notes, determining research goals			1 (H)	33			1 (M)	33	2	17
Generating Products	Production of machines and manufacturing products after making investigations	1 (M)	33			1 (L)	33			2	17
Communication of Information	Scientists consult and share their perspectives with each other and to society					1 (L)	33	2 (M-L)	67	3	25
Searching from Sources	Searching information with using variety of sources such as books, articles, experiments, internet, atlas.	1 (H)	33	2 (H-L)	67	1 (M)	33	2 (H-M)	67	6	50
Reviewing Studies	Searching for what has been conducted before and making new contributions to studies					2 (M-L)	67	1 (H)	33	3	25
Identifying concept	Determining and defining the concept as a first step			1 (L)	33	1 (M)	33			2	17

At first, most middle school students (92%) explained observation as watching, tracing changes, and examining scientific phenomenon such as plants, species, planets in which nearly all students were able to regard observation as scientific practice. For instance, 6^{th} grade high RFN level student stated that

> Scientists can trace the growth of one plant. They can put an unmovable camera in front of the plant. Then, they can put it nearly 30 days or for the growth time of plant so that they can speed up the video and trace it. [6^{th}-H] (Appendix F, line 3)

Hence, this student views direct observation and associates it as a data collection method which shows this student's comprehensive views. However, none of students were unable to explain other observation types that scientists use such as indirect, obtrusive, nonobtrusive observation, etc.

Similarly, for the classification, more than half of students (83%) considered it as scientific categorization of scientific phenomenon. However, none of students were able express the descriptive, predictive, or explanatory power of classification which were complementary components for epistemic characteristics of the classification according to Erduran and Dagher (2014). On the contrary, two students viewed the classification of materials or properties as a scientific activity. For instance, low RFN level 7^{th} and 8^{th} grade students mentioned the scientists' separation of their lab coats, goggles, etc as scientific classification. These showed their limited and naïve understanding of classification.

Furthermore, while some students (50%) viewed experimentation as making mixtures and adding liquids, some of them (75%) considered experimentation as a way of trying and testing with each grade level students' agreement. Furthermore, higher grade level students associated them with also as proving mechanism. For instance, high RFN level 6^{th} grader explained that,

> With experiments scientists make many trials until they found thing that they are looking for. They perform these experiments for proving their study. [8^{th}-M]

Another higher grade level student was also explaining the role of trying and testing in science. This shows that high RFN level students were able to link experiments with scientists' work unlike students who relate experiments with basic science demonstrations and utilization of laboratory materials.

Additionally, the investigation as an overarching code means that planning and conducting scientific studies, making research, performing experiments and observations. Form the table it can be said that most students (83%) view making investigations as practices of science which shows their comprehensive views on scientific practices.

Furthermore, another remarkable codes such as data and communication of information can be associated with the benzene ring heuristic of Erduran and Dagher (2014). For example, 25 % of students mentioned collecting data from environment and linked the communication of information with scientific practices. These students were thinking that discourse environment such as discussing and sharing the results are the scientific practices which can be associated with social and cultural components of scientific practices. In sum, these ideas were clues of students more structured perceptions.

Moreover, the specific zooming to 5^{th} grade students' codes showed that most 5^{th} graders (67%) consider direct observation, use of materials and scientific categorization as scientific practices. For example, the moderate and high-level students expressed experimentation as adding and mixing materials rather than its role and link with theoretical knowledge. Although these showed their limited views, their ideas on collecting data and making scientific classification as practices of science were more complex. Compared to low level student who was unable to provide answers for this category (see Table 4.18), moderate and high-level students' explanations were considerably more organized.

In the 6^{th} grade level, direct observation, the way of testing and systematic categorization were the most appearing codes in which all three students (100%) highly agreed on. These students were viewing that watching the phenomena as observation, testing the studies for their accuracy, and classifying species, plants (etc) as scientific practices. One of outstanding ideas was theory construction that was not evident in any other grade level students' notions. For example, surprisingly, 6^{th} grade low level student stated the putting theories on concepts. Although the student doesn't provide further explanations for his thoughts, this student was able to link and think that scientists construct theories as a scientific practice. However, in general, the moderate and high-level students' explanations and ideas for same codes were varying with having more structured views. For instance, high RFN level student explained observation in more scientific way with giving examples from observations of plants while low level student mentioned it with general expressions.

Similarly, 7th graders' ideas were revolving around same codes, however as a different from other levels, naïve ideas such as classification of properties as scientific classification were provided by low level students. For example, low RFN level 7th grade student explained that

> I think that scientists can make scientific classifications. For instance, umm... I don't how they do but they have lab wardrobes and materials, equipment inside. They can separate those. They can also label their lab coats and put their personal properties to find them easily. [7th-L] (Appendix F, line 4)

However, other students' expressions on investigations, making reviews, importance of communication of information were more abundant which also showed their diverse views for scientific practices. These social perspectives of scientific practices were only evident at 7th and 8th graders.

Moreover, the 8th graders had similar perceptions with 7th and 6th graders. As a difference, the number of students who agreed on the communication of information as a scientific practice, making reviews and searching sources which can be associated with the literature review process in studies were emphasized in 7th and 8th graders generally. According to these students, scientists identify the concept to study, review sources and search for similar studies which were considered as complementary features of scientific practices. Then, these students' ideas were differing and structuring with complex explanations.

In overall, all middle grade students associated direct observation as practice. All students had lack of understanding on explanatory and predictive power of classifications and epistemic-cognitive role of scientific practices. Furthermore, the specific and comparative examination for grade levels showed that each grade level students know main scientific practices such as observation and experimentation. However, their explanations and definitions of these concepts were rather limited in each grade level students in terms of epistemic-cognitive role of these practices and interlink among them. Generally, 7th and 8th grade students' explanations were more diverse and detailed with explaining importance of communication of information and making the literature review process in studies as scientific practices.

4. 2.1. 3. Middle School Students' Perceptions of Method and Methodological Rules. This section reflects students' perceptions on methods and methodological rules of science through questions such as scientific methods that scientists use, methods in different branches of science, presuppositions of scientists, etc (see Appendix D). In this perspective, from the Table 4.19, most students thought that general methods, use of instruments and data collection were the methods of science. In addition, the diversity of methods and verification of presuppositions of scientists were also other prevalent codes among middle school students.

As methods of science 58% of middle schoolers considered performing experiments, making observation, and doing research. They explained making observations in astronomical studies and experiments in vaccine investigations are some methods used in science. Some students explained diverse scientific methods that scientists use. For instance,

> Making observations, scientists can observe the space. Apart from this they can also use different methods such as making research and preparing surveys. They can ask survey questions and look for that answer. [6th-H]

This quotation shows that some students were able to view methods of science from general perspective including different type of methods. However, none of students explained the variety of methods such as hypothesis/non hypothesis testing, manipulative/non manipulative descriptions which are critical to understand explanatory consilience according to Erduran and Dagher (2019). Moreover, students were also thinking

Table 4.19. Middle school students' perceptions of methods and methodological rules.

		Grade Levels									
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)		Total Code	
		Level (#)	%	Level (#)	%	Level (#)	%	Level (#)	%	#	%
Methods of Science											
Testing	Testing ideas and concepts with experiments and making trial and errors.			1 (H)	33	1 (M)	33	1 (L)	33	3	25
Data Collection	Collecting data for research	2 (H-M)	67	1 (H)	33	1 (L)	33	1 (M)	33	5	42
Use of Scientific Instruments	Using telescopes, microscopes, magnifying glasses, calibrating equipment	1 (L)	33	2 (H-L)	67	1 (M)	33	1 (H)	33	5	42
General Methods	Performing experiments, making observations, doing research	2 (H-M)	67	2 (H-M)	67	2 (H-M)	67	1 (H)	33	7	58
Examination	Making descriptive examinations			1 (L)	33			1 (M)	33	2	17
Branches of Science											
Diversity of Methods	Use different methods (observation, experimentation, consulting different ways)	1 (H)	33	2 (H-M)	67	2 (H-M)	67	2 (H-M)	67	7	58
Same method**	The scientific method myth that scientists follow one basic steps for their studies	1 (L)	33	1 (L)	33	1 (L)	33			3	25
Presuppositions											
Verification	The verification of presuppositions as a result of certain procedures	1 (H)	33	3 (H-M-L)	100	2 (H-M)	67	2 (H-M)	67	8	67
Fail in Presuppositions											
Repeating the Study**	Redoing or develop studies for reaching desired outcome.	1 (M)	33			1 (L)	33	1 (L)	33	3	25
Methodological Errors	Errors that made in their methods such as inappropriate tools, inadequate search			1 (M)	33	1 (L)	33	1 (M)	33	3	25

that data collection and use of scientific instruments were scientific methods. 42 % of students viewed the use of scientific equipment and collecting data from environment as a method of science. These students were considering calibrating equipment and materials are methods of science mistakenly. These codes were also evident and mentioned as a scientific practice by students with similar explanations. This shows that students have nearly same ideas and explanations for scientific practices and methods and methodological rules of science.

In the branches of science, while most students stated the diversity of methods in science, some basically focused on the pursuit of same methods. Only low RFN level students (25%) advocated the need of commonness on scientific procedures and same certain steps to follow for investigations which showed their naïve understanding for methods of science.

In the presuppositions theme, most students (67%) thought that scientists verify their suppositions and reach scientific knowledge. For example, 8^{th} grade moderate level student expressed that

> Scientist can have suppositions and try to verify their expectations. If they can reach his/her expected result, s/he can prepare a file about them and reach scientific knowledge. S/he can also present his findings and make speeches on his work. [8^{th}-M] (Appendix F, line 5)

This student was aware of scientists' presuppositions as a first step of scientific studies and agreed on confirmability and falsifiability of studies. However, 5^{th} grade level students' agreement on this code were relatively low when compared with other grade levels.

More interestingly, 25% of students justified the methodological errors in scientific studies and attributed this to scientists' errors, inappropriate tools or inadequate investigations. For instance, the 8^{th} grade student who had mentioned on verification of suppositions also contributed to failure in studies due to errors that scientists made. Thus, this means that these students were aware of possible errors in scientific studies which shows their comprehensive views. Besides, students' ideas on methods and methodological rules of science were showing similarity with their explanations in scientific practices category. For example, some students explained trying as an experimentation in scientific practices and methods of science as well. Experiments, observations and doing research have been defined in same context as scientific practice and methods of science. Similarly, some students explained the use of materials as scientific practices and similarly scientific instruments as methods of science. They tried to explain these concepts for explaining both these two categories of science which shows students inability to differentiate some concepts in these categories of science.

From the examination of 5th graders' perception, it has been seen that most students (67%) thought data collection, making observation, experiments, and research as methods of science. For example, when methods of scientists related with COVID 19 were asked to the student, she stated that

> Researcher: What comes to your mind when I say scientific methods? For instance, scientists have a question related with COVID 19 and want to study on that. Which methods they can use?
> Student: They can take people' perspectives on what they experienced during their illness so that scientists can get information about the virus, and they observe these people. They can also make blood test to understand. [5th-H] (Appendix F, line 6)

This points that this student links the data collection and observation with methods of science. Similarly, the moderate level student's explanations were closer to these expressions. However, these ideas were restricted with moderate and high RFN level students. 5th grade low level student had mainly limited understanding and explanations for this category. For instance, she was believing the use of scientific instrument and the one scientific method myth. In brief, 5th graders were considering diverse methods, the importance of verification and some naïve ideas for methods and methodological rules of science.

Moreover, 6th graders perceive methods of science as the use of scientific instrument, performing experiments and observations. For example, direct quotation from low RFN level student is that

> As a method, umm, they can use microscopes for their investigations. They can use magnifying glass, so something like cottony. Soo umm... DNA thing, you put it to capsule and investigate it. They put it to box and extract it. [6th-L] (Appendix F, line 7)

Use of tools, calibration of scientific instruments such as telescopes, microscopes and other materials were considered as methods of science. This shows this student's naïve perspectives and inability to differentiate material practices from experimental tools which were evident in most low RFN level students as well. However, when all 6th graders were examined, they explained the importance of verification, the use of scientific instrument and diversity of methods in science.

Additionally, 7th graders' perspectives on methods of science are discovering, performing experiments, observations, and investigations. They also though diversity of methods and satisfaction of presuppositions connected with this category. For instance, different diverse methods have been exemplified by the moderate RFN level student.

> Researcher: Do you think that scientists who work in different areas can have same or different scientific methods?
> Student: They can make space observations other than experiments. There can be a difference in many cases. There is no obligation that they should always add or mix something.
> Researcher: What can be those differences. Can you give an example?
> Student: Different scientists can use different procedure and reach same result. For instance, one scientist can say that the lighter will brighten, and fire will occur. Another one can say oil lamb will fire. They use different methods and reach same result. [7th-M]

Although the student didn't give scientific example, her logic and structed explanation shows her understanding of diversity of methods. When all 7th grade students' ideas were examined, it was seen that these students' ideas were nearly similar with 6th graders such as verification of studies, diversity of methods and general methods (making observations, performing experiments, etc). However, as it is also seen from 7th grade level students' quotations that their explanations were more diverse and structured.

8th graders, on the other hand, also focused on the diversity of methods and verification of presuppositions. As diversity of methods, students reflected experiments, observations, and various techniques as a way of justification. However, these students explained these codes with connecting other categories of science. For instance, some students attributed experiments with importance of proving which is one of the epistemic-cognitive values of science. For instance, student explained

> At the begging to get certain answer or result from our experiments we need to look for experiments whether it provides proof or not. We can form file from that, or we need to prove the thing that we search for. [8th-M]

This shows that the student' ideas for experiments is constructed around proving of ideas in addition to perceiving as one of methods that is used in science.

With zooming out to general border, it has been examined that all grade level students view performing experiments, observations, data collection and use of scientific instruments as scientific methods. However, the students mainly expressed these methods in scientific practices category as well with using similar definitions and examples. Although the same concepts and terms appeared from the students' ideas, higher grade levels (7^{th} and 8^{th}) had more complicated and structured ideas. On the other hand, the low RFN level (5^{th}, 6^{th}) students had naïve perceptions. Higher grade students were able to provide more clear answers and examples in general such as associating the importance of empirical evidence and verifications with experiments. In addition, it was evident that explanations of low RFN level students were restricted in general.

4.2.1.4. Middle School Students' Perceptions of Scientific Knowledge. The students' perceptions of scientific knowledge have been explored with asking the meaning of scientific knowledge, theories, laws and scientific models, types of scientific knowledge and the development of scientific knowledge. Then from the Table 4.20 appearing dominant codes are models as representation of knowledge, tentative feature of scientific knowledge, governmental rules, and development of knowledge.

Firstly, when students were asked about the types of scientific knowledge none of students was able to explain the coherence of theories-laws-models and these key terms. Most students (42%) have been perceived theories as putting ideas forward. Even further, some students advocated that the theories are unproven assumptions and believed conspiracy theories. On the other hand, the laws were mainly perceived by 58 % of students as governmental rules that statesmen assert on public. None of students except high RFN level 8^{th} grader described law as a scientific law. Thus, most students' explanations couldn't have full richness for definition of theories and laws. They were not able to notice explanatory power of theories and understanding distinction between them which showed their naïve understanding for theories and laws.

Table 4.20. Middle school students' perceptions of scientific knowledge.

		Grade Levels									
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)		Total	
		# (Level)	%	# (Level)	%	# (Level)	%	# (Level)	%	#	%
Definition of SK											
Empirical Base	Knowledge that science has, scientists explain, and necessary for making science	1 (H)	33	2 (H-M)	67			1 (L)	33	4	33
Everyday knowledge**	Published knowledge at new/newspapers and relation of everyday knowledge			1 (L)	33	1 (L)	33			2	17
Theory											
Unproven Suppositions**	Scientists' thoughts and suppositions that are not proven	1 (M)	33			1 (H)	33			2	17
Putting Ideas Forward**	Ideas that scientists propose and put forward			1 (L)	33	1 (M)	33	3 (H-M-L)	100	5	42
Personal theories**	Personal thoughts and believes in social life such as conspiracy theory					1 (L)	33			1	8
Laws											
Governmental Rules**	Rules that government assert, and public must follow	2 (H-M)	67	2 (H-L)	67	2 (M-L)	67	1 (M)	33	7	58
Scientific Rules	Rules that have been proved in science such as law of gravity							1 (H)	33	1	8

Table 4.20. Middle school students' perceptions of scientific knowledge (cont.).

		Grade Levels									
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)		Total	
		# (Level)	%	# (Level)	%	# (Level)	%	# (Level)	%	#	%
Models											
Representation of Knowledge	The knowledge type that scientists represent accurate knowledge	2 (H-M)	67	2 (H-M)	67	1 (M)	33	3 (H-M-L)	100	8	67
Concrete Models	Physical 3D models that students make which are solar system model, sun-earth-moon model, lung model	1 (M)	33	3 (H-M-L)	100	1 (M)	33	1 (L)	33	6	50
Aims of Models											
Proving the truth	Aim of model is to prove and inform people what is true			2 (H-L)	67	1 (M)	33	2 (H-M)	67	5	42
Features of SK											
Tentative	Change of scientific knowledge with new research and investigations	2 (H-L)	67	2 (H-M)	67	2 (H-M)	67	2 (H-M)	67	8	67
Static**	SK is unchanging, static doesn't open to change	1 (M)	33	1 (L)	33	1 (L)	33	1 (L)	33	4	34
Proven	SK should be proven by certain procedures	1 (M)	33			2 (H-M)	67	2 (H-M)	67	5	42
Growth of SK											
Development of Knowledge	As scientists make research and perform experiments, they get new knowledge and develop knowledge with time			3 (H-M-L)	100	2 (H-M)	67	2 (H-M)	67	7	58

The scientific models, on the other hand, have been regarded as representation of knowledge and concrete models by most students. Majority of students (67%) stated that scientific models are the knowledge forms and way of representation of knowledge. However, 50% of students were relating models with physical concrete models that mainly constructed in science lessons. Thus, these students' examples of models were bounded with the solar system, earth-moon-sun, lung model that they have made or familiar in science lessons.

When TLM is evaluated in general, unfortunately none of students were able to consider and explain work of theories, laws, and models for producing scientific knowledge They mainly considered these knowledge forms as unrelated piece of information. Just as importantly, many students reported that scientific knowledge can change or develop as scientists make experiments and research. In this perspective, 7th and 8th graders also associated the tentative nature of science with testing and proving. For example, following quotation shows that

> Student: Scientific knowledge can change. I mean if there is a scientific knowledge, after testing many times, it can change. This knowledge should also be proven to be scientific knowledge. Let's say that I put my idea forward and tested it. Then it became a scientific knowledge. Then, again when I tested, checked and proved, it become a scientific knowledge. After testing many times and when I found different thing, it can change. [7th-M] (Appendix F, line 8)

The student mention not only tentative feature of science but also other characteristics of science such as proving and testing with explicit example. However, the static nature of scientific knowledge has been also justified by 25% of students which were considerably from low RFN level.

With focusing on each grade level students' ideas specifically, it was seen that the majority of 5th graders were viewing the scientific models as a representation of knowledge, theories as unproven suppositions and laws as governmental rules with 67% of students' agreement. In addition, they were also advocating the tentative feature of scientific knowledge. Students were able to explain the changeability of scientific knowledge and naively believe laws as juridical laws. Their limited ideas were on generally theories, laws, and models with perceiving them as separate and unrelated pieces of knowledge. However, their ideas on features of scientific knowledge such as its changeability, empirical base and proven base of scientific knowledge were showing their more structured ideas which were evident among the moderate and high RFN level students' perceptions.

When 6th graders' notions were examined, their agreement on concrete models and the development of scientific knowledge was very high (100%). Moreover, these students view concrete models that they have practiced in science lessons as scientific models rather than their role as conceptual properties and relation with theories and laws. Generally, 6th grade students were also viewing tentative nature and development of scientific knowledge. These students were also believing the governmental rules as scientific laws and theories as putting ideas forward. However, low level 6th grade student naively believes its static nature and everyday knowledge as scientific knowledge.

7th graders' ideas on scientific knowledge were around the proven knowledge for the definition of scientific knowledge, tentative nature of scientific knowledge and its empirical base, development of scientific knowledge and governmental laws. Their ideas were generally structured except their perceptions on scientific laws. Many of naïve ideas such as static nature of scientific knowledge, personal theories and governmental rules had appeared came from low RFN level student.

Lastly, 8th graders' common ideas were around putting ideas forward for theories and knowledge type for scientific models. Non-scientific and unrelated codes didn't appear from 8th graders except for governmental laws and static feature of science which were indeed from low-level students' explanations. For instance, scientific laws were viewed as

> Researcher: What comes to your mind when I say scientific laws?
> Student: For instance, law of gravity. it was a scientific law. It has mathematical equations and pattern.
> Researcher: What about scientific model? What could it be?
> Student: Scientific models are suitable way that fits for scientific representations. Like introducing and presenting something within a scientific way. [8th-H]

While this high RFN level 8th grade student accurately explains laws, models and associated them with making proofs, other students have naïve notions for laws and theories.

It can be said that 8^{th} grade students had more complex and nuancing understanding as in both number of codes and their verbal expressions.

To sum up, middle school students were unable to view work of TLM (Erduran & Dagher, 2014) and how TLM lead the growth of scientific knowledge. Their naïve perceptions of laws and theories also showed their limited understanding of scientific knowledge. However, most students were familiar with the tentative nature of science and growth of scientific knowledge. Most of them were able to view proving and empirical base of scientific knowledge. From the grade level examinations, it can be deduced that as grade level increase students' ideas and explanations become more complex and diverse.

4.2.1.5. Middle School Students' Perceptions of Social Institutional System. In this subsection, middle school students' perceptions of social institutional system of science were reflected with examining the social certification and dissemination of knowledge, professional activities, scientific ethos, social values of science, political power structures, financial system and social organizations and interactions. In these perspectives, each category was summarized briefly in terms of general overview on middle schoolers' perspectives. But the examination for each grade level students' perceptions were achieved at the end of the chapter with interpreting all categories holistically.

4.2.1.5.1. Social Certification and Dissemination.

Students' perceptions for social certification and dissemination category have been obtained with asking students about their ideas on scientists' activities and disseminating and certification of knowledge, etc (see appendix D). From students' answers it was clear from the Table 4.21 that informing public, presenting, and discussing the results and broadcasting were prevalent codes. Students (92%) view that scientists need to inform public

Table 4.21. Students' perceptions of social certification and dissemination.

		Grade Levels									
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)		TOTAL	
		# (Level)	%	# (Level)	%	# (Level)	%	# (Level)	%	#	%
Presenting & Sharing Results	Making presentations, speeches and sharing the results of scientific studies	2 (H-M)	67	2 (H-M)	67	2 (H-M)	67	3 (H-M-L)	100	9	75
Dissemination Channels	Dissemination and sharing studies through TVs, news, newspapers, Internet	2 (H-L)	67	3 (H-M-L)	100	1 (L)	33			6	50
Publishing Articles	Publishing articles, compiling studies and preparing rapport			1 (H)	33	1 (H)	33			2	17
Reviewing Improving Study	Making improvements and reviews in the study	1 (M)	33			2 (M-L)	67	1 (L)	33	4	34
Social Discourse	Scientists discuss their methods, the results of studies, get feedbacks and take advice from their colleagues			1 (H-M)	33	2 (M-H)	67	2 (H-M)	67	5	42
Implications	Real life applications and implications of studies for benefit of public			1 (H)	33	1 (L)	33	2 (H-M)	67	4	34
Informing Public	Scientists inform people about their studies	2 (H-M)	67	3 (H-M-L)	100	3 (H-M-L)	100	3 (H-M-L)	100	11	92
Secrecy of knowledge	Keeping study' results secrete due to competency among scientists or its harm on people			1 (H)	33			2 (H-L)	67	3	25

for the results of their studies. Related with this code, most students (75%) thought that scientists present their results of studies when they conclude their studies or reach important results. Students were thinking the importance of discourse environment such as taking others' ideas, giving advice or help for publishing process.

The dissemination channels, as another dominant code, has taken consideration by 50% of students. Students were thinking that TVs, news, newspapers, or Internet are the ways of communication to disseminate scientific knowledge. It was evident that mainly lower grade students (5th and 6th) consider broadcasting while most high-grade students think social discourse environment for community. Lastly, another remarkable code was the secrecy of knowledge which means that scientists' keeping their results of studies secret. For example, the low RFN level 8th grade student explained that

> Researcher: Do you think that scientists want to inform people and other scientists for their results of studies?
> Student: I don't share my study with other scientists. I keep it to myself.
> Researcher: Why?
> Student: It is my discovery. I develop my study so much that I become a rich when I launch it to the market. And people' love for me increase. They say what a man he was! for me. My reputation rises when I die. [8th-L] (Appendix F, line 9)

While this low-level student views ownership of studies to increase ones' reputation, high level students consider possible harm of studies (e.g., damage of atomic bomb) on people. Erduran and Dagher (2014) emphasized the students' awareness of both positive and negative aspects of dissemination of knowledge. In this regard, it has been seen that high RFN level students have already adopted these negative sides explicitly. In sum, students' ideas revolved around informing people, presenting, and sharing the results and dissemination channels. While most low-level students consider broadcasting and informing people for social certification and dissemination, middle and higher-level students view presenting the results and social discourse mainly. In grade levels it can be said that 5th grade students were able to consider and explain this category in more limited way while 6th,7th and 8th graders had more structured explanations.

4.2.1.5.2. Scientific Ethos

Students' perceptions for scientific ethos have been gained through asking the social relationship between scientists, ethical perspectives in studies, effect of scientists' ethnicity, nationality and gender on studies (appendix D). As it can be inferred from the Table 4.22 universalism, showing respect, intellectual honesty and behaviours of scientists were the most abundant codes among students' answers. The universalism code affirms that evaluation of scientific knowledge is not affected by personal factors. Most students (83%) were thinking that having different religion, ethnicity or thoughts cannot be barrier and factor while scientific studies were evaluated.

In addition to this, some students also believed that personal factors could affect scientific works. For example, 8^{th} grade student explained

> Student: Let's say scientist conduct his/her study and this study can be inappropriate according to his/her religion. For example, for Muslim researchers it can be hard to understand Christians and conducting studies related with them. Then it can affect his/her research negatively. Maybe even s/he can choose to change his study. [8^{th}-H] (Appendix F, line 10)

This student had logical and more structured perspectives while explaining the relationship between personal factors and scientific studies. These diverse and clear examples came mainly from 8^{th} grade students.

In addition, more diverse views such as intellectual honesty and ethical behaviours emerged from 6^{th},7^{th} and 8^{th} graders. These students were able to explain that taking ownership of other scientists' ideas as unethical and academic guilt. Having mutual understanding and no underestimation for other scientists were critical ethical behaviors according to some students.

> For instance, two scientists that work should not yell each other. They should not intimidate their work and scientific knowledge that they reached. They can work together and develop the study. [7^{th}-H] (Appendix F, line 11)

The quotation shows the importance of scientists' personal relationship and behaviours which are ethical principles as stated by students. In sum, when students' grade level was

Table 4.22. Students' perceptions of scientific ethos and social values.

Code	Explanation of Code	Grade Levels 5th Grade (n=3) # (Level)	%	6th Grade (n=3) # (Level)	%	7th Grade (n=3) # (Level)	%	8th Grade (n=3) # (Level)	%	Total #	%
Scientific Ethos											
Showing respect	Scientists have to respect each other	3 (H-M-L)	100	1 (H)	33	1 (M)	33	1 (M)	33	6	50
Universalism	Evaluation of scientific works are not affected by personal factors (ethnicity, religion and gender)	2 (H-M)	67	2 (H-L)	67	3 (H-M-L)	100	1 (M)	100	8	67
Effect of personal factors	Effect of ethnicity, religion and personal thoughts on scientific studies			1 (M)	33			3 (H-M-L)	100	4	33
Intellectual honesty	Dissemination of true information, not cheating or avoidance of plagiarism			2 (H-L)	67	1 (M)	33	2 (H-L)	67	5	42
Behaviours	Attitudes of scientists (not threatening/ underestimating others, being nice and polite)			2 (H-L)	67	1 (H)	33	2 (H-L)	67	5	42
Working ethics	Being careful and successful while working together and performing experiments			1 (M)	33	1 (L)	33	1 (M)	33	3	25
Social Values											
Respect for Environment	Protecting and not harming environment	1 (H)	33	2 (M-L)	67	1 (H)	33	3 (H-M-L)	100	7	58
Freedom	Freedom of scientists for making science	2 (M-H)	67	1 (H)	33	3 (H-M-L)	100	3 (H-M-L)	100	9	75
Unfreedom	Unfreedom of scientists for making science	1 (L)	33	2 (M-L)	67					3	25
Protecting rights	Responsibility for protecting the human rights and subjects			2 (H-L)	67	1 (H)	33	1 (L)	33	4	33
Social utility	Providing benefit for people, environment			2 (H-M)	67			1 (H)	33	3	25

compared, it can be concluded that students from all levels except 5th graders were able to view these ideas. This was also the case for students from different RFN levels. Most students' already established ideas on scientific ethos showed their diversity in conceptualization and nuancing perceptions.

4.2.1.5.3. Social Values

For eliciting students' perceptions of social values category students were asked about scientists' rules and values that scientists need to abide in their studies. According to students' answers, the Table 4.22 showed that the freedom and respect for environment were dominant codes. Students (67%) advocated freedom and independence of scientists' ideas. 7th grade level student also added that scientists should not restrict other person' freedom. For example,

> Scientists should be free while they carry out their studies. However, they cannot restrict other scientists' freedom. Nobody has right to do this. They cannot restrict people' and living beings' freedom. [7th-H]

Most students' ideas were related with not only cultural climate of freedom in science but also respect and care for living beings. More than half of students consider necessity of scientists' respect for environment as well. Additionally, students also believed that the benefits of scientists' work on people such as social utility while others viewed protecting human rights. To sum up, students' perceptions on social values of science revolve around social utility of science, cultural climate of freedom, being respectful for environment.

4.2.1.5.4. Professional Activities

To obtain students' perceptions scientists' professional activities, the relation of conferences with scientists and their professional activities were asked to students (see appendix D). According to students' answers the Table 4.23 has been created. As it was obvious from the table that most common codes were presenting the results and discussing findings, attending conferences and meetings. Students were able to recognize making

Table 4.23. Students' perceptions of professional activities and social organizations and interactions.

		Grade Levels									
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)		Total	
		# (Level)	%	# (Level)	%	# (Level)	%	# (Level)	%	#	%
Professional Activities											
Attending Conferences	Taking other scientists' ideas, comparing and examining their studies	2 (H-M)	67	1 (H)	33	1 (M)	33			4	33
Making Speeches	Expressing thoughts and give information on the study					1 (L)	33	2 (M-L)	67	3	25
Presenting Discussing Results	Reporting study results, presenting them to people	2 (H-M)	33	1 (L)	33	1 (M)	33	1 (M)	33	5	42
Informing People	Transmission of scientific knowledge to public	2 (H-M)	67							2	17
Social Organizations and Institutions											
Universities	Education institutional which scientists carry out their research	1 (M)	33					1 (L)	33	2	17
Laboratories	Places to make experiments, equipped with instruments, include chemicals	1 (H)	33	1 (H)	33	2 (H-M)	67	1 (L)	33	5	42
Outside environment	Conducting studies at outside such as in natural environment, far places from city	1 (H)	33			2 (H-M)	67	1 (H)	33	4	33
Safe Places	Building or room that is safe or protect scientists from dangerous experiments			1 (L)	33	1 (L)	33	1 (M)	33	3	25
Other places	Observatories, space stations, offices, science centres			2 (H-M)	67			1 (L)		3	25

presentations, discussions, attending meetings and conferences, informing people as professional activities. For example, 5th grade moderate level student stated that,

> Student: Scientists can attend conferences and this way they also inform people on their studies and investigations.
> Researcher: What else they can perform as professional activity?
> Student: They can attend meetings and talk on their studies. They explain their desired results and what they found. [5th M] (Appendix F, line 12)

This student provided more than one explanation for professional activities such as attending conferences, informing people, attending meetings, and presenting and discussing the results. It is obvious from the table that most moderate and high-level students were providing more codes for explaining these professional activities.

4.2.1.5.5. Social Organizations and Interactions

For understanding students' perceptions of social organizations and interactions the questions related with places and organizations that scientists conduct their studies have been asked. As it is seen from the Table 4.23, students' answers were diverse such as universities, laboratories, outside environment, safe places, observatories, etc. The most abundant code among students was laboratories which they view this place to make experiments with having scientific equipment. For instance, the high-level 5th grade student explained how scientists interact and work together at laboratories.

Briefly, it was obvious that majority of 5th grade level students view laboratories as scientists' work environment while 8th grade level students' thought spread over various codes. Most students were able to view universities, research centres, observatories, etc as socially organized system where scientists carry out projects.

4.2.1.5.6. Political Power Structures

For understanding students' perceptions of political power structures of science, students were questioned about the relationship between government and science, the effect of politics on scientific works, etc. With the light of students' answers, the most common

Table 4.24. Students' perceptions of political power structures and financial system.

		Grade Levels									
Code	Explanation of Code	5th Grade (n=3)		6th Grade (n=3)		7th Grade (n=3)		8th Grade (n=3)		Total	
		# (Level)	%	# (Level)	%	# (Level)	%	# (Level)	%	#	%
Political Power Structures											
Contributing to Country	Making contributions to country and serving the needs of government					2 (H-L)	67			2	17
Support of Government	Financial support of government and appreciating the work					1 (H)	33	1 (H)	33	2	17
Warn Notice	Government can warn the scientists for obeying the rules and laws					1 (M)	33	2 (H-M)	67	3	25
Approval	Government approves the scientists' studies			1 (H)	33	1 (L)	33	2 (M-L)	67	4	33
Transmission of Knowledge	Transmission of scientists' findings to public by government			2 (M-L)	67	1 (L)	33	1 (H)	33	4	33
Financial System											
Equipment & Materials	Need of technical equipment and materials to conduct studies	2 (M-L)	67	2 (H-L)	67	2 (H-M)	67	1 (H)	33	7	58
Maintaining Studies	Money is needed for long term continuity of studies and necessary to conduct research	1 (H)	33					2 (L-M)	67	3	25
Appropriate Research Area	Need of money for supply of appropriate research environment			1 (H)	33			1 (H)	33	2	17
Earning Money	Scientists need money for maintaining their life					1 (L)	33			1	8

answers were the role of government on approving and transmitting knowledge to public. Most students thought that government approves appropriateness of their studies, warn them for obedience of laws and transmit or inform public for scientific studies. For example, 6^{th} grade high level student stated that

> For example, let's say I invented guilty product. So, it is not beneficial. I discovered the invention that harms the environment. Government doesn't let scientists to share the product. But let's say other scientist invented prosthetic leg for animals. They approve that study. [6^{th}-H]

From this student's perspective approval from government is important for conducting studies. Moreover, even students from moderate and high RFN levels hold view of the manipulation and power of government on science. However, some students also associated the support of government with scientific studies. In overall, emerging codes in this category were most abundant among 7^{th} and 8^{th} graders while most 5^{th} graders couldn't make any association between political power structures and science. Most middle school students were concentrating on control of government on scientific works such as warning, approving the studies and transmitting scientific knowledge.

4.2.1.5.7. Financial Systems

For this category, the questions related with money or financial issues in science were asked to students (Appendix D). In accordance with answers, from the Table 4.24, the most common code was equipment and materials in which students' agreement (58%) was very high. For example, even low-level 5^{th} grade student who was unable to provide explanations in many categories of science agreed for financial need of studies.

Another common code was maintenance of studies. Some students related money or financial issues as long-term need for conducting and maintaining studies. Furthermore, some students thought that research environment needs equipment to be funded. For example, big telescopes require special place which need a support of financial help according to 6^{th} grade high level student. In overall, it can be seen that all grade levels had nearly same understanding for financial systems. Additionally, higher level students' ideas were more diverse and were capable of providing more diverse codes with explaining the reasons of their thoughts.

As a brief summary of social institutional system of science, students' ideas in this category were more diverse compared to other categories. Students had perceptions for main key elements of each subcategory of this category. Their ideas on how knowledge is disseminated and certified, professional activities of scientists, ethical considerations in science, social values, the relationship of finance with science and social institutions were evident among middle schoolers. This also supports the quantitative data that students' mean scores in this category were higher than other categories. However, it was obvious that low level (5^{th} and 6^{th} grade) students' explanations and abundance of these ideas were more limited than 7^{th} and 8^{th} graders.

Middle school students' responses to all categories of science have been interpreted holistically. The qualitative results for aims and values category showed that informing people, serving to humanity, making developments, and satisfying curiosity were the aims of science while for values of science ethical perspectives have been favoured by middle schoolers. However, students from all grade levels concentrated on the social aspects of aims and values of science rather than epistemic-cognitive components. It can be inferred that high RFN level students highlighted ethical, and epistemological aims and values more systematically and comprehensively than low levels. Each grade levels have provided nearly same ideas while explaining this category.

In scientific practices, students view direct observation such as watching, examining while for classification and experimentation they were able to view scientific categorization and testing as scientific practices. Their examples were relying on direct experience from their daily life and limited in making interrelations among other practices. Students from both different grade and RFN levels had these ideas. Although descriptive, predictive, or explanatory power of classification and experimentation have not been evident in any grade level student, they were familiar with the basic concepts of scientific practice category. Moreover, more diverse concepts such as review of studies, identifying study topic which can be associated with the literature review process was advocated by mainly higher grade (7^{th} and 8^{th} grade) level students.

In method and methodological rules category, most students' ideas were relying on performing experiments, making observations, and doing research. Use of instruments such as calibrating equipment, using microscopes, telescopes which are categorized as the material practices (Irzik & Nola, 2011) has been considered as methods of science by most students. In addition, some students were naively believing the use of same methods in different branches of science such as basing scientific studies solely on experiments. High grade level students explained methods as a way of proving ideas which shows their nuancing understanding on how epistemic-cognitive aims and values operate in relation with other categories. Lastly, most students used same concepts and context to explain scientific practices as well.

Scientific knowledge, on the other hand, has been perceived by students as proven knowledge that is necessary for making science. They also advocated the tentative nature of scientific knowledge with believing change of scientific knowledge with new evidence and studies. However, most students were viewing forms of scientific knowledge as discrete piece knowledge and none of them were able to make relationship between them. Theories are scientists' suppositions, thoughts or ideas and laws are government' rules or assertions according to half of students. In brief, students' perceptions of this category of science were more limited with definition and characteristic of scientific knowledge.

When students' ideas in social institutional system were examined, it was found that students' explanations were more diverse and had key elements. Professional activities of scientists, the importance of dissemination, ethical principles, social values, effect of finance issues in science and social institutions were clearly reflected by students. However, they were still limited in how politics direct and affect science. The interrelations among these subcategories have not evident among students. In overall 5th graders' notions were less obvious and structured than other grades.

When the quantitative results were considered in which significant difference between 7th and 6th grade students were found, the qualitative results showed that 7th and 8th grade students' verbal expressions were more structured. Their response rates and explanations for codes were more abundant and more scientifically oriented. In other words, the qualitative results which emerged from students' interviews showed that higher grade students' RFN perceptions were more organized and sophisticated. This result supports the quantitative data in term of differences between 7th and 6th graders in some extend. However, each grade level students' detailed notions and comparison among them were achieved in the next subsection.

4.2.1.6. Different Grade Level Students' RFN Perceptions (The Sub Research Questions of Main Research Question 4). In this part each grade level students' perceptions of RFN with considering students with different RFN levels were presented holistically. Although in the previous section all students' ideas in each category of science were reflected, for holistic perspective and with the aim of answering research questions each grade level students' RFN notions wrapped up and summarized in this part.

In this regard, when 5th grade students' explanations in each category of science were interpreted comprehensively, it has been seen that students' ideas in some categories were more divergent and complicated. Firstly, 5th graders' perceptions of aims and values of science were serving to humanity and informing the people with 67% agreement. Students considered ethics as scientific values which was generally related with social perspectives. While existence of these codes was more abundant for high level student, low level student's ideas were less dominant. For scientific practices most students were perceiving direct observation, investigations, scientific categorization and use of instruments. All 5th grade students were able to view classification as scientific categorization. They were thinking use of materials as experimentation which can be characterized as experimental practices (Gooding *et al.*, 1993) and mainly consider direct observation rather than indirect, obtrusive, etc observation types. Students couldn't interlink these practices with any other epistemic practices. Data collection, performing experiments, making observations were general methods used in science according to students. Manipulative-non manipulative experiments, hypothesis- non hypothesis testing and how evidence from these methods work to yield explanatory consilience has not been provided by any of students. In this category only low-level students were naively believing that the myth of one scientific method such as use of same methods in many disciplines. In forms of scientific knowledge most 5th grade students couldn't elaborate what theories and laws mean. Scientific knowledge is tentative, and models are the representations of scientific knowledge according to the moderate and high-level students. In the social institutional system students were able to link importance of discussion environment and the dissemination of results, relationship among scientists and their professional activities. However, students couldn't associate politics with science and limited in making connections among different categories of science. When students' explanations in each category have been considered, categories especially related with social aspects were more apparent and divergent. However, in epistemic cognitive categories they had more naïve ideas and limited understanding.

When 6th graders' perceptions for each category of science have been examined, for aims and values of science their ideas were based on social dimensions such as ethics, serving to humanity, etc. which were nearly similar with 5th graders. However, their ideas were prominent in epistemic perspectives as well such as proving as aims of science and novelty in scientific studies as values of science. These ideas were mainly from the moderate and high-level students' ideas. As scientific practices in addition to direct observation, investigation, and scientific classification, testing and using diverse sources for research considered by 6th graders more. Surprisingly, the low RFN level student's ideas were comprehensive in this category. The use of scientific instruments and testing have been mentioned as practices of science by students. Like 5th graders 6th grade students mainly considered direct evidence such as performing experiment, making observations, and making investigations as methods of science. The 6th grade students' perceptions for scientific knowledge showed similarity with 5th graders except considering development of scientific knowledge and aims of models. Students were centralizing their ideas on proving and justifying the studies. As scientific models they were viewing physical models that were mainly constructed in science lessons such as solar system, lung, cell model, etc. These students were also restricted for explaining the meaning and coherence of theories, laws and models like other grade level students. None of students mentioned the work of TLM (Erduran & Dagher, 2014) or its role for scientific knowledge. However, students' perspectives on social institutional system were more diversified. They viewed publishing articles, discourse environment, intellectual honesty, working ethics, social utility, effect of politics, etc more comprehensively. In sum, like 5th graders this grade level students were also thinking and explaining these categories with their direct experiences such as classroom experiments, models that they made in science classes. In general overview students' RFN perceptions were still insufficient in many categories of science. The relationship between different categories of science and views that is connected with the holistic image of science were not evident in their notions.

7th graders, on the other hand, had more outstanding ideas that can be inferred from both students' explanations and their response rates. While making life easier and developments were considered as aims of science, empirical evidence and ethics were values of science according to their notions. In addition to social perspectives epistemic cognitive dimensions were also considered by most students. In scientific practices, as a different from other grade level students' ideas, in addition to direct observation and testing, students were also focusing on searching sources, identifying concepts, and reviewing studies generally. Students also related importance of communication of information which is complimentary and interrelated component with epistemic cognitive practices. This notion was also prominent among 8th graders as well. Students' perspectives in method and methodological rules were nearly same with pervious grade levels (5th and 6th) such as performing experiments, making observations, use of instruments, etc. Most 5th, 6th and 7th graders' ideas were around same concepts for methods of science. Forms of scientific knowledge has been still regarded as discrete piece of knowledge and naïve believes were evident among this grade level students as well. Perceiving scientific laws as governmental rules, theories as putting ideas were some of their ideas. However, tentative nature, development of scientific knowledge and the importance of proving scientific knowledge have been considered within broader perspective. In social institutional system as being different from 5th and 6th graders, 7th graders focused on reviewing process, discourse environment and political power structures of science broadly. Their complex perspectives and explanations in this category such as scientific ethos, social values and political power structures were evident. Although other grade level students expressed these notions as well, 7th and 8th graders provided and exemplified their ideas with further details and clear expressions. In this respect, 7th grade students' RFN perceptions were more structured in terms of their justifications, concrete examples and expressions. Although they were still limited in making interrelations between categories, their explanations, and general view on science were more diversified.

Lastly, 8th graders' perceptions in each category of science were examined. For aims of science curiosity, making developments and daily life easier were abundant codes which were similar to 7th graders' notions. Novelty in scientific studies were considered as epistemic value and ethics as social values of science. According to students' ideas investigations, direct observation, testing are scientific practices. This grade level students also emphasized importance of communication of information, reviewing studies and searching from sources as practices which they mentioned these practices with linking other practices such as making observation and experiments. In methods and methodological rules of science students' ideas showed difference. Their ideas were diverse such as testing, data collection, use of instruments, performing experiments, making observations, etc. All 8th grade students were believing diversity of methods rather than the one scientific method. However, similar to other grade level students, 8th graders were also viewing scientific practices and methods and methodological rules of science. In scientific knowledge although the forms of scientific knowledge and its role in scientific explanations have been disregarded by 8th graders, some students' expressions for laws and models were accurate. For instance, only high RFN level student explained scientific laws with exemplifying law of gravity and its function. Students were also thinking that scientific models are the representation of scientific knowledge. Importance of proving and change of scientific knowledge were also emphasized as role and feature of scientific knowledge. Only low RFN level student was believing static nature of scientific knowledge and scientists' unproven assumptions as theories. For social institutional system presenting and sharing results, secrecy of scientific knowledge, effect of personal factors, respect of environment, the relationship between politics and science has been considered generally. In sum when students all expressions for categories of science have been considered, it can be concluded that students tend to explain some categories in more structured way. Although they don't still get to full richness of RFN, their overall ideas were more overarching and comprehensive than lower grade levels (5th and 6th grade).

In sum, each grade level students were prone to express social dimensions in categories of science in broader way. Although their ideas on epistemic cognitive dimensions were evident, these were more limited in lower grade levels (5th and 6th). Students' ideas were inclusive of several naïve ideas of science in viewing methods of science and scientific knowledge. Additionally, it can be said that students explained science and its categories with their direct experiences. For instance, they express the direct observation such as watching, tracing that they are familiar in everyday life, physical models that they made in science classes and judicial laws as scientific laws. While they were viewing categories, they were prone to associate and give examples from daily life. As an overall summary for grade level examinations, it can be concluded that 7th and 8th graders' notions, expressions were more systematic and inclusive for several categories of science than 5th and 6th graders.

The differences between high-moderate and low RFN level students can be briefly summarized. It can be concluded that low RFN level students were limited in elaborating concrete examples and explanations in their verbal expressions. Most naïve ideas came from low RFN level students. On the contrary, high RFN level students' notions were superficial in their responses.

Middle school students perceive science and its categories as separate pieces rather than interrelations among categories and holistic structure that build up image of science. Most students were familiar with basic key terms in categories but the epistemic-cognitive aims and values, how these aims and values linked with other categories, explanatory, predictive dimensions of scientific practices, epistemic- discursive practices, domain specific perspectives in methods and methodological rules, explanatory consilience of methods, the work of TLM and how social system of science work were not evident in any of middle schoolers.

4.2.2. Metacognitive Awareness Interview Results

This section reflects the middle school students' self-reported metacognitive awareness which is based on semi structured interview results and includes main six components of metacognitive awareness. The main research question 5 (What are middle school students' self-reported metacognitive awareness?) has been answered with examining all middle school students' notions related with metacognitive awareness. All subcomponents of metacognitive awareness were represented separately in each subsection. However, to explain students' metacognitive awareness all these subcomponents were interpreted holistically as a whole. At the end of the section each grade level students' metacognitive awareness has been examined detailly with the aim of answering the sub research questions of the main research question 5 (5a, 5b, 5c, 5d).

The meaning that has been emerged from students' excerpts has been analyzed in addition to direct vocabulary. The students' verbal expressions on specific situations in which they were required to imagine and remember, their reports on how they handle problems, what they do and think in certain situations were some of focuses of interviews to

Table 4.25. Main themes of metacognitive awareness and explanations.

Declarative Knowledge	Knowledge about one's skills Knowledge about others' thinking Awareness of ones strengthens and weakness Judging and understanding one's own learning process Activating relevant information to achieve task
Procedural Knowledge	Use of learning strategies Knowing ones' effective strategy that works best for
Conditional Knowledge	Knowing how and when to apply strategies Application of strategies for different learning environments Strategic selection of techniques
Planning	Planning and allocating time Goal setting and sub goaling Use of diverse resources to understand topic and strategic selection among them
Monitoring	Checking comprehension and task performance Periodically self-testing behaviors and actions Estimating the eventual outcome of task Utilization of self-questioning, checking strategies
Evaluation	Revising ones' own goals Reflecting and providing ones' own feedback, Deciding and analyzing options to proceed the task Assessing the performance

elicit students' thoughts and metacognitive actions. This allowed researcher to gain depth investigation of students' ideas. The thematic analysis of data revealed diverse emerging themes which are the declarative, procedural and conditional knowledge, planning, monitoring and evaluation. Each theme and code have been formed within the light of Brown' general framework of metacognition and Sperling *et al*. (2002) study. The emerging themes and explanations of them were provided at the Table 4.25.

Main themes were the declarative, procedural, conditional knowledge, planning, monitoring and evaluation. Explanations of themes were the metacognitive behaviors that students expressed such as their behaviors and actions that was related with the components of metacognitive awareness. Thus, in these aspects main themes and students' expressions have been provided at following part.

4.2.2.1. Students' Knowledge of Cognition: The Declarative Knowledge. One of the overarching terms of metacognitive awareness is the knowledge of cognition which refers to individuals' own knowledge, awareness on their own and others' learning/ thinking process. It encompasses subcomponents of the declarative, procedural and conditional knowledge. The declarative knowledge means learner's own knowledge on what they are learning. Students with the declarative knowledge knows what to learn and know, judge their learning, activate relevant knowledge and aware of their weakness and strengthens. (Pintrich, 2002; Schraw & Dennison, 1994). In this respect, all students were asked about how they know whether they learn the topic or not, what their weakness and strengthens are (see Appendix D). In general view, it can be said that most students judged their understanding according to their test or exam results, teachers' questions, or their ability to summarize the topics. This means if the student provides wrong answers to exam or teachers' questions, they understand that they don't learn the topic. For instance, the high metacognitive awareness level 5th grade student stated that

> For example, when I solve the test related with that topic and have a difficulty, I thought that I don't understand the topic. I study that topic one more time and make review.
> Researcher: Is this way enough for you to decide for understanding of your learning on topic? You don't use any strategy?
> Student: Yes! I don't use any other thing. It is enough for me. [5th- H] (Appendix F, line13)

Rather than viewing various alternatives to check or ensure their understanding such as reflection, elaboration, retaking the task, most students mainly concentrated on external control such as test, results, teachers warn, etc. In overall 75 % of all students were concentrating on external source of control for judging their understanding rather than self-control. On the other hand, the remaining students (25%) stated they don't know whether they understand the topic, or some needed a parental help in this process.

> Researcher: How do you know whether you learn the topic or not?
> Student: ……… (No answer)
> Researcher: So, you can think of your moment. For instance, something will happen that you will say that I couldn't learn the topic. When you said that or what could be?
> Student: Those such things never happened to me.
> Researcher: So, you don't think that you learn something or know what you learn.
> Student: I don't usually think. [7th- L] (Appendix F, line 14)

This student' lack of explanation and limited control in his understanding shows his limited capability in his own learning. Similarly, one of students mentioned his mother' help in his learning and studying process. He stated that her mom decides what to learn and check his actions. His role in this learning process was mainly guided by his parent. It was evident that mainly the low-level students have lack of judgement and non-aware of their learning process and gains. It can be said that these students were less aware of this process and ability to judge their understanding.

Moreover, the realization of ones' own strengthens and weakness is a part of metacognitive knowledge. Metacognitively aware students are the ones who know what their strengthens and weakness are (Pintrich, 2010; Schraw, 1994). When all students were questioned about their strengthens and weakness, it has been seen that half of students couldn't answered and explained what their cognitive strengthens and weakness were. Some students stated working hard to learn topics and focusing easily on the task as their strengthens while their weakness is the difficulty of understanding topics, managing learning process and motivational problems according to their statements. For instance, 6^{th} grade moderate level student expressed that

> Soo…generally, I have lots of questions in math. I have a cousin and ask my questions to him. He comes to our home, and we study together. This really provides benefit to me since I am really bad at math. My scores boosted after his help. Even if I listen lessons carefully, I couldn't achieve at math. I don't understand lessons and mathematical equations. [6^{th}-M]

The student's statements shows that she knows and able to detect what her weakness was and able to state her lack of understanding. She was aware of her difficulty and get external help for this process. Same student also explained her strengthens as understanding and getting high scores from English lessons as a result of her systematic work and careful actions. She was knowing that she can easily grasp English concepts and words. Thus, these notions are the evidence of this student's awareness of her own strengthens and weakness. When most students' notions have been examined in general, these students who were able to express their weakness and strengthens had moderate and high metacognitive awareness level. In overall, 50% of middle schoolers were aware of what their strengthens and weakness are. However, the remaining 50% of students who don't know or couldn't explain them were less metacognitively aware for their self-knowledge than those.

When all students' declarative knowledge has been interpreted in overall, it can be said that students' own knowledge on their learning process, the way of their judgment and limited knowledge in their strengthen and weakness showed their limited in their self-knowledge.

4.2.2.1. Students' Knowledge of Cognition: The Procedural Knowledge. Other complementary construct of metacognitive awareness is the procedural knowledge which is related with ones' knowledge about his/her own strategies, selection of strategies while thinking, problem solving or studying and effectively using them (Butler & Winne, 1995; Jacobs & Paris, 1987). In these respects, all students' learning strategies, their aim of using their strategies, what they do for learning and understanding the concept were questioned (see Appendix D). From interview analyses, it was found that most students mainly know and use effective learning strategies. For instance, 7^{th} grade high level student confidently explained and was sure about how he learns better. He stated that

> For example, I learn better when I listen or hear the voices. And using tables and figures help me to understand the topics better. For instance, I realized that I have difficulty in grasping concept if I try to write or summarize concept. Especially in science I get most benefit from watching videos since they ease my study. For example, I really liked periodic table when I first coincided with it. Since elements and their atomic numbers were ordered at table, it was very easy for me understand elements and their atomic number. [7^{th} H]

It is seen that this student knows which strategy works best for him and how he uses them for understanding concept better. In overall, most students (75%) were able to state their learning strategies and how these strategies effect their learning. These students were aware of which strategies are effective for them, how they could utilize these strategies. Additionally, some students were also using these strategies for resolving their weakness. These students were not only aware of their weakness but also effective in selecting most appropriate strategy for themselves. For instance, 8^{th} grade moderate level student stated her weakness as having anxiety at school and solved this problem with strategy that she developed for herself. She stated that putting goals for herself and her study techniques ease her learning process and reduced her anxiety. It can be said that this student was aware of her weakness and deliberately using these effective strategies such as studying and making regular practices. In overall, it can be interpreted that the students who clearly expressed their learning strategies, benefits for them and how they learn better while using strategies were aware of their study techniques and knowledge on their cognitive actions. These students were corresponding to % 75 of all students. However, there were also students who has never use or don't know what they do while studying and learning the topic. The following quotation shows one of these students who had no strategy or wasn't aware of what he manages while managing task.

> Researcher: Now I want you to describe your learning process at science lessons. For instance, first topic of 7th grade science lessons, solar system and galaxies. What did you do to learn this topic?
> Student: For science, umm… like other lessons. For example, we do activities in the class. I delete them and try to redo. That's all.
> Researcher: Do you use strategies while studying? Or something you do for understanding topics?
> Student: No, I have no technique. I just read.
> Researcher: How do you understand whether you learn the topic or not?
> Student: I don't know. I have never asked myself these kinds of questions.
> Researcher: So, you don't know what you know and learn.
> Student: I read the topics as I said. [7th-L] (Appendix F, line 15)

This low-level student has lack of awareness on his learning process and use of no strategy for lessons. He stated no apparent learning strategy and indication of his utilization of them. His negative answers show his limitedness or disinterest in studying in addition to nonawareness of his actions for learning habits. In general, students who stated having no strategy or studying habit were low level students. The difference between high- and low-level students' quotations were clear that the high-level students used more than one learning strategy while the low-level students were mainly limited in using strategies.

To sum up, most students who effectively and deliberately use learning strategies, has knowledge about their own strategies and selection of strategies while thinking or problem solving, and they were aware of their role in their learning process. These students were more dominant than ones who don't use or know any strategy for accomplishing task in more effective way.

4.2.2.2. Students' Knowledge of Cognition: The Conditional Knowledge. The conditional knowledge is ones' knowledge on the use of declarative and procedural knowledge, knowing when and how to use strategies, selecting best strategy that works best for oneself in learning situations (Flavell, 1981). In this perspective, to understand all students' conditional knowledge, they were asked about when and why they use strategies and questions related with their learning environments. For this process, all students were required to rethink their learning process, when they use their strategies, whether they can learn themselves when needed, their observations to changes in different learning environments were asked to students (see Appendix D). Since this subcomponent is related with both previous components of metacognitive awareness, appearing ideas were somehow similar with them. It has been found that some students were able to realize when to use these strategies and the reason of their selection of these strategies. For instance, 8^{th} grade high level student mentioned that he understands topic better when he repeats the topic before the lesson. He mentioned his strategy of making practices, reading aloud, and rehearsing the knowledge. He was also able to justify and had a specific purpose of using them.

> Researcher: Why do you use these strategies that you mentioned?
> Student: I understand better when I listen and when I repeat and read again. This is my studying style. I tried some strategies before, but I realized these are better for me while learning. Some of my friends understands better when they write. But I don't understand well when I write. Because of this, I read a lot, watch videos, and listen to them. I understand better when I repeat them. [8^{th}-H]

This excerpt shows that student not only uses strategies but also has particular aim on how he uses them. His procedural knowledge such as knowing strategies that work best, his aim and awareness on learning are evidence of how he uses conditional knowledge. Additionally, his knowledge about others such as his friends' strategy shows his monitoring process and awareness about others which relates to declarative knowledge.

Moreover, some students can compensate and articulate their own learning process for their learning environment and try to use alternative strategies unlike to some students who need assistance or no idea on how they learn in this process. For example, 7^{th} grade moderate level student stated that

> I think that the lessons before the COVID were more effective. In online lessons, I know that I have difficulty. However, I try to compensate these negative sights with studying more. For example, before the lessons I definitely read the texts and try to be ready. After the lesson I read the texts one more time and study that topic immediately. Then, I try to solve tests related with that topic and check whether I understand it. [7^{th}-M] (Appendix F, line 16)

This 7^{th} grader has awareness on her difficulty in online lessons and uses alternative strategies to ease this process. This shows that how effective she uses strategy that works best for her and actively retrieves information to check her learning process. However, most students (67%) were able to neither identify their learning process nor overcome their difficulties by themselves. For example, when low level 6^{th} grade was asked about his strategy selection and management of learning, he stated that

> I search from Internet and books. I get support from them. My mom also helps me to learn. For example, she tells me what to study. We generally study together. She asks me questions. If I can answer them, she tells me that I learned it. And in this way, I learn. I do these things. [6th-L]

This student stated that her mother takes decisions and interfere his learning process. It is seen that he needs external help for articulation of his learning process rather than regulating and navigating his own cognitive process. This shows this low-level student's limited capacity and awareness. Moreover, most other low-level students had also similar difficulty in this process. These students were also restricted with using strategies and monitoring them. For instance, 7th grade low level student expressed that he uses reading strategy for understanding topics. He mentioned none of specific strategy and what benefit he gets from his learning strategies. He couldn't elaborate his answers with reasons of his actions. Therefore, it was evident that this low-level student also doesn't use concrete strategy and evaluate the effectiveness and applicability of strategies that works best for him. Unlike to high level students who express their specific reasons, examples and aims for use of their strategies low level students were less capable of managing this process.

In sum, students' expressions showed that students who were ineffective in articulating their own learning process with using limited or no strategy were less metacognitively aware. However, opposite to students with low metacognitive awareness level high level students were aware of their personal role in their learning process, their strategy selection and how to compensate their limited aspects. In overall the number of these students (25%) who were able to articulate this learning process were relatively low. Students (75%) who need assistance and don't know what and when to use these strategies were more dominant as number. In these respects, these showed that most students had very limited capacity in their conditional knowledge.

4.2.2.3. Students' Regulation of Cognition: Planning. Another subcomponent of metacognitive awareness is planning which includes the strategies that has been used for planning, management of resources and goal setting (Lai, 2011; Schraw & Dennison, 1994). Students who are aware of their planning would be able to know and describe their organizing, planning skills, goal settings, manage information and time effectively (Brown, 1987; Schraw & Dennison, 1994). In this scope students were questioned about their planning approach for lessons, their goal setting for their learning and how they use resources for learning (see Appendix D). From students' notions it was interpreted that most students were able to make programs for their learning process, sequence problem solving strategies and put goals while some students had failure in planning. For instance, the high-level 8th grade student expressed the planning of time and studies as his aims for lessons.

> Researcher: Do you make planning for your studying?
> Student: Yes. So, it changes according to my aim. For example, teacher gives homework after lessons. Since I do them right after the lessons, I don't make plan for them. However, for studying topics I make plans. For example, firstly, I devote time for understanding topic and solving tests.
> Researcher: Can you give example? For instance, what was your planning way to understand seasons and climate topic?
> Student: At the begging, I repeated the topic, read the texts and tried to understand what it is. I also look from other sources such as Internet. Then, I solve tests that teacher gave. For this plan, firstly I thought myself. I talked myself and said that did I study well today; did I understand appropriately. If I don't, I give much importance on that and study more [8th-H] (Appendix F, line 17).

This student checks his activities with self-questioning, actively thinking his planning and learning process. He also achieves this as his one of the aims for studying. From his words, it can be interpreted that he makes well-structured time management in terms of knowing and determining what to do beforehand. However, some students mentioned none of these planning skills or strategies which indicated their limited capacity in regulating cognition. For instance, low level 5th grader stated that

> Researcher: Do you study your lessons regularly?
> Student: I don't love studying. I don't study much.
> Researcher: So, do you plan your studying or what you will learning?
> Student: I have no plan. I study generally last day of exam.
> Researcher: Do you put aims for yourself?
> Student: What? What do you mean?
> Researcher: For instance, do you put aims for understanding lessons or studying?
> Student: No. Never! [5th-L]

It can be seen that this student neither uses planning strategies such as putting aims, making plans, etc. nor study periodically. Similar expressions came from students who have no planning strategy and non-aware of h/she learned. These students were generally low-level students.

Furthermore, a mastery goal is another associated construct with metacognitive planning which helps to increase students' metacognitive awareness (Winne & Azevedo, 2014). In this respect, students' goal settings for their learning process were also asked to them. From the analysis, it has been seen that only four students were putting their goals for their learning process. For instance, 8th grade high level student stated his aims for doing homework, solving test, and watching many videos to understand and to be master in science topics. He further explained that he always checks his goals after finishing his task and determine his plans according to his aims. These students who actively checks their goals were prone to regulate and monitor their learning in more systematic way. However, the remaining students couldn't be effective in maintenance of their planning process. For example, low level 8th grade student stated that

> Of course, I put goals. We made one with my mom. I devote two hours of my day for games and 5-6 hours for studying. This plan is not for holidays. I made similar program last year at 7th grade. But I was really got bored. There should be no limitation and borders for me. I want to make those things with my intention. Otherwise, I give up. [8th- L] (Appendix F, line 18)

This student perceived his planning and putting aims as compulsory action. Further, he had difficulty and was unable to maintain this process. His planning was for regulating his daily routine with external help and unable to pursue his program. It can be said that this student failed in regulating his planning strategies. In total, the number of students who were lack of setting their mastery goals (desire to learn and understand new material) were more abundant.

In sum, all students' statements showed that half of students were aware of their planning strategies and actively using them in their daily life according to their statements. However, half of students showed inability to articulate planning of their own learning process.

4.2.2.4. Students' Regulation of Cognition: Monitoring. Monitoring, on the other hand, means to detect and check ones' own way of thinking, regulating cognitive process and self-testing. Persons who monitor their plan of action check their comprehension, task performance, monitor their learning process and question themselves (Baker & Brown, 1984, Schraw & Dennison, 1994). It has complimentary role for helping students to correcting their metacognitive behaviors (Winne & Azevedo, 2014). In this regard, to understand whether students question their thinking way, regulate their behaviors, and test themselves, students were required to imagine and describe their specific moment such as while solving tests, doing homework or trying to understand topic and what they specifically do during and after the task (see Appendix D). In this way students' thoughts on their actions related with their monitoring skills were gathered. As a general overview, it was seen that many students generally utilized alternative and self-questioning strategies. Students were using strategies such as self-questioning, activating related background knowledge, consciously encoding, and reviewing for memory schemes, etc. For instance, 8th grade moderate level student stated that

> For instance, I remembered when I was solving problem related with seasons and climate. I thought the positions of the Earth relative to Sun. For example, I confused at which position summer or winter appears. And I said…. umm... at June Earth is below to Sun. Umm... in December it is above. I thought like that. Then, I coded like this to remember easily. But before coding, I realized my mistake and corrected it with reviewing the topic again. [8th-M] (Appendix F, line19)

This excerpt shows that this student actively monitors her problem-solving process with realizing her fault and developed strategy for herself. She was also questioning herself during task and realize her failure at the end. Similarly, other students (60%) who were also effective in using these techniques were concentrating and aware of their actions. They were able to state their cognitive process such as questioning themselves, forming alternative solutions and the aim of their actions. These were reflecting their monitoring strategies. The direct example can be given from 7th grade student' explanations. For instance, 7th grade student stated that

> When solving problems, I ask myself questions. For example, I say that am I right for this solution and how can I solve this problem. I check whether my answer is true. If I have lots of wrong answers, I look which one was wrong and try to solve them again. I try to understand why I have those mistakes. If I couldn't move on, I ask for help. [7th-H]

This excerpt shows that this student was actively using monitoring strategies such as checking answers and questioning his cognitive process. He asked himself whether he is on the right track and adjusted his pace according to his needs. It can be said that he also used self-evaluation techniques with judging his plan of action. These two quotations were the clues that give us understanding of students' activities connected with monitoring strategies. However, when some students were asked to describe their approach while completing task, they provided irrelevant ideas or none of statements that indicated their monitoring strategies. In the following quote student stated use of no strategies and limited answers to in his monitoring skills

Researcher: I want you think your moment while solving problems. What do you think about your thinking while solving problems? For instance, you faced with very hard problem. What do you do at this moment?
Student: If that problem is hard, I don't think much over it.
Researcher: Do you use specific strategies for solving problems or taking your actions?
Student: Umm. What strategies?
Researcher: For example, do you ask questions yourself while doing something or think alternative solutions of problems?
Student: No, I don't.
Researcher: So, what do you while solving these problems achieving something? Can you explain your internal speech?
Student: I don't think that I have self-talks in my head. [5^{th}-M] (Appendix F, line 20)

Response showed the non-existence of this student's strategic approach in monitoring and regulating cognitive process. This was also evidence for his limited awareness on his actions on tasks and specific situations.

When all students' statements were examined, it has been seen that 5 students (40%) didn't express notions that were related with their monitoring skills or specific strategies. On the other hand, 60% of students were using monitoring strategies such as self-questioning, determining their plan of action, providing feedbacks to themselves.

<u>4.2.2.5. Students' Regulation of Cognition: Evaluation.</u> Another complimentary component of metacognitive awareness is the evaluation which includes persons' critical judgments of their own ideas, revising ones' own goals, assessing own performance, reflecting, and providing own feedback, deciding how to proceed with task (Brown, 1987; Lai, 2011). For understanding students' evaluative actions, students were required to describe their evaluation strategies, imagine their moment at exam, and express their behaviors after finishing their task (see appendix D). In this way, students' strategies and certain behaviors were tried to be inferred from their self-reports. From students' excerpts it was found that 6 students (50%) were able to consistently evaluate their learning process such as their prediction about their performance, realization of their mistake, revising their actions and aims. For example, 6^{th} grade high level student stated that

Student: After the exams, I always look for what I have done and check whether my answers are true or not. I generally predict my score and get that score at the end. For instance, I was expecting to get 90 from science exam and I didn't get lower score than. I know myself and sure from my answers.
Researcher: Okey. Now, can you imagine specific question that you encountered in the exam and trying to solve. How do you solve question, can you explain your internal speech?
Student: For example, I solve the question and if I realize and feel that it is wrong, I recheck and question myself for true answer. I tried to think how well I did. After the exam, if it is wrong, I ask myself why it is wrong and try to understand it. [6^{th}-H]

This student explains his self-evaluation process for what he had achieved and managed with judging and revising his cognitive process with self-evaluation techniques. The student also claimed that he generally gets his expected score from tests which shows his consciousness and confidence of managing his tasks. This high-level student provided more structured explanations with explaining reasons and results of his behaviors. However, students who were lack of self-evaluation couldn't explain their self-evaluative behaviors and stated that they don't generally check or evaluate what they have done. In the following quote 5th grade low level student explains her approach:

> Researcher: Now I want you to think your moment after the exam.
> Student: Okey.
> Researcher: Think that you have just finished your exam Do you evaluate or rethink for what you have done in the exam?
> Student: No, I don't. I don't feel any need to control or rethink them.
> Researcher: Okey, apart from exams, do you evaluate your learning in general? For example, do you check whether you learned the topic or not.
> Student: I don't study in general. Even if I study, I don't do this. Why should I do this? [5th-L] (Appendix F, line 21)

It can be seen that this student doesn't control and reevaluate her tasks as necessary behavior. She stated no apparent strategy or expression that indicated her evaluation process. These expressions showed this student's limited awareness or ability to consider regulative cognitive actions such as rethinking or checking actions, critically evaluating the process accordingly.

When all students' evaluation strategies were examined, it has been seen that the 50% of students were are able to express their self-evaluation process and strategies while remaining half were not aware or adapted no strategy for this process. Students' expressions showed that students who actively used these strategies were generally the high or moderate level students. Correspondingly, the low-level students had more unsophisticated and limited explanations.

To sum up, in broader perspective, all components of metacognitive awareness were interpreted holistically within the aim of answering research question 5 (What are middle school students' self-reported metacognitive awareness?). From the analyses, it was concluded that students more frequently explained and utilized the metacognitive strategies (planning, monitoring and evaluation) when compared with their strategies in the knowledge of cognition (the declarative, procedural and conditional knowledge). Students who utilized and expressed these strategies described their learning process explicitly with using learning strategies effectively, monitoring their thoughts, self-evaluating their progress, and stating their own self strengthens and weakness. Briefly, when students' expressions for each subcomponent of metacognitive awareness was examined, it was found that there were metacognitively aware students according to their descriptions of behaviors or explanations. However, there were also students who were metacognitively non aware of their thinking, regulating their cognitive process with limited or no explanations.

Particularly in metacognitive awareness level comparisons, it was found that the high-level students were more aware in both the metacognitive knowledge (complex cognitive process, awareness of their self-knowledge) and regulation of their cognition (articulation of cognitive strategies, strategically selecting them). High level students' metacognitive knowledge and their regulatory strategies (justification of cognitive process, procrastinating the results of metacognitive strategies) were more hierarchically organized than low level students.

4.2.2.6. The Sub Research Questions of Main Research Question 5 (Different Grade Level Students' Metacognitive Awareness). Within the guidance of sub research question 5, each grade level students' metacognitive awareness was examined. In this respect, for answering the sub research question 5a that is "What are 5th grade middle school students' self-reported metacognitive awareness?", 5th grade students' descriptions have been analyzed, it has been seen that students' approach and expressions were centralizing on some subcomponents of metacognitive awareness. For instance, while students' declarative and conditional knowledge were more limited, their procedural knowledge such as use of learning and thinking strategies were more sophisticated. These students' awareness on their own knowledge, their thinking, strengthens and weakness and methods that work best for them were also restricted in 5th graders. Generally high-level student's expressions in the procedural and declarative knowledge were more complex such as their use of learning strategies and being explicit on their knowledge about themselves. In the regulation of cognition, most students were not facilitating many metacognitive strategies such as goal setting, revisiting their goals, self-questioning, judging and critically thinking their actions or monitoring their behaviors. Even high-level student was not setting aims for learning process and using no apparent planning strategy to manage cognitive actions.

> Researcher: Do you put aims for learning or accomplishing your lessons?
> Student: Not really.
> Researcher: I mean that do you set specific goals for science lessons such as determining what to do and learn?
> Student: No, I don't do this for science lessons. But for Turkish lessons I determine to read at least one book per week. [5th-H]

> Researcher: Do you put aims for learning or accomplishing your lessons?
> Student: I don't remember. Nothing comes to my mind. [5th- M]

> Researcher: Do you put aims for your learning process?
> Student: What? How so?
> Researcher: For instance, do you set goals for learning science topics or arranging your study plan?
> Student: No. Never! [5th- L]

High level student's goal settings were around for daily activities such as reading books or doing homework which were enough for her to make plans and monitor their learning. Other students were not putting goals for their study plans or actions. Their notions were also restricted in other subcomponents of metacognitive awareness. They were not using cognitive strategies such as time management, self-testing, questioning, putting aims and making reflections etc. which were evident in higher grades (7th and 8th grades). In sum, it can be interpreted that 5th graders' metacognitive awareness were restricted within many aspects and components of metacognitive awareness. Students' inconsistency, simple examples and explanations for their metacognitive answers were clues of their limited metacognitive awareness.

When 6th grade students' statements were examined, it was seen that they were able to describe their strategies, selecting best strategy according to their needs and were aware of their knowledge of cognition. But they were limited in viewing their strengthens and weakness and still difficulty in assessing their learning in general. Student with high metacognitive awareness level was able to express complicated and diverse strategies that he uses for monitoring his thinking, planning and evaluation his actions compared to students from other levels. These were evident in their expressions. For instance, different level students' quotations to same question were provided below:

> Student: Science lessons are more based on making research. I mean that the more research we make the more we can learn. For this reason, I try to make much research from Internet or books.

> I read my books and if I don't understand something, I ask my parents or persons who is more knowledgeable than me. For example, in science lesson the human body was complicated and important topic since I have never encountered this topic before. And I consult many different sources to learn this topic. For instance, I watch videos from different websites and searched from the internet. I follow these steps for every science topic. This helps me and ease my studying. [6th-H]

> Student: I generally put goals. For instance, I have long and short-term goals. My general goal is to be successful and always trying best. My short-term goals are generally for learning topics. For instance, I try to complete and ensure what I have learned. For this, I plan to study topic and solve tests. [6th-M]

> Well, I generally put aims for math lessons not science lessons. I say myself to study hard, but I couldn't achieve.
> Researcher: Why do you think that you don't achieve?
> Student: I try to study, but topics are so bored and give up. [6th-L]

These students' deep explanations and exemplifications for their aims such as allocating, facilitating diverse sources and diversity of strategies were evident. In addition, these diverse ideas were also prominent in other components of metacognitive awareness as well.

In brief, 6th grade students (except low level one) were able to explain their metacognitive strategies in the declarative, conditional knowledge, monitoring categories such as checking their answers, actions, revisiting goals, self-questioning techniques, allocation of resources. It can be said that 6th grade level students' explanations were more organized and diversified in many components of metacognitive awareness when compared with 5th graders' notions which were exclusive of these complex metacognitive strategies. For instance, most 6th graders used self-questioning and evaluation strategies, organizational skills and were aware of their own knowledge.

7th graders, on the other hand, were using metacognitive strategies such as thinking about their understanding, setting, and revising goals, planning actions, allocating diverse resources, considering alternative strategies, using self-questioning techniques, and judging their idea or knowledge and regulation of cognition. For instance, both high and moderate level students were considering self-questioning and strategy selection for solving and understanding problems. These students' answers to same questions are

> Sometimes, I found myself with asking questions during managing task. For instance, I ask myself questions like am I right, how I can do this problem, how we were solving these kind problems. Asking these kinds of questions helped me to track what I have done. If I couldn't'

find answers for them, I review our book and ask my parents. If they don't know, I search from Internet. [7th-H]

While solving problems, I try to think possible ways to solve that problem. Since If I solve that immediately without thinking, it can be wrong. I say to myself that lets try with another way. Then I test whether the same result appear or not. If different result appears, I solve it one more time to be sure about my solution. I make this my daily life as well. I generally check and apply another strategy [7th-M]

Student: I use no strategy.
Researcher: I mean can you describe your internal speech while solving problems?
Student: I read question and circle the answer. That's all.
Researcher: Do you ask yourself or discuss answer to questions by yourself?
Student: No. I don't. [7th-L]

It can be seen that these moderate and high-level students not only effectively use these strategies but also realized their self-knowledge, monitor their thinking, evaluate their learning process. The low-level student has not revealed these strategies and notions related with metacognitive behaviors. He was not able to neither explain nor know his metacognitive skills. His awareness was rather limited when compared with the moderate and high-level students.

In sum, 7th grade students mainly have metacognitive knowledge and use metacognitive strategies, but these students were mainly the moderate and high-level students. When compared with other grade levels, 7th grade level students' metacognitive behaviors and expressions were not apparently different from 6th graders. The expressions in monitoring, planning and knowledge of their cognition were evident and emphasized in both 6th and 7th graders.

Lastly, 8th graders' explanations were centralizing around the learning strategies, management of time, planning strategies, allocation of resources, use of alternative strategies, self-evaluation such as criticizing their performance. It can be said that this grade level students were more aware of their own knowledge and actions, put particular aims for their tasks and regulate their tasks effectively. For instance, both low, moderate and high-level students were using the monitoring and planning strategies in their tasks. The following excerpts are from the students' descriptions when they were questioned about their problem-solving strategies:

> I check my goals for my studies. I start to think myself. For instance, did I study well today, did I understand todays' topic. After checking this, if I don't understand, I try to give importance and focus on that topic more [8th- H]

> While solving science problems if my answer is wrong, I ask myself why it is wrong and what can be the reason of this. Then, to compensate my deficiency I make my practices again, try to understand it and take my notes [8th-M]

> For instance, I have certain task to do. I said myself to finish at the end of the two hours and complete it, I mean I plan like that. However, if I couldn't complete it, I started think why I couldn't finish it and why it took too much time [8th-L]

It can be interpreted that these students' structured examples from their daily life applications shows their awareness in their monitoring skills, evaluation strategies and realizing their limited aspects. They were also able to describe their learning process with describing their specific actions. On the contrary, in other components of metacognitive awareness such as their metacognitive knowledge some students had difficulty in describing their cognitive strengthens and weakness, learning process and understanding.

In overall, when all grade level students were compared, it was seen 6th,7th and 8th grade level students were more metacognitively aware than 5th graders. These students' descriptions of their metacognitive actions were more organized, systematic, and structured. For instance, 8th graders provided concrete examples such as their plans, specific aims, the way that use metacognitive strategies and how their actions and metacognitive knowledge shaped their learning process. It was evident that 5th grade students' explanations were more limited and less structured compared to other grade levels.

Another tangible result that appears from metacognitive awareness interviews is differences between high, moderate, and low metacognitive awareness level students. The gap between high- and low-level students' expressions were huge in terms of their metacognitive actions, strategies, and knowledge. Low-level students' metacognitive awareness was limited in many dimensions while high level students' metacognitive tasks were more based on using metacognitive techniques. High grade level students were more aware of their self-knowledge, tasks that they need to achieve and critic in strategy selection. This comparison was obvious in each grade level students who have high and low metacognitive awareness level.

Moreover, the convergence of the quantitative and qualitative results provided a more complete perspective for students' metacognitive awareness. In the students' metacognitive awareness test results, 5^{th} graders' mean score was corresponding to 85% while 6^{th}-7^{th} and 8^{th} graders' 80%. When this result was compared with students' metacognitive awareness results in the qualitative data, students' metacognitive awareness in verbal reports were contradicted with their results in test scores. Students' verbal expressions were more limited and restricted of subcomponents of metacognitive awareness. However, in general, middle school students had still nuancing perspectives in specific thinking strategies, how, when they use them or aware of this process.

To sum up, the results of metacognitive awareness interviews showed that middle school students were metacognitively aware in some extend and students' regulatory activities, use of metacognitive skills and strategies showed difference between different grade levels. The grade level examinations showed that 6^{th}, 7^{th}, and 8^{th} graders' metacognitive awareness levels were higher than 5^{th} graders. Their metacognitive actions, strategies were more organized and structured than lower grades. When this result was compared with the quantitative result that shows no significance difference between 6^{th}, 7^{th}, and 8^{th} graders, it can be said that the qualitative results somehow supported this result. Students from each 6^{th}, 7^{th} and 8^{th} grade levels explained their metacognitive actions, skills, and their thinking process but 8^{th} graders' examples were more diverse and structured compared to other grade levels.

4.2.3. The Relationship Between Students' RFN Understanding and Metacognitive Awareness

In this part the relationship between students' understanding of "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) and their metacognitive awareness was examined. This was achieved through examining the qualitative data and interpreting its convergence with the quantitative data. Firstly, at the first subsection (4.2.3.1) the qualitative relationship between students' RFN understanding and their metacognitive awareness was explained. For achieving this, students' notions in RFN were investigated in terms of inclusion of metacognitive actions or descriptions. For example, whether students' RFN expressions include metacognitive skills, techniques or descriptions were explored.

Moreover, the students' levels have been matched in terms of combability of answers in these constructs. Whether the high/low RFN level students correspond to high/low metacognitive awareness level at their expressions in metacognitive awareness interviews were examined. This detailed procedure has been explained at the following subsection. At the second section (4.2.3.2), for examining the convergence of qualitative and quantitative results, both results that has been found in quantitative and qualitative data have been interpreted holistically.

4.2.3.1. Qualitative Relationship Between Students' RFN Understanding and Their Metacognitive Awareness. In this part, all students' answers to RFN interviews were interpreted in terms of the emergence and existence of metacognitive skills. Firstly, metacognitive aspects that have been mentioned so far (the declarative, procedural, conditional knowledge, monitoring, planning, evaluation) were examined in students' RFN expressions. Afterwards, the same level students' answers to RFN and metacognitive awareness questions have been compared. In other words, it was considered whether students who use metacognitive skills for their learning process or in their actions were able to explain science and its categories. If students who use metacognitive skills and actions have high RFN and metacognitive awareness level, and if most students' answers were aligned in this way, there could be a possibility of relationship between these concepts. This has been performed for each high, moderate, and low-level students' expressions.

As a first point, when students' answers for science and its categories were investigated in terms of existence of their metacognitive skills or awareness of metacognitive thinking, it has been seen that some metacognitive clues exist at high and some moderate level students' expressions. The key metacognitive skills such as monitoring learning process, use of learning strategies and self-questioning were evident in students' RFN answers. For instance, 5th grade high level student expressed the effect of her observation experience on learning the science topic. She explained her experience and how that experience helped her learning process. Her notions include some traces of metacognitive actions.

> My uncle had a telescope. We observed the stars, moon and the phases of moon over one month. I see the crescent, full moon and each phase of moon with observing over one month. Every week moon transitioned new phase and I took notes. While we were observing, I was thinking why we see moon in different shapes and what has been causing this to happen. I asked this to my teacher. Before learning this at class I had reinforced the topic, and this provide benefit for

> me to learn the phases of moon easily. For instance, I know the name of the phases and the time interval between them since I have already observed it. [5th-H-RFN] (Appendix F, line 22)

While this student was making observation, she was asking questions and try to make scientific reasoning for what she observed. She was also aware that this activity eases her learning process. The same student's answer to metacognitive awareness was also aligned and parallel with complex metacognitive actions. For instance, when she was questioned about her monitoring strategy, it has been seen that she was utilizing many strategies. For instance,

> I sometimes think in my head. For instance, when I come up with hard question, I start to think how I can formulate this and what I will going to say. I ask these kinds of questions. I can say that I am person who always asks questions and think internally. [5th-H-MAI]

This student's expression in metacognitive awareness was also pointing how she process her thinking. It was evident that she was using self-questioning techniques while making observations and in metacognitive actions. Her notions were in the alignment of her approach in understanding science and supportive for her utilization of skills. This means that the student with high metacognitive awareness level can use these metacognitive skills while trying to understand science and its categories as well. When other grade level students' notions were examined, it was seen that some students mention the learning strategies that they used for learning science. For example, high level 6th grade student explained his responsibilities and learning strategies for understanding science.

> Student: Making lots of research is important for me to understand science. We learned the human body this year and it was not easy topic. For understanding this topic, I studied hard. I have to make research not only for learning topics but also knowing more. The things that we learn is not all the science. Science is more than what we learn at lessons. Even books emphasize this. It says to make research and EBA suggest making research. So, for these reasons I make lots of research.
> Researcher: What do you mean by research? Can you give example?
> Student: For example, we were required to make a search for our last homework. Teacher asked the difference between human and animals' circulatory system. But I made further research on animals' blood pumping and read science magazine and article on that. For instance, the heart of giraffe beats 75 times and plump 180-liter blood per minute. [6th-H-RFN] (Appendix, line 23).

This student's expression and his awareness on importance of making research and passion for learning shows his advanced approach to science. He further elaborated his ideas with example of his search for science lesson. The use of different sources and his awareness on what is required to learn are some of metacognitive clues that he utilized for learning science. Although direct focus in his expressions were not on RFN, his activities and investigations in science points his elaborated key activities that can be associated with RFN. For instance, he tried to reach scientific knowledge through careful examinations and making investigations like scientists. When same student's answers in metacognitive awareness questions were examined, his explanations were still diverse. This student elaborated same example as aims for learning science in this component of metacognitive awareness as well.

> Student: Science lessons are more based on making research. I mean that the more research we make the more we can learn. For this reason, I try to make much research from Internet or books. I read my books and if I don't understand something, I ask my parents or persons who is more knowledgeable than me. For example, in science lesson the human body was complicated and important topic since I have never encountered this topic before. And I consult many different sources to learn this topic. For instance, I watch videos from different websites and searched from the internet. I read the studies related with this topic. [6th-H-MAI] (Appendix F, line 24)

This student expressed his learning strategies and allocation of resources for learning the science topic. It is seen that he developed systematic and strategy for himself. He was aware of how to cope with complicated topics and consult alternative ways. From these two excerpts it has been seen that students' notions in both RFN and metacognitive awareness interviews were parallel. In addition, these students were using some metacognitive strategies while trying to understand science and its categories. When other high RFN level students' notions were examined, these parallel explanations were also evident in their expressions as well. Students from high RFN level were indicating scientists' cognitive process and their presuppositions in studies with including some metacognitive clues in his expressions.

> Student: Scientists' presuppositions can be verified as a result of their studies. So, their suppositions can be same or different with results. But their presuppositions may not satisfy the results since their thoughts cannot aligned with the results. Every scientist' the way of thinking and methods cannot be same. For instance, I can approach differently, and my suppositions can be different normally. But sometimes they can reach their expectations so their thoughts and suppositions can be satisfied as well. It depends on the people' thinking way and knowing. They need to be careful about thoughts with knowing and being conscious on what they do. In sum, presuppositions can be satisfied or dissatisfied. [7th-H-RFN] (Appendix F, line 25)

This student mentioned the presuppositions of scientists and their differences in thinking. Due to differences in persons' thinking way some presuppositions can be satisfied and some not according to this high RFN level student. It can be said that he can link metacognitive thinking and assumption checks in scientific studies. He was aware of others' thinking way and outcomes of their thinking. Moreover, the same student's metacognitive awareness was also structured and showing metacognitive processes. His awareness on his own thinking way and learning was reported by him.

> I can understand whether I learn the topic or not… I ask questions to myself and try to solve problems by myself. For instance, I try to summarize the things that I learned to someone. If I can't manage this, I thought that I couldn't understand the topic and need to feel for studying hard. [7th-H-MAI] (Appendix F, line 26)

This student's metacognitive awareness interview also showed his strategy and articulation of this metacognitive process. He was checking and monitoring his actions, using learning strategies and ensuring learning process. Student was aware of metacognitive process in scientists' presuppositions such as their actions. Thus, student had sophisticated and advanced ideas for both RFN and metacognitive awareness. This means that the high-level student may have metacognitive skills and actions while engaging or thinking science and its categories. This can be an indicator or show possibility of the relationship between these two constructs. In addition, similarly related notions for these constructs can be given from other students' answers. Some students were aware of importance of thinking and evaluating process before disseminating the results. For instance, when 6th grade high level student explained the dissemination of the results, he answered that

> Let's say I have new invention or found something. But I don't share my study with people since it will not provide benefit to people. If it is useful and beneficial for humans, I share it. For instance, atomic bomb was firstly thought as logical and beneficial. But, after using it, because of its possible harm, they understand that it is very dangerous and not beneficial. So, scientist need to carefully evaluate and criticize his invention after thinking carefully. After knowing the possible effects of their studies, they need to be disseminated. [6th-H-RFN]

The student mentions the importance of scientists' evaluation of their own results and critical thinking process. These are the main steps of one's own thinking process and indicators of awareness in cognitive procedures of others. Although student doesn't directly perform these behaviours, he mentions other people's possible reactions in that possible scenario. It can be said that he was aware of scientists' self-evaluation and importance of critical thinking process. Moreover, other high-level student also mentioned the importance of self-evaluation process and scientists' planning strategies such as being coordinated, planned for every possible result. 8th grade high level student explained the importance of planning in scientific studies such as coordinating, timing, planning the experiments. In addition to high level students' notions, moderate level students' ideas in science and its categories were including some notions related with metacognitive awareness. For instance, in the following quotation student explains the effect of personal factors while carrying out scientific studies which was asked within the scope of scientific ethos category.

> Everyone has different subjective judgment. Everyone has different thoughts and scientific studies, and these can be affected because of differences in personal characteristics. So, scientists with different characteristics can have different thoughts even on same issue. This happens in my life as well. I could defend different thoughts as oppose to my friends' ideas. Different kind of scientists can have different thoughts. So personal characteristics have effect on scientific works. [8^{th}-M-RFN] (Appendix F, line 27)

This moderate level student was also aware of differences in others and their own thinking process. Then she related this difference with effect of personal thoughts on scientific studies. This student was also aware that scientific studies are subject to rational criteria which she mentioned in her previous notions. This means that evaluation criteria of scientific studies should not be under the scrutiny of personal factors, but the ongoing process can be affected by these factors according to her. Since this student was aware of others' thinking process and judgment, her responses to questions related with knowledge of cognition was examined.

> Let me explain how I learn the topics. When I try to learn something such as body cells, I tried to understand what happens at body cells. Firstly, I tried to figure out what they are. I visualized them in my head and memorized since some of them was happening in body cells and occurring. I asked to teacher' examples of body cells. After teacher' examples, I also searched it and look examples. But I was not knowing mutation at these cells. Afterwards, I thought the structure of nucleotides, change in their place or something from external. I looked for examples again and thought how they was occurring. In reality it was also like thing that I thought. I took notes about them for not forgetting. [8^{th}-M-MAI] (Appendix F, line 28)

The student was expressing her learning process and aware of what she was thinking. She was mentioning what happens in her mind confidently. Thus, this moderate level student who had high RFN level had also structured explanations in metacognitive awareness interviews. In this regard, high-level students generally explained and elaborated their perceptions of science and its categories with having awareness and consciousness on main concepts or utilizing metacognitive techniques. They were prone to explain more diversified and sophisticated notions with either reflecting metacognitive process or actions in explaining science and its categories. These metacognitive RFN notions were appearing especially in epistemic and cognitive categories of science. However, low level students were unable in detailed and structured explanations with no clues of metacognitive actions in their explanations of science and its categories. For instance, questions that has been asked to 7th grade high level student has been directed to 7th grade low level student as well. He answered that

> Researcher: Now I want you to describe your learning process at science lessons. For instance, first topic of 7th grade science lessons, solar system and galaxies. What did you do to learn this topic?
> Student: For science, umm… like other lessons. For example, we do activities in the class. I delete them and try to redo. That's all.
> Researcher: Do you use strategies while studying? Or something you do for understanding topics?
> Student: No, I have no technique. I just read.
> Researcher: How do you understand whether you learn the topic or not?
> Student: I don't know. I have never asked myself these kinds of questions.
> Researcher: So, you don't know what you know and learn.
> Student: I read the topics as I said. [7th-L-MAI]

This low-level student answered his science learning process in more limited way regarding limited reflection on his learning strategies, awareness of what need to be learned, or achieved. The student was not checking or monitoring any of learning situations. However, the high-level student was explaining importance of making research to learn topics, watching videos, management of his learning process. In addition, this low student's explanations in categories of science were including none of metacognitive actions or clues and rather his naïve believes were more evident. For instance,

> Researcher: Do you think that scientific knowledge can change?
> Student: No. It doesn't change.
> Researcher: Why, so?
> Student: I don't think that it has a relation, so it doesn't change.
> Researcher: Can you explain more about what you are thinking?
> Student: In scientific studies knowledge tries to be revealed. So, it is what scientists first find. [7th-L-RFN]

This student neither uses metacognitive skills nor explain superficial ideas in scientific knowledge category. His expressions in metacognitive awareness were also more limited in reflecting, monitoring, and managing the learning process. When other low level students' notions were considered, their responses were matching and aligned with limited expressions in both RFN and metacognitive awareness. Like this low-level student their RFN notions were including the none of metacognitive strategies. Compared to low level students high level students were more proficient in both metacognitive awareness and perceptions of science/its categories. They were also using more metacognitive skills and their descriptions include clues of advanced metacognitive process. Most high-level students' expressions in RFN were in the alignment and matching with these clues. In connection with this, for instance, low-level 8th grade student's statements for science and its categories include none of indicators of metacognitive actions. His descriptions were bounded with basic ideas. For example, when he was asked about the dissemination of the results, he stated that

> I don't share my study with other scientists. I keep it to myself.
> Researcher: Why?
> Student: It is my discovery. I develop my study so much that I become a rich when I launch it to the market. And people' love for me increase. They say what a man he was for me. My reputation rises when I die. [8th-L-RFN]

Although this student's RFN explanations were more divergent when compared to other low-level students, he had still some restricted ideas in categories of science. Student pointed keeping the results of studies secret because of scientists' competency and his expression for importance of dissemination of knowledge was far from reaching full richness of this category of science. When his metacognitive awareness' notions were examined, student was expressing techniques that he failed to achieve. He lacked motivation, fail in satisfying goals, and had absence of planning strategies. Following two quotations show his difficulty in cognitive activities.

> I am weak person. I don't understand in lessons, and I am unwilling generally. If I don't understand something, I become more unwilling. If I couldn't do anything, I become downhearted. I don't want to do anything. Sometimes my mom forces me to study. But I pretend like I studied. [8th-L-MAI]

> Researcher: Can you explain the last planning that you have made for your study?
> Student: The last one…um… it is all in my head. I made this plan in my head. For instance, I say that I will study this part within two hours today. But I couldn't realize how time pass. I generally run out of time. [8th-L-MAI]

From this student's explanations in metacognitive awareness interview, it can be interpreted that he was limited in motivational believes, planning activities and his cognitive process. These two quotations were parallel in terms of student's motivational loss and difficulty in cognitive actions. As he mentioned he couldn't manage his time effectively and fail to achieve in completing tasks. Even though these are some examples of his answers to some components of science, his general approach was in this way. When his answers in RFN interviews were considered, his motivational believes were evident while explaining social certification and dissemination category as well. For instance, his motivation was earning money and reputation, if he would become a scientist. Thus, his notions in these constructs were showing some similarities and were matching in terms of limitedness and poor explanations in both RFN and metacognitive awareness. Another low-level student's (5th grade) responses in RFN and metacognitive awareness can be also evident for this.

Researcher: Do you think that government and politics can affect the scientists' work?
Student: No. It does not. Why would it be?
Researcher: So, do you think that financial issues such as are related with science?
Student: For materials, and things, yes.
Researcher: At which places scientists conduct their studies?
Student: umm… its name is on my mind...
Researcher: You can try to describe those places.
Student: ….. (No answer). [5th-L-RFN] (Appendix F, line 29)

Student's expressions for political power structures, financial system and social organizations and institutions showed her low-level perception in these categories. Her other notions in RFN categories were also restrictive and far from deep explanations. When her metacognitive awareness' answers were depicted, it was seen that student was not aware of what she was thinking and using no regulatory activities.

Researcher: Now I want you to think your moment after the exam. Think that you have just finished your exam. (After 30 seconds)
Student: Okey
Researcher: Do you evaluate or rethink for what you have done in the exam?
Student: No, I don't. I don't feel any need to control or rethink them.
Researcher: Okey, apart from exams, do you evaluate your learning in general? For example, do you check whether you learned the topic or not.
Student: Umm…. I am not sure. I don't study generally. Even if I study, I don't do this. Why should I do? [5th-L-MAI] (Appendix F, line 30)

This low-level student's expressions showed that she generally doesn't control and reevaluate her tasks. She lacked rethinking or checking actions, critically evaluating the process. Thus, this student's statements were also indicating connections in terms of students' restrictive perceptions in both constructs. When low level students' responses were interpreted comprehensively, it can be concluded that they were limitedly aware or successful in cognitive procedures. Their reports were including no apparent clues of metacognitive skills or actions in understanding science and its categories according to their reports. Thus, these students were corresponding low level in both RFN understanding and metacognitive awareness. In addition to low level students, 5th grade moderate level student was also showing the limited notions in his RFN and metacognitive awareness answers in some extent. Student's expressions in many categories of science and metacognitive awareness were limited compared to high level students. Thus, it has been seen that high level students were using some metacognitive skills and actions while trying to understand science and its categories. Students with high metacognitive awareness level who were using metacognitive strategies mainly had sophisticated RFN perceptions as well. Low level students were limited in explaining science and its categories with indicating no metacognitive clues. Most different level students' answers were aligned in this way.

4.2.3.2. The Convergence of Qualitative and Quantitative Results for The Examination of Relationship. The inclusion and utilization of metacognitive strategies have auxiliary role for enhancing students' NOS understanding. Metacognitive skills enhance scientific reasoning, thinking with helping advancement in NOS ideas (Peters-Burton & Burton, 2020). The relationship between these constructs has crucial role for NOS instruction and students' learning process. With this logic, in this part the emergence of qualitive and quantitative results for the relationship between students' RFN understanding and their metacognitive awareness was investigated.

The relationship between these two constructs has been investigated with quantitative perspective including the statistical tests and qualitative perspective through interviews. With reminding the quantitative results, there was a significant positive relationship between middle school students' (6^{th},7^{th},8^{th} grade) RFN understanding and their metacognitive awareness. This relationship was evident for each grade level students as well. Although the degree of relationship was small, the result pointed the significant relationship. However, to support these results the relationship has been investigated in qualitative perspective as well. Some students' explanations for science and its categories were including some metacognitive clues such as awareness of their own or others' thinking, monitoring, planning, evaluation strategies. For instance, while one student stated the observation and her activities, she was also using learning strategies and self-questioning techniques with monitoring her learning process. Some students mention the differences in scientists' thoughts such as having different assumptions in studies and scientists' personal characteristics. Students' notions were giving clues about their metacognitive actions or thoughts in science and its categories which indicated the possibility of relationship. Although it cannot be directly concluded that their answers directly resulted from their metacognitive skills or actions, these were only indicators of possibility of relationships.

In addition, many students who were using these metacognitive skills in RFN were corresponding to high metacognitive awareness level as well. For instance, it was found that the student who had high metacognitive awareness level was corresponding to high RFN level and vice versa. This matching allowed researcher to consolidate the quantitative results as well. Since the students' levels have been determined with the light of their scores in scale, there was an opportunity to evaluate their qualitative notions and match their consistency in both RFN and metacognitive awareness interviews as well. When examination of each level (low-moderate-high) students' responses and match of their answers in these two interviews were interpreted with the quantitative results, it can be concluded that students who had low metacognitive awareness tend to have low RFN understanding as well. This was also the case for students with high metacognitive awareness who also tend to have high RFN understanding. Since most students' answers were consistent and aligned like this way, this could point the possible relationship.

In sum, while students with high metacognitive awareness level tended to view science in more comprehensive way, students with low metacognitive awareness level were prone to view science and its categories in more limited way. Although the qualitative results didn't directly give statistical inference, these results indicated that metacognitive awareness can be related construct with RFN. When these results have been considered in broader perspective, it has been inferred that the qualitative data supports the quantitative statistical results. Convergence of them were pointing the possible relationship between metacognitive awareness and RFN understanding.

4.3. Summary of the Results

The relationship between middle school students' RFN understanding, and their metacognitive awareness was investigated by administrating the "RFN Student Questionnaire" and "The Metacognitive Awareness Inventory for Children" with including semi structured interviews for RFN and metacognitive awareness. Along this, students' RFN understanding, and their metacognitive awareness have investigated separately through the quantitative and qualitative results. According to the quantitative and qualitative data results RFN understanding and metacognitive awareness were found as related constructs. The quantitative results showed that there was a significant positive relationship between students' RFN understanding and metacognitive awareness. This relationship was significant and positive for 5th, 6th,7th and 8th grade level students separately. The degree of relationship was increasing through grade levels. In addition, predictive ability of metacognitive awareness on RFN understanding was examined and founded that metacognitive awareness had predictive ability on RFN understanding but change in 11% of RFN understanding could be explained by the metacognitive awareness. The qualitative results for examining this relationship have been revealed that students who had higher metacognitive awareness level had also diversified and structured notions in RFN as well. Thus, students who had higher metacognitive awareness level were prone to have higher RFN understanding. Metacognitive actions and skills were evident in high level students' RFN perceptions and complexity of their answers were matching in both these interviews. These students were explaining the RFN concepts with giving examples from their learning strategies and their learning process. Some were aware of differences their own and others' scientific thinking process. Likewise, students with low level metacognitive awareness had limited and restrictive explanations in RFN interviews. Their RFN ideas included no clues of metacognitive activities and skills. In brief, the relationship between students' RFN understanding and metacognitive awareness were evident in both quantitative and qualitative results. Although the qualitative results didn't provide statistical data, it revealed and supported the existence of relationship from students' explanations.

Besides the relationship, middle school students RFN understanding, and its five categories were investigated through "RFN Student Questionnaire" and RFN based interviews. The descriptive analysis revealed that 7th and 8th graders' mean scores were higher than 5th and 6th graders' scores. When middle school students' understanding of each category of science have been investigated, it was found that students got higher scores from the social institutional system, scientific practices, scientific knowledge, methods and methodological rules and aims and values respectively. From the inferential statistics it was found that there was a statistically significant difference between 5th, 6th, 7th and 8th grade students in terms of their total RFN scores. The analysis revealed that 7th grade students' RFN understanding was higher than 6th graders. In aims and values and scientific practices categories there was no statistically significant difference between 5th, 6th, 7th and 8th grade students. In methods and methodological rules category the significance difference was between 8th and 5th graders in addition the difference between 8th and 6th graders. 8th graders had higher score in methods and methodological rules category than 5th and 6th graders. In scientific knowledge there was significant difference between 8th and 5th grader in which 8th graders had higher scores in this category. There was also significant difference between 7th and 5th graders which 7th graders' scores were dominant. Lastly in the social institutional system the significance difference was between 7th and 6th graders. 7th graders understanding in social institutional system was higher than 6th graders.

Middle school students' perceptions of RFN and its categories have been examined with respect to their grade and RFN level. In aims and values middle school students were considering the social aspects dominantly such as informing people, serving to humanity, ethics, but 6th,7th and 8th graders also emphasized the epistemic-cognitive aims and values as well. However, all grade level students' ideas were nearly similar especially focusing on practical and application-based aims of science.

In scientific practices category most students were familiar with concepts such as observation, use of materials, scientific classification and consider them as scientific practices but they were restrictive in explaining their role and contribution to scientific knowledge. Higher level students (7th and 8th graders) also emphasized the communication of information and discussion environment as scientific practice as well as reviewing studies, searching sources that can be related with the literature review process in studies. In methods and methodological rules category students considered performing experiments, observations, data collection and use of scientific instruments as scientific methods. However, they explained these concepts for scientific practices category as well with providing similar connotations. Manipulative-non manipulative experiments, hypothesis-non hypothesis testing and explanatory work of these methods were provided by none of students.

Most students' perceptions in scientific knowledge category were more naïve especially in the law and theory concepts. Students were able to explain neither theories-laws-models and coherence of them nor definitions of them separately. Students were simply believing the governmental laws and unproven suppositions as scientific laws and theories. Only 8th grade high level student exemplified scientific laws such as law of gravity. However, most students were familiar with tentative nature of science and growth of scientific knowledge. In social institutional systems students were able to explain the importance of dissemination of knowledge and reviewing studies. Some 6th and 8th graders were aware of the negative aspects of dissemination of knowledge. In scientific ethos and social values more sophisticated codes such as intellectual honesty, working ethics, protecting rights, social utility came from 6th,7th and 8th graders. 5th graders couldn't relate politics with science and most middle school students were thinking financial needs for equipment and materials. Students' perceptions in this category were more diverse when compared with other categories. This result also supports the quantitative results that students get higher scores at this category. The grade level examinations showed that higher grade level students (7th and 8th graders) had higher RFN understanding and perceptions than lower grades (5th and 6th graders). Students RFN level examination showed that low RFN level students generally naïve perceptions and limited in their explanations while high level students' ideas were more advanced.

Furthermore, students' metacognitive awareness has been examined through the quantitative and qualitative results as another scope of the study. From the descriptive analyses it was found that 5th graders' metacognitive awareness means scores were corresponding to 85%, 6th (79%), 7th (80%) and 8th graders (81%). In addition, the inferential statistics showed that there was no statistically significant difference between 6th, 7th and 8th grade students' metacognitive awareness scores. When the qualitative data was examined, students' own reports in metacognitive awareness showed that students with high metacognitive aware level were metacognitively aware such as regulating their cognition with monitoring and planning strategies. Students who utilized and expressed these strategies described their learning process explicitly with using study strategies effectively, monitoring their thoughts, self-evaluating their progress, and stating their own self strengthens and weakness. These students were generally 6th,7th and 8th grade level students who belong to higher RFN and metacognitive awareness level. However, there were also students who were less metacognitively aware. These students were not aware of their learning strategies, why they use or how to use those strategies, use no self-questioning, planning techniques or how they learn science. In addition, there was no significant difference between 6th,7th and 8th graders' metacognitive awareness in both quantitative and qualitative results. However, 8th grade students had more nuancing and complex metacognitive actions. When compared with 5th graders 6th,7th and 8th graders' metacognitive awareness levels were higher than 5th graders. Their metacognitive actions, strategies were more organized and structured than low grade level students.

5. DISCUSSION

This chapter reflects the summary of the study, discussion of results, implications of the of the study, limitations of the study and suggestions for future studies. In the first section, the theoretical framework, rationale and aim of the study and methodology of the study were summarized. In the discussion of results section, the main results of the study have been discussed in two sub sections. In both sections, the main results have been argued with providing possible reasons of the results within the light of previous studies. In first subsection the relationship between students' RFN understanding and their metacognitive awareness and in the second section these two concepts have been discussed separately as well. In remaining sections implications of the study in science education, main limitations and suggestions for future studies have been reflected. In this scope, the need of improving metacognitive techniques in RFN lessons, enhancement of students' RFN understanding and metacognitive awareness, introduction of this new construct to RFN teaching and learning, possible limitations, recommendations, and suggestions for further studies have been discussed.

5.1. Summary of the Study

In the nature of science (NOS) various contemporary views and approaches exist to describe, teach, and learn its essence. One of these frameworks has been proposed by Erduran and Dagher (2014) recently with inclusion of political-financial- social organizational perspectives to science, applicable suggestions of theory into practice, emphasis on domain specific-general characteristics and providing holistic account for the nature of science. This framework is Erduran and Dagher's version of FRA to NOS (Erduran & Dagher, 2014) which has been later renamed as "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) by Kaya and Erduran (2016) for emphasis of pedagogical dimensions.

In NOS learning, on the other hand, students' proficiency in science, conceptual development of NOS concepts, students' organization of ideas around scientific disciplines are important (Ryder *et al*., 1999). It requires metacognitive effort for reasoning scientific ideas and controlling learning process (Beeth & Hewson, 1999; Peters-Burton & Burton, 2020). With this perspective, the use of metacognitive prompts or strategies broaden students' nature of science understanding with making them aware on disciplines of science, how science and scientists works (Akerson & Donnelly, 2008; Peters, 2007). Thus, these two constructs (RFN understanding and metacognitive awareness) have potential to be related concepts.

This explanatory sequential mixed method design study examines the relationship between students' RFN understanding and their metacognitive awareness through quantitative and qualitative perspectives. For this aim, at first middle school students RFN understanding, and perceptions have been examined. Participants were 180 5^{th}, 167 6^{th}, 170 7^{th} and 184 8^{th} grade students as total 701 middle school students who attended to the study. The data source was 37-item "RFN Student Questionnaire" (Cilekrenkli, 2019) which reflects epistemic-cognitive- social dimensions of science holistically.

Secondly, students' metacognitive awareness has been examined through "The Metacognitive Awareness Inventory for Children" (Karakelle & Saraç, 2007) which consists of form A (for 5^{th} grades) and form B versions (6^{th},7^{th} and 8^{th} grades). After administration of inventory, students who get high- moderate and low scores in both scale were selected for interview process which consists of both RFN and metacognitive awareness-based questions. For this qualitative part three different level (high-moderate-low) students from 5^{th}, 6^{th}, 7^{th} and 8^{th} grade students in total 12 students were selected. These high-moderate and low-level students were selected on the base of their scores in "RFN Student Questionnaire" and "The Metacognitive Awareness Inventory for Children". In this way, qualitative data came from RFN based and metacognitive awareness interviews.

The relationship between students' RFN understanding and their metacognitive awareness has been examined through both quantitative and qualitative data. For analysis of quantitative data, Pearson r correlation, simple linear regression and one-way ANOVA were used in addition to descriptive statistics. As a result, there was a significant positive relationship between students' RFN understanding and their metacognitive awareness. This relationship was evident for each grade level students (5^{th},6^{th},7^{th} and 8^{th} grade) separately as well. However, while the degree of relationship was low for 5^{th} graders (r=.292), it was moderate for 6^{th} (r=.317), 7^{th} (r=.332) and 8^{th} graders (r=.347). This relationship was also evident for all 6^{th},7^{th} and 8^{th} graders as a whole (r=.331). The qualitative results also showed that students with high metacognitive awareness level tend to explain RFN and its categories in more structured way. Additionally, these students were using some metacognitive prompts and skills while thinking and understanding science. However, students with low metacognitive awareness level revealed limited expressions for RFN and its categories.

Moreover, for students RFN understanding it can be said that there was a statistically significant difference between different grade level students' RFN understanding. The qualitative data also showed that 7^{th} and 8^{th} grade level students had broader and comprehensive RFN understanding. On the other hand, the metacognitive awareness results showed that there was no statistically significance difference between 6^{th}, 7^{th} and 8^{th} grade students' metacognitive awareness. The qualitative results revealed that there was no apparent difference in these grade level students' metacognitive awareness explanations. This study affirms the introduction of new construct to RFN framework. The examination of this relationship provides basis for the use of metacognitive strategies and techniques in RFN enriched science classrooms and opens new research focuses for experimental and causal comparative studies. In the following section these results and convergence of quantitative and qualitative results with discussing the possible reasons and previous studies were reflected.

5.2. Discussion of the Results

This section has been divided in two subsections for linking students' RFN understanding and their metacognitive awareness. Moreover. these two constructs separately need to be discussed detailly due to the scope of the study. Firstly, the results were discussed with making relationship between RFN understanding and metacognitive awareness with discussing the results through previous studies. In the second subsection, these two constructs have been discussed separately with giving possible reasons of results and connecting to relevant literature.

5.2.1. The Relationship between Students' RFN Understanding and Metacognitive Awareness

The outcomes of the study showed that students' RFN understanding is related with their metacognitive awareness. This means that students' awareness in their own thinking, ability to articulate cognitive process, ability to regulate their cognition are related with their understanding of science and its categories. This gives clues that if students become aware of their RFN learning process, they can understand and explain RFN in more comprehensive and structured way. Thus, it is possible that the use of metacognitive prompts while teaching or practicing science and its categories may bring positive outcomes in science lessons. According to Erduran and Dagher (2014) RFN framework is related with other various areas such as metacognition (Zohar & Dori, 2012), critical thinking (Bailin, 2002), etc. Some components that offered in categories has metacognitive dimension and role in understanding science. Thus, proposed framework also points the possible relationship between metacognition and RFN.

The one of prominent outcome of this study is its contribution and basis for the experimental designs. The correlation studies provide stepping-stone for powerful experimental methods. Researcher had advantage of making foresight about variables and allow hypothesis testing beforehand (Curtis *et al*., 2016; Polit & Beck, 2012). Thus, the study forms a baseline for experimental study on using metacognitive prompts in RFN teaching. From previous RFN based experimental studies, it was evident that RFN teaching enhances students' NOS understanding (Cilekrenkli, 2019) and social institutional category of science develops students' understanding of social dimension of science and their attitudes towards science (Akbayrak & Kaya, 2020), but effect of this new construct in RFN teaching has not been in the focus. Thus, this study gives the rationale for using metacognitive construct in RFN based experimental studies. In the literature, there were experimental studies (Abd-El-Khalick & Akerson, 2009; Baraz, 2012; Peters & Kitsantas, 2010) that shows the effectiveness of metacognitive prompts in nature of science teaching which result in advanced NOS understanding. Even though theoretical framework of these studies on consensus view and focus on preservice teachers, it was evident that use of metacognitive prompts in NOS bring affirmative outcomes. Thus, within the light of existing literature there is a higher possibility of effectiveness of use of metacognitive prompts in RFN teaching which can enhance students understanding of science and its categories holistically.

Moreover, in the previous accounts of nature of science the relationship between metacognitive awareness and nature of science was in the focus of limited studies (Akerson & Donnelly, 2008; Cetinkaya-Aydın & Cakıroglu, 2017; Gulsuyu, 2019). These studies concentrated mainly on consensus view as theoretical base and particular groups were generally preservice science teachers with the quantitative scope. For instance, Cetinkaya (2012) investigated the relationship between characteristics of preservice teachers (e.g., understanding of scientific inquiry, science teaching self-efficacy, metacognitive awareness) and their nature of science understanding. The researcher founded that statistically significant difference in the subcomponents of metacognitive awareness (the knowledge and regulation of cognition) between the students who have informed/adequate and inadequate views of NOS. In another similar study Gulsuyu (2019) examined the relationship between middle school (5^{th},6^{th},7^{th} and 8^{th} grade) students' NOS understanding and metacognitive awareness. Researcher founded the significant positive relationship between these two constructs and correlation coefficient value that was found is .306. Thus, this result is also aligned with correlation coefficient value that was found in this study ($r = .331$). However, researcher (Gulsuyu, 2019) examined this relationship with only quantitative perspective with basing study on consensus view framework. In brief, the related literature also supports the results of this study and results were in the same line with previous studies. Additionally, when this relationship has been examined for each grade level students as well, it has been seen that the degree of relationship increases across grade levels. For instance, the degree of relationship in 5^{th} graders ($r = .292$) were lower than 6^{th} ($r = .317$), 7^{th} ($r = .332$) and 8^{th} graders ($r = .347$). The possible reason of this result can be due to development of metacognitive skills through age. This development is ongoing process and has not been completed until before the age of 11-12 (Veenman *et al.*, 2004; Veenman, & Spaans, 2005). These developmental phases can be logic of low-level relationship at 5^{th} graders.

Another significant result of the study is predictive dimension for RFN understanding. In other words, metacognitive awareness has ability to forecast RFN understanding according to the statical results. This means that one can predict the students' RFN scores or understanding with looking their metacognitive awareness level. However, this prediction is limited within certain extent (11%). Furthermore, the possible reason of low value in shared variance (11%) can be due to moderate degree of correlation coefficient among RFN understanding and metacognitive awareness. In the similar study (Yenice, 2015) it was found that preservice teachers' epistemological beliefs were significant predictor on their metacognitive perceptions about the nature of science. Researcher concluded that students with the higher epistemological beliefs also have higher metacognitive perceptions of NOS. Thus, these cognitive constructs can be related and mediator in development of NOS perceptions from metacognitive aspects.

Lastly, the qualitative and quantitative results both pointed the relationship between these concepts. In addition to quantitative statistical relationship, students' explanations in RFN and metacognitive awareness were aligned. Students' explanations in RFN were showing some metacognitive clues such as monitoring, evaluating thinking process and awareness of others' thinking. Students who explain RFN in more structured way were also more metacognitively aware. On the other hand, low RFN level students' answers to metacognitive awareness questions indicated their limited awareness in metacognitive skills and actions. In sum, the convergence of quantitative and qualitative data affirms the possible relationship between these concepts.

5.2.2. Students' RFN Understanding and Metacognitive Awareness

This subsection provides the discussion of RFN understanding and metacognitive awareness separately. Firstly, the students' RFN understanding results in which each category of science has been reflected have been discussed with relating previous studies. Afterwards, the results of students' metacognitive awareness have been summarized with reasoning and connecting to the related literature.

The examination of students' RFN understanding in different grades showed that RFN understanding differs among middle schoolers. Although the descriptive results indicated that 7^{th} and 8^{th} grade level students' RFN mean scores were higher, the significant difference emerged among 7^{th} and 6^{th} graders. The reason of this difference can be due to age level development which may interfere with students' science learning process and its categories. However, the qualitative results pointed that 7^{th} and 8^{th} graders' explanations were more diverse and structured in many categories of science. Thus, from the qualitative results it can be said that 7^{th} and 8^{th} graders had higher RFN understanding. However, in general, even though students had general ideas on RFN and its categories, they were not able to associate different categories of science with considering epistemic cognitive components and viewed scientific knowledge as discrete piece of knowledge, considered limited number of methods of science and restrictive in viewing the holistic image of science. In similar studies, Celikdemir (2006) investigated the 6^{th} and 8^{th} grade students' NOS understanding with quantitative and qualitative perspectives. Researcher founded that while 8^{th} graders had more realistic views of NOS, 6^{th} graders had traditional epistemological believes which are aligned with the results of this study. Kang *et al*. (2004) and Lederman and Khishfe (2002) concluded that 6^{th} and 8^{th} grade level students' NOS ideas were restricted and need further development as suggestions for NOS instruction. Kang *et al*. (2004) founded that 6^{th} graders' NOS views were similar to of 8^{th} and 10^{th} graders. But each grade level students' ideas were restrictive in dimensions of science. Lederman and Khishfe (2002) concluded that 6^{th} graders had naïve views in most NOS aspects.

Another prominent result came from the examination of each category of science in terms of grade levels. In aims and values and scientific practices category there were no statistically significant difference among grade levels. When the qualitative results which gave more broader understanding on students' differences in their ideas were examined, students from all grade levels were able to explain serving to humanity, informing people, ethics with considering social aspects more. Students were mainly concentrating on effect or benefit of science on humanity and these social aspects were at the centre as both aims and values of science. In previous similar study (Cilekrenkli, 2019) in which effect of RFN based teaching on 5^{th} grade students' RFN understanding was examined, informing public, making inventios, serving for humanity, accuracy, doing no harm were seen as aims and values of science in the pre-interview results. These codes were generally related with social utility which was very closely related with the appearing results of students' perceptions on aims and values of science in this study. In addition, number of previous studies (Elder, 2002; Stein & McRobbie, 1997) also showed that students regard science as making and inventing practical products for serving humanity. 6^{th} and 8^{th} grade students consider the importance of science on people (Kang *et al*., 2004).

In scientific practices students explained concepts such as observation, use of materials and scientific classification more easily with linking and proving daily life examples. They were able to explain main concepts such as observation, experimentation, and classification. However, the interrelation among other epistemic practices and how these practices yield scientific knowledge has not evident among any of grade levels. These emerging results has been parallel with the similar study (Cilekrenkli, 2019). When students' answers in scientific practices were considered, Cilekrenkli (2019) found that most 5th graders were expressing experimentations, observations, and classification in pre interviews. In addition to these, explanation, social certification, and real world were less dominantly appearing codes. In this study, most 5th,6th,7th and 8th graders were familiar with these main concepts. However, communication of information has been broadly emphasized and diverse codes such as testing, investigations, searching from sources, reviewing studies, appeared among middle school students. Moreover, there were also no significant differences among middle school students' aims and values scores. This was also the same for scientific practices category. The reason of non-significance differences can be due to all grade level students' familiarity with these concepts beforehand or dependence of students on personal experiences such as their daily life observations, experiences or etc.

In methods and methodological rules, the quantitative results showed that there was a significance difference between 8th and 5th graders. In addition, there was a significant difference between 8th and 6th graders as well. The students' descriptions, on the other hand, were diverse such as testing, data collection, use of instruments, performing experiments, making observations. Although each grade level students explained these ideas, 8th and 7th graders expressed these concepts in more structured and complicated way with interlinking other components of science. Naïve and limited perceptions such as believing one scientific method and use of scientific instruments as methods of science came from 5th graders generally. In the similar study (Cilekrenkli, 2019), 5th grade students were thinking that experimental tools, having presuppositions and activities such as drawing diagrams and excavations were the methods of science. None of students mentioned hypothesis/non hypothesis testing, manipulation/non manipulation in the pre interviews which were aligned with the results of this study. However, differently, the more diverse ideas such as making observations, experiments, examinations, investigations, methodological errors in studies and diversity of scientific methods have been emphasized by most students in this study.

They explained some concepts such as testing, making observations and experiments in scientific practices category in similar way.

For the scientific knowledge category there was significant difference between 8th and 5th grader in which 8th graders had higher scores in this category. There was also significant difference between 7th and 5th graders which 7th graders' scores were dominant. Most middle schoolers were able to view tentative nature and development of scientific knowledge. However, naïve beliefs among middle schoolers were reasonably apparent in this category. Students thought the scientific laws as governmental laws and scientific theories as unproven suppositions. Only 8th grade high level student exemplified scientific laws such as law of gravity. The reason of 8th and 7th graders' superiority in these categories can be due to students' accumulation of content knowledge, experiences, or developmental differences in constructing scientific knowledge (Carey & Smith, 1993; Driver *et al*., 1994). Existing literature also points the students' inability in differentiating theories, laws, facts, etc. (Parker *et al*., 2008). Çelikdemir (2006) emphasized the 8th graders' realistic believes such as tentative and subjective nature of science. Likewise, Kang *et al*. (2004) also pointed that junior middle school students had some modern philosophical perspectives and show more diverse ideas on changeability of scientific knowledge which were aligned with the outcomes of this study.

In social institutional systems the significant difference was between 7th and 6th graders in which 7th graders understanding were superficial. Students' verbal expressions indicated that 6th,7th and 8th graders' explanations in scientific ethos, social values and political power structure were more diverse while 5th graders were restrictive in viewing these aspects. However, in general students' perceptions in this category were more diverse when compared with other categories. Students were thinking intellectual honesty, working ethics, protecting rights, social utility as scientific ethos and social values. In addition, presenting and sharing results, informing public, and using dissemination channels were students' thoughts for social certification and dissemination and professional activities of scientists. These results were aligned with Akbayrak and Kaya's (2020) study. They investigated the effect of teaching science as social institution system on 5th grade students' understanding of social institution system on science. Researchers founded that the students were able to view attending conferences, making presentations on findings, publishing works, reviewing, meetings, social organizations, and effect of politics on science within social institution system of science. Lastly, in this study most students couldn't relate politics with science and most middle school students were thinking financial needs for equipment and materials mainly. The results of Cilekrenkli's (2019) study for this category were also showing the diversity of the number of codes in pre-interviews. She also pointed the students had already structured ideas in financial system category. Similarly, most students were perceiving government as controlling mechanism and inspecting scientific works.

The quantitative results of this study showed similarity with RFN based experimental studies on middle school students in certain extent (Akbayrak & Kaya, 2020; Cilekrenkli, 2019). In this scope Cilekrenkli (2019) examined the effectiveness of RFN based teaching on 5^{th} grade students' RFN understanding and perceptions. In pre-test RFN scores the control and experimental groups get 123 and 126 respectively. In this study, 5^{th} graders' RFN mean scores was found as 133 in general which is higher than Cilekrenkli's (2019) results. This can be due to nature and characteristics of participants in this study (Gravetter & Wallnau, 2014). Akbayrak and Kaya (2020) investigated the effect of teaching social institutional system on the 5^{th} grade level students' understanding of social institutional system of science and their attitudes towards science. They found that students' pre-test scores in this category as 54 for experimental and 47 for control group (out of 75). In this study all middle school students' (5^{th},6^{th},7^{th} and 8^{th} grade) scores in the social institutional system were 53 (out of 70) which is consistent with the previous study results (Akbayarak & Kaya, 2020).

When all categories have been discussed holistically, the quantitative results from descriptive analysis showed that 7^{th} and 8^{th} grade students' RFN understanding were higher than 5^{th} and 6^{th} graders. However, inferential results pointed that the significant differences were between 7^{th} and 6^{th} graders. The qualitative results, on the other hand, affirmed that all students had general ideas and concepts in each category of science. However, 7^{th} and 8^{th} grade students' explanations and examples were more scientifically oriented and structured than 5^{th} and 6^{th} graders. In the related literature, researchers (Kang *et al*, 2004) founded no differences between 6^{th}-8^{th} and 10^{th} grade students' NOS views. In another study (Celikdemir, 2006) it was concluded that 8^{th} grade students' NOS ideas and views were more structured than 6^{th} graders. 8^{th} graders had contemporary view on science as opposed to traditional views that 6^{th} graders had. In the similar study (Demir & Akarsu, 2013) in which the 6^{th} and 7^{th} grade students' NOS ideas were examined and compared with the quantitative and qualitative data, no significant difference between 6^{th} and 7^{th} grade level students was found and their' ideas were similar. However, the number of students that attended to their study was restrictive with 31 students while in this study the number of 6^{th} and 7^{th} grade students were corresponding to 337 students. Thus, the big difference between the number of students and having different theoretical approach in their study can be the reasons in contradictory results.

As another part of the study, students' metacognitive awareness was investigated for middle schoolers (6^{th},7^{th} and 8^{th}) as a whole and each grade level separately. In the descriptive results, students' mean scores were corresponding to 71.52 (6^{th} grade), 71.94 (7^{th} grade), 72.59 (8^{th} grade) while 5^{th} graders' mean scores were 30.73 (out of 36). The whole middle school students' (6^{th},7^{th},8^{th} grade) mean score were corresponding to 72.3. From inferential statistics, no statistically significant difference between 6^{th}, 7^{th} and 8^{th} grade students' metacognitive awareness scores were found. In the related literature although there are studies (e.g. Evran & Yurdabakan, 2013; Kırbac & Kaya, 2019; Kurtulus & Ozturk, 2017) which shows the significant difference among different level preservice or middle school students' metacognitive awareness, some studies (Deniz *et al*., 2014; Kolic-Vehovic & Bajsanki, 2006; Pressley & Ghalata, 1989; Şahin & Küçüksüleymanoğlu, 2015; Seckin-Kapucu & Oksuz, 2016) revelaed the non significant difference among different grade level students. In these studies, researchers (Gulsuyu, 2019; Seckin-Kapucu & Oksuz, 2016) examined 5^{th}-6^{th}-7^{th} and 8^{th} grade middle school students' metacognitive awareness and differences between these grade levels. Seckin-Kapucu and Okuz (2016) who investigated 448 5^{th}-6^{th}-7^{th} and 8^{th} grade middle school students' metacognitive awareness within the quantitative and qualitative perspectives founded the 70.75 for all students' mean score. This score was 72.3 in this study which is very closer result with the previous study. In the examination of statistical differences researchers (Gulsuyu, 2019; Seckin-Kapucu & Oksuz, 2016) revealed the non-significant difference among 5^{th}-6^{th}-7^{th} and 8^{th} graders' metacognitive awareness. Thus, the results of this study show similarity and aligned with the previous results of this study.

Lastly, in the qualitative results students with high metacognitive awareness level were utilizing the metacognitive strategies and described their learning process explicitly with using learning strategies effectively, monitoring their thoughts, self-evaluating their progress, and stating their own self strengthens and weakness. However, low level and 5th grade students were limited in these aspects. In general, even though some students showed metacognitive skills, majority were limited in these skills and actions. Mainly 6th-7th-8th graders had more structured explanations and reports on metacognitive clues. These results were showing similarity with previous studies (Seckin-Kapucu & Oksuz; 2016). For instance, Seckin-Kapucu and Oksuz (2016) concluded that students' awareness in their goals, understanding their strengthens and weakness need to be enhanced. Aydın-Aşk (2016) also pointed that students' goal setting, judgement of their learning was limited before the intervention. Thus, these outcomes were aligned with this study in terms of students' limitedness in some aspects of metacognitive awareness.

5.3. Implications of the Study

The results of the study indicated that metacognitive awareness is related construct with RFN understanding. This new construct has been introduced to RFN teaching originally at first. Because of the nature of correlation studies, it opened and provided basis for experimental studies in terms of the inclusion of metacognitive prompts in RFN based lessons. As a result, RFN understanding and metacognitive awareness are related with each other and increase in students' RFN understanding can be explained by increase in their metacognitive awareness. Thus, the science lessons can be designed in a way to enhance students' metacognitive awareness which can result increase in their RFN understanding. In addition, since this study gave credit for experimental studies for inclusion of metacognitive prompts in RFN teaching, after examining the effect of these prompts with further studies, lessons can be enhanced for using these prompts or strategies for this holistic account of NOS.

Learning NOS is one of the most crucial aim of science programs and curriculum (MEB, 2018). Students need to graduate from middle school with having basic NOS understanding and scientific literacy. When this aim is considered, this study affirmed that although students have general ideas on RFN and its categories such as their familiarity with basic concepts in categories of science, they were still limited in linking different categories and considering holistic image of science. Most students couldn't explain TLM (Erduran &

Dagher, 2014), explanatory consilience, epistemic- cognitive aims and values of science, predictive and explanatory structure of classification, domain specific and general characteristics of science. Thus, there is a need to enhance students' RFN ideas for having students understand science holistically, its domain specific and general characteristics. Students' RFN understanding can give insight or inform the science education practice and curriculum in terms of revisions of these components. Since integration of these components into RFN based lessons increase students' RFN understanding (Cilekrenkli, 2019), science lessons can be enriched with the categories of science to increase their understanding in NOS comprehensively.

Moreover, this study affirms that even lower grade level students who are nearly 10-year age can have understanding of RFN concepts and express their RFN ideas clearly. The previous studies (Khishfe & Abd-El-Khalick, 2002; Lederman & Khishfe, 2002) that propose lower graders such as 5th and 6th grade students can have difficulty in understanding subjectivity of scientists and can be limited in their cognitive ability. However, these grade level students are able to reflect their NOS ideas in many aspects of science (Jimakorn & Yuenyong, 2018). Thus, it was also evident from this study that students can explain epistemic-cognitive and social aspects of science within a holistic account of NOS as well.

Lastly, the students' metacognitive awareness showed that even though the quantitative results indicated higher scores, the qualitative results revealed that some students were not still aware of their learning process, monitor the cognitive actions, use of metacognitive techniques. An integration of metacognitive techniques into lessons shows the affirmative outcomes in different education branches (Amzil, 2014; Sandi-Urena *et al.*, 2011). It also concerns in NOS science education with pointing the enhancement in students' NOS understanding (Abd-El-Khalick, & Akerson, 2009; Peters & Kitsantas, 2010). Thus, this study showed students' limited aspects and awareness on their metacognitive skills and need for concern of metacognitive awareness in NOS lessons. Having students to use these techniques or skills for active learning environment can enhance their metacognitive awareness. Lesson plans or curriculum can be reviewed in way to facilitate these prompts which allow students to think their learning process, monitor their actions or reflect the process. Additionally, since this study also revealed the apparent differences between low- and high-level students' metacognitive awareness, the careful inspection for these differences in classrooms are needed. Teachers can practice lessons with considering or monitoring the high/low metacognitively aware students while teaching the nature of science. Since the students RFN understanding is depend on and related with their metacognitive awareness, students' RFN learning can be enhanced with inclusion of metacognitive strategies or techniques. The enrichment of RFN based lessons such as the use of figures in each category of science, RFN based activities, teachers' careful observation for inspecting high/low metacognitively aware students, the use of metacognitive skills and techniques while teaching RFN can be some of implications of this study for both curriculum and teaching perspectives.

5.4. Limitations of the Study

There are limitations of this current study that need to be touched upon. As first limitation, participants were from 3 different public schools from different regions of Istanbul and the majority of data were from two schools. The inclusion of private schools would yield more different or broader results.

Secondly, the data source that was used to measure students' RFN understanding and metacognitive awareness can be supported with additional data source. For instance, online measures such as observation, think aloud, eye movement registration, etc could bring more boarder and deep data on students' metacognitive awareness (Veenman, 2011). Even though these measures have their disadvantages such as inability in verbalization of thoughts or interference of cognitive process with verbalization, multiple online methods of assessment of metacognition would bring more data and closer inspection for this construct. However, offline measures such as self-report questionnaires, interviews, and teacher ratings are still acceptable and provide reliable data according to the literature (Baker, & Cerro, 2000).

In this study the relationship between students' RFN understanding and metacognitive awareness was found. The predictive variable was students' metacognitive awareness and outcome variable was students' RFN understanding. Students' previous levels or experiences with nature of science or metacognitive awareness can be as extraneous or uncontrolled variable in the study. This variable is confounding variable that cannot be directly measured since they cannot be separated from other variables (Creswell, 2012). Thus, these variables can be one of the limitations of the study.

Lastly, the predictive model has been provided and predictor ability of metacognitive awareness has been examined. However, the aim of the study was not making deep examination of prediction or providing valid prediction model further analyses are needed for validation process. Thus, applicability and validity of model need to be assured with independent data in terms of inspecting the accuracy of model in different data. Thus, before providing prediction model and applying for experimental studies, validation process is essential with additional measures such as cross-validation (*VEcv) or* McCabe's efficiency (E_1) measures for accuracy measures (Li, 2017).

5.5. Suggestions for Future Studies

Introducing new concept to "Reconceptualized Family Resemblance Approach to Nature of Science" (RFN) opened experimental research area for further studies. Since the relationship was found in this study, experimental or causal comparative studies in this area can be broadened. The metacognitive prompts can be facilitated as a supporter and an advanced instructional tool in RFN teaching as a result of these experimental studies. The prediction model that has been developed can be broadened and crosschecked for another independent data with the additional research. Thus, model can be developed with further studies.

Moreover, since students' RFN understanding and metacognitive awareness were found as limited in some perspectives and the number of students who use metacognitive skills for understanding science and categories were relatively low, enhancement of metacognitive skills in science teaching can be suggested for science curriculum. Thus, new research can be conducted in a way to design lessons or enhance students' RFN understanding and metacognitive awareness. The representations of these elements can improve students' RFN understanding and need to be examined in further studies.

Last but not least, the study points to the need of metacognition in NOS teaching and consideration of students' metacognitive awareness levels in science classes. It informs further research on both enhancing RFN teaching and embedding metacognitive prompts in RFN based lessons.

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APPENDIX A: "RFN STUDENT QUESTIONNAIRE"

BİLİMİN DOĞASI ANKETİ" (Cilekrenkli,2019)

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

	Kesinlikle Katılmıyorum	**Katılmıyorum**	**Kararsızım**	**Katılıyorum**	**Kesinlikle Katılıyorum (5)**
1. "Bilimsel bilgi değişmez".					
2. "Bilim insanları birbirlerinin çalışmalarını inceler ve değerlendirir".					
3. "Deneyler bilim insanları tarafından çokça test edildiği için güvenilirdir".					
4. "Bilim, üniversiteler ve araştırma merkezleri gibi kurumlarda gerçekleşir".					
5. "Fizik, kimya ve biyoloji gibi bütün bilim dallarında aynı bilimsel yöntem kullanılır".					
6. "Bilim, insanlar arasındaki sosyal ilişkilerden ve toplumdan etkilenir".					
7. "Bilimde ilerleme, bilim insanlarının bilimsel bilgiyi gözden geçirmesiyle ve değerlendirmesiyle gerçekleşir".					
8. "Bilim insanları doğaya saygı göstermelidir".					
9. "Bilimsel verilerin (araştırma sonuçlarının) incelenmesi ve yorumlanması bilimsel pratiklerden (uygulamalardan) bazılarıdır".					
10. "Teoriler ve yasalar bilimsel bilgi türleridir; ancak modeller (örneğin şekil, sembol ya da resim) bir bilimsel bilgi türü değildir".					
11. "Bilim insanları araştırmalarını toplumla paylaşmak zorunda değildir".					
12. "Bilimsel modeller (örneğin şekil, sembol ya da resim) karmaşık bilimsel fikirleri anlamamızı kolaylaştırır".					
13. "Gözlem tüm bilim dallarında kullanılır".					
14. "Bilim insanları, problemleri çözerken yeterli miktarda kanıt bulabilmek için farklı yöntemler kullanmak zorundadır".					
15. "Bilim insanları araştırma yapmak için paraya ihtiyaç duyarlar".					

	Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
16. “Sınıflandırma yapmak (örneğin canlıların sınıflandırılması) bilim insanlarının olayları açıklamasına ve tahmin etmesine yardımcı olur”.					
17. “(Klonlama gibi) Bilimin ürettiği yeni yöntem ve teknolojiler toplumlarda yeni değer yargıları oluşturabilir”.					
18. “Bilim insanlarının cinsiyetleri onların bilimi nasıl yaptıklarını etkiler”.					
19. “Eğer bilim insanları düşüncelerini ispat edemezlerse düşüncelerini değiştirmeleri gerekir”.					
20. “Devletlerin aldıkları kararlar bilimsel bilginin gelişimini etkiler”.					
21. “Bilimsel modeller (örneğin güneş sistemi modeli gibi) gerçek dünyadaki olayları, varlıkları ve durumları temsil eden araçlardır”.					
22. “Bazı bilim insanlarının diğerlerinden daha fazla para kazanması bilim insanları arasında gerginliğe yol açar”.					
23. “Bilimsel gerçekler bilim insanlarının şahsi fikirlerinden etkilenmezler”.					
24. “Bilim insanlarının ırkları ve milliyetleri bilimi etkilemez”.					
25. “Teoriler, yasalar ve modeller birlikte çalışarak bilimsel bilgiyi oluşturur”.					
26. “Bilim insanları fizik, biyoloji ve kimya gibi farklı bilim dallarında (mikroskobik canlılar, hayvanlar, maddenin yapısı ve kuvvet gibi farklı konularda) çalışırken aynı bilimsel pratikleri (deney, gözlem, veri toplama ve model gibi uygulamaları) kullanırlar”.					
27. “Bilim insanları akademik dergilerde bilimsel yazılar yazarlar”.					
28. “Teorilerin bazıları kabul edilmiştir, bazıları ise hala tartışılmaktadır”.					
29. “Bilimsel bilginin oluşum süreci nesnellik ve bilim insanlarının maddi beklentileri gibi değerlerden etkilenmez”.					
30. “Bilim insanları, araştırmalarını diğer bilim insanlarıyla paylaşmak için konferanslara katılırlar”.					

31. “Bütün bilim dallarında çalışan bilim insanları çalışmalarına başlarken sonuca dair varsayımları (beklentileri) vardır”.					
32. “Bilimsel çalışmaların güvenirliği nesnellik ve yeterli kanıt sunma gibi bazı standartlara göre değerlendirilir”.					
33. “Teori, kanun ve modeller bilim insanlarının olayları açıklamalarına ve tahmin etmelerine yardımcı olur”.					
34. “Yasalar teorilere göre daha doğrulanabilir bilimsel bilgilerdir”.					
35. “Bilim insanları araştırdıkları soruya göre deney ve gözlem gibi farklı yöntemler kullanır”.					
36. “Bilim insanları araştırma yaparken diğer bilim insanlarıyla iletişim kurarlar”.					
37. “Bilimsel çalışmalar sadece değişkenler değiştirilerek yapılabilir”.					

APPENDIX B: "METACOGNITIVE AWARENESS INVENTORY FOR CHILDREN (Jr.MAI) FORM A"

(Karakelle & Saraç, 2007)

"ÇOCUKLAR İÇİN ÜSTBİLİŞSEL FARKINDALIK ÖLÇEĞİ"

Sınıf Seviyesi: 3 4 5

Bu anket öğrenciler çalıştıkları zaman neler yaptığını anlamak üzere sizlere hazırlanmıştır. Aşağıdaki cümleleri okuyup size en uygun ve doğru olanı işaretleyiniz.

	Asla	**Bazan**	**Her zaman**
1. "Bir şeyi anlayıp anlamadığımı bilirim".			
2. "İhtiyacım olduğunda kendi kendime öğrenebilirim".			
3. "Daha önce işime yaramış olan çalışma yollarını kullanmaya gayret ederim".			
4. "Öğretmenin neyi öğrenmemi istediğini bilirim"			
5. "Konu hakkında daha önce bir şeyler biliyor olsam konuyu daha iyi öğrenirim".			
6. "Şekil ve resimler çizmek konuyu daha iyi anlamamı sağlar".			
7. "Çalışmam sona erdiğinde kendime öğrenmek istediğim konuyu öğrenip öğrenemediğimi sorarım".			
8. "Bir problem çözmek için birçok yol düşünür, aralarından en iyi olanını seçerim".			
9. "Çalışmaya başlamadan önce ne öğrenmem gerektiğini düşünürüm".			
10. "Yeni bir şey öğrenirken kendime ne kadar öğrenebildiğimi sorarım".			
11. "Önemli bilgileri çok dikkatli dinlerim".			
12. "İlgimi çeken konuları daha iyi öğrenirim".			

APPENDIX C: "METACOGNITIVE AWARENESS INVENTORY FOR CHILDREN (Jr.MAI) FORM B"

(Karakelle & Saraç,2007)

"ÇOCUKLAR İÇİN ÜSTBİLİŞSEL FARKINDALIK ÖLÇEĞİ"

Sınıf Seviyesi: 6 7 8 9

Bu anket öğrenciler çalıştıkları zaman neler yaptığını anlamak üzere sizlere hazırlanmıştır. Aşağıdaki cümleleri okuyup size en uygun ve doğru olanı işaretleyiniz.

	Asla	**Nadiren**	**Bazen**	**Sık sık**	**Her zaman**
1. "Bir şeyi anlayıp anlamadığımı bilirim".					
2."İhtiyacım olduğunda kendi kendime öğrenebilirim".					
3. "Daha önce işime yaramış olan çalışma yollarını kullanmaya gayret ederim".					
4. "Öğretmenin neyi öğrenmemi istediğini bilirim"					
5. "Konu hakkında daha önce bir şeyler biliyor olsam konuyu daha iyi öğrenirim".					
6. "Şekil ve resimler çizmek konuyu daha iyi anlamamı sağlar".					
7. "Çalışmam sona erdiğinde kendime öğrenmek istediğim konuyu öğrenip öğrenemediğimi sorarım".					
8. "Bir problem çözmek için birçok yol düşünür, aralarından en iyi olanını seçerim".					
9. "Çalışmaya başlamadan önce ne öğrenmem gerektiğini düşünürüm".					
10. "Yeni bir şey öğrenirken kendime ne kadar öğrenebildiğimi sorarım".					
11. "Önemli bilgileri çok dikkatli dinlerim".					
12. "İlgimi çeken konuları daha iyi öğrenirim".					
13. "Öğrenirken zayıf yönlerimin üstesinden gelmek için güçlü yönlerimi kullanırım".					
14. "Çalıştığım konuya bağlı olarak farklı öğrenme yöntemlerini kullanırım".					
15. "Ara sıra durup öğretmenin verdiği görevi zamanında bitirip bitiremeyeceğimi kontrol ederim".					
16. "Bazen öğrenme stratejilerini düşünmeksizin kullanırım".					
17. "Öğretmenin verdiği bir işi bitirdikten sonra kendime, bu işi yapmanın daha kolay bir yolu olup olmadığını sorarım".					
18. "Bir işe başlamadan önce nelerin yapılması gerektiğine karar veririm".					

APPENDIX D: ENGLISH VERSION OF INTERVIEW QUESTIONS

Introduction

1. What do you think about science lessons? What are your responsibilities and duties for this lesson?
    - What do you do in science lessons? What your teacher and you do in lessons?
2. What comes to your mind when I say science?

RFN based questions

3. Who does science? What do you think on how they do scientific works?
4. Why scientists conduct scientific studies? What are their purposes for conducting these scientific studies?
    - What are values of science? (What are the values that scientists must follow?)
5. What does scientific practices mean to you? What kind of scientific practices does scientists have?
    - What comes to your mind when I say observation? Have you ever had an opportunity to make observation in science lessons?
    - Do you think that science or scientists are related with observations? Do you think that these terms are related?
    - What do you know about classification? Do scientists make classifications?
    - What comes to your mind when I say experiment? What can be the purpose of making experiments in science?
6. What comes to your mind when I say scientific methods? For instance, you are scientist and have a research question. You want to examine celestial bodies or features of COVID 19 virus. Which scientific methods do these scientists use?
    - Think of scientists who work in different branches can methods that they used be same or different? (If you think use of same or different methods, what you think on that?)

- Do scientists have presuppositions or expectations for the results of their studies? (If yes, can their suppositions contradict with their results? / their results can appear different from their expected results?)

7. What do you think about scientific knowledge? How scientists reach to the scientific knowledge?
    - What are the forms of scientific knowledge? (What can be meaning of theory and law?)
    - What do you think about scientific model? Do scientists use scientific models? (If yes, what can be their aim for using scientific models? If no, why they don't use?)
    - Do you think that the scientific knowledge change? (If yes, how it can change and develops? If no, why?)
8. What scientists do when they discover new thing or reach important conclusion?
9. Do you think that scientists want to inform and share their results with people and other scientists? (If yes, what they do for doing this? Can you explain this process?)
10. What do you think that professional activities that scientists take?
    - Have your ever heard the words like conferences and seminars? Do you think that there is a relationship between scientists and conferences/seminars? (If yes, what kind of relationship could be? / What could they do in these conferences?)
11. What are the things that scientists need to be careful while working together or their relationship with each other?
12. Do you think that does religion, gender or personal thoughts have effect on scientists' results of studies? If yes, how and in what way? If no, why?
13. Lets' say that a scientist do a scientific work about environment. Another scientist study with animals. What are the rules or values that these scientists need to follow?
    - Does scientist free in their works?
14. Do you think that government affect scientists' work? How?
    - What kind of relationship exist between science and political structures?
15. Do you think that financial issues related with science? Why?
16. In which places scientists perform these scientific works?

Metacognitive awareness questions

17. Now I want you to imagine yourself while learning new topic in science. Let's say you are learning new topic and try to understand it. (After waiting half minutes) which thoughts pass through in your mind?
    - Now I want you to describe your learning process in this science topic. Let's take an example of seasons and climate unit. What you have done to learn this topic and what did you do?
18. How do you understand whether you learned the topic or not?
19. What kind of strategies do you use while studying or trying to learn new topic?
    - Why do you use these strategies? Is there a specific time for you to use these techniques?
20. What you generally do when you come up with important information while studying?
21. Do you put specific goals for learning? Can you give example for them?
    - Do you ask yourself whether you reach or accomplished your aim?
    - How do you check whether you reached your goal?
22. What are your cognitive strengthens and weakness?
23. Now I want you to think of your specific moment. You have just finished your exam. Can you imagine that moment? (After short moment) While solving problems and after the exam what you generally think?
    - Do you generally evaluate your learning process?
    - For instance, you had exam and after that do you predict your score?
24. What do you think on your thinking way? For example, you have hard question and trying to solve it. What do you think while doing this? Do you think alternative ways or ask questions to yourself while thinking and problem solving? If yes, can you give example about last situation you did this?
25. Now, I want you to think of your special moment while studying again. Can you describe your internal speech, thoughts or things that you realized that moment?
26. How do you manage your time and time you devote for learning?
    - Do you specifically set time intervals or goals for yourself? How do you manage this?
27. You have mentioned learning techniques before. How and when you use them?
    - Is it easy for you to learn with online lessons?
    - Can you learn yourself when needed?

APPENDIX E: TURKISH VERSION OF INTERVIEW QUESTIONS

Giriş

1. Genel olarak fen bilimleri dersi ile ilgili ne düşünüyorsun? Bu ders için görev ve sorumluluklar nelerdir?
    - Fen derslerinde neler yapıyordunuz/yapıyorsunuz? Öğretmeniniz ve siz derste neler yapıyordunuz?
2. Bilim denilince aklına neler geliyor? Sence bilim ne demektir?

RFN Temelli Sorular

3. Sence kimler bilim yaparlar? Bu insanlar bilimsel araştırmalarını nasıl yaparlar?
4. Bilim insanları sence neden bilimsel çalışmalar yaparlar? Yaptıkları çalışmalardaki amaçları ne/neler olabilir?
    - Sence bilimin değerleri nelerdir? (Bilim yaparken sence hangi değerlere dikkat edilmeli veya neye önem verilmeli?)
5. Bilimsel pratikler denildiğinde aklına neler geliyor? Sence bilim insanları ne tür faaliyetler gerçekleştirirler? (Ne tür işler yaparlar?)
    - Sence gözlem yapmak demek ne demektir? Daha önce fen derslerinde gözlem yaptınız mı?
    - Bilim veya bilim insanlarının gözlem ile ilişkisi var mıdır? Bu iki kavram ilişkili midir?
    - Sınıflandırma yapmak ne demektir? Bilim insanları sınıflandırma yapar mı sence?
    - Deney yapmak deyince aklına neler geliyor? Bilimde deney yapmanın amacı ne olabilir?
6. Bilimsel yöntemler denildiğinde aklına neler geliyor? Örneğin bir bilim insanının aklında bir soru var bunu cevaplamak istiyor. Mesela uzaydaki gök cisimlerini ya da KOVID 19 virüsünün özelliklerini incelemek istiyorsun. Bu bilim insanı bu soruları yanıtlaması için kullanması gereken yöntemler nelerdir?
    - Farklı alanlarda çalışan bilim insanlarının kullandıkları yöntemler aynı mıdır farklı mıdır? (Aynıysa neden aynı olduğunu farklı ise neden farklı olduğunu düşünüyorsun? Örnek verebilir misin?)
    - Peki bu bilim insanı bilimsel çalışmasını yaparken sonucun ne olacağına dair bir

beklentisi var mıdır? (EVET ise çalışmanın sonucu onun beklediğinden farklı olabilir mi?)

7. Bilimsel bilgi ne demektir? Sence bilim insanları bilimsel bilgiye nasıl ulaşırlar? (SK)
    - Bilimsel bilgi türleri nelerdir? (Teori, yasa gibi kavramlar sence ne demektir?)
    - Sence bilimsel model ne demektir? Bilim insanları bilimsel model kullanırlar mı? (Evet is sence bilim insanlarının bilimsel model kullanma amacı nedir? Hayır ise neden kullanmadıklarını düşünüyorsun?)
    - Sence bilimsel bilgi değişir mi? (Evet ise sence bilimsel bilgi nasıl değişir ve gelişir? Hayır ise neden değişmez?)
8. Bilim insanları yeni bir şeyler keşfettiklerinde veya bir sonuca ulaştıkları zaman ne yaparlar?
9. Peki, sence bilim insanları araştırmalarının sonuçları hakkında toplumu ve diğer bilim insanlarını ve halkı bilgilendirmek isterler mi? Eğer isterlerse bunun için ne yaparlar? Bu süreci anlatabilir misin?
10. Sence bilim insanlarının gerçekleştirdikleri profesyonel aktiviteler nelerdir?
    - Daha önce konferans, seminer gibi kelimeler duydun mu? Bilim insanları ve konferans ve seminerlere arasında ilişki var mıdır? (Evet ise nasıl bir ilişki olabilir? /Bu toplantılarda neler yaparlar?)
11. Bilim insanlarının birbirleriyle olan ilişkilerinde ve yaptıkları işlerde dikkat ettikleri hususlar /dikkat etmeleri gereken şeyler nelerdir?
12. Bilimsel çalışmaların sonuçları bilim insanlarının inançları, cinsiyetleri ve kişisel düşünceleri gibi faktörlerden etkilenir mi? Nasıl, ne yönden etkileyebilir?
13. Diyelim bir bilim insanı çevre ile ilgili bir çalışma yapıyor, örneğin çevre ile ilgili bir durumu ya da meseleleri inceleyecek. Başka bir bilim insanı hayvanlarla ilgili çalışma yapıyor. Bu bilim insanlarının takip etmesi gereken değerler/kurallar nelerdir?
    - Bilim insanları yaptıkları çalışmalarda özgürler midir? Neden?
14. Sence devlet bilim insanlarının yaptıkları çalışmaları etkileyebilir mi?
    - Sence bilimin devlet ve politik yapılarla nasıl bir ilişkisi vardır?
15. Sence para veya parasal meseleler bilim ile ilişkili midir? Nasıl ilişkili olabilir? Neden?
16. Bu bahsettiğimiz bilimsel çalışmaları bilim insanları nerelerde/hangi ortamlarda yaparlar?

Üst bilişsel farkındalık soruları

17. Şu an kendini bir fen dersinde yeni bir konu öğrenirken hayal etmeni istiyorum. Örneğin yeni bir fen konusu öğreniyorsun diyelim. (Yarım dakika bekledikten sonra) o sırada aklından neler geçer?
    - Şimdi bir fen konusunu öğrenme sürecinden bahsetmeni ve özetlemeni istiyorum. Mesela bir üniteyi örnek alalım (Mevsimler ve iklim.) Bu konuyu öğrenme süreci nasıl oldu ve neler yaptın?
18. Bir konuyu öğrenip öğrenmediğini nasıl anlarsın? / bilirsin?
19. Yeni bir konu öğrenmeye çalıştığında ne tür teknikler/stratejiler kullanılırsın? / Neler yaparsın?
    - Bu yöntemleri neden kullanıyorsun? Bu yöntemleri özellikle kullandığın zamanlar oluyor mu?
20. Ders sırasında örneğin fen dersini dinlerken veya kendin dersi çalıştığın sırada önemli bir bilgiyle karşılaştığında ne yaparsın? (Information management skills)
21. Kendine düzenli olarak hedefler koyar mısın? Bunlara örnek verebilir misin?
    - Bunların sonunda amaçlarına ulaşıp ulaşmadığını düzenli olarak kendine sorar mısın?
    - Bu amaçlarına ulaşıp ulaşmadığını nasıl kontrol edersin?
22. Zihinsel olarak sence güçlü ve zayıf yönlerin nelerdir?
23. Şimdi senden belirli bir anı canlandırmanı istiyorum. Mesela yeni sınavdan çıktın. Bu anı bir düşünür müsün? (Yarım dakika sonra) Sınavı çözerken veya sınav sonrasında neler düşünürsün?

    -Kendi öğrenme sürecini değerlendirir misin?

    - Mesela bir sınava girdin ve sınav çıkışı ben şu puanı alabilirim gibi bir tahminde bulunabilir misin?
24. Kendi düşünme şeklin ile ilgili neler düşünüyorsun? Örneğin zor bir problemle veya durumla karşı karşıyasın bu problemi çözme sırasında ne düşünürsün? Problemi çözmeden önce alternatif yolları düşünür müsün ya da kendine sorular sorar mısın? En son karşılaştığın bir örneği anlatır mısın?
25. Peki şu an kendini test çözerken ki veya bir konuyu çalışırken ki bir anını düşünmeni istiyorum. (Düşünmesi için gerekli zaman verilir). Bu anını bana anlatabilir misin örnek vererek? O an içinden geçenler, kendine sorduğun sorular ya da fark ettiğin şeyler neler?
26. Bir konuyu öğrenmek için ayırdığın zamanı nasıl yönetirsin?

- Kendine belirlediğin amaçlara ulaşman için belirli zaman aralıkları tanır mısın? Bunu nasıl yaparsın?

27. Daha önce öğrenme stratejilerinden bahsetmiştin. O stratejileri nasıl ve ne zaman kullanırsın genelde?
    - Online derslerle öğrenmek senin için nasıldı? Bu süreç senin için nasıl geçti?
    - İhtiyaç olduğunda kendi kendine öğrenebilir misin?

APPENDIX F: TURKISH VERSION OF INTERVIEW QUOTATIONS AND EXCERPTS

1. Amaçları insanları bilgilendirmek. Mesela, bilim insanları yaptıkları çalışmalarında sonucunda bakıyorlar, araştırıyorlar. Eğer Dünya'ya taş çarpacağını düşünüyorlarsa söylüyorlar ve insanları bilgilendiriyorlar ki ona göre ki tedbirlerini alalım. Bizi koruyorlar.

2. He, çalışmalar bilimsel çalışmalar yaparak mesela bir şeye katkı bulunmak için yapabilirler. Mesela bilimsel deney atıyorum, mesela hayatı kolaylaştırmak amaçlı bir şeyler. İlaç ya da bir icat ya da tasarım aleti gibi bir şey yapabilirler. Hayatı kolaylaştırmak için öyle icatlar yaparlar.

3. Mesela bilim insanları bir bitkinin büyümesini takip ediyor olabilirler. Bir kamera koyup bitkinin önüne hareket etmeyecek şekilde onu bir 30 gün ya da bitkinin büyüme süresine göre o videoyu hızlandıra hızlandıra bakabilirler.

4. Şöyle bilim insanları bilimsel sınıflandırma yapabilirler. Mesela hani bilim adamları böyle mesela nasıl yaptıklarını bilmiyorum ama dolapları olur bence yani dolaplarının içinde işte aletleri edavatları var. Oraya ayırarak koyabilirler. Önlüğünü işte böyle etiketlendirir. Eşyalarını koyar daha kolay bulması için.

5. Bilim insanları çalışmaları ile ilgili beklentisi olabilir ve bu beklentisini kanıtlamaya çalışabilir. Eğer beklediği şeye çalışması sonucunda ulaşmışsa ve eee aynı bulduğunda onunla ilgi şey bir dosya haline getirir ve onunla bilimsel bilgi çıkartmış olur ya da onunla aynı çıkan şeyi söyler konuşmasını yapar onunla ilgili.

6. Araştırmacı: Bilimsel yöntemler denildiğinde aklına neler geliyor? Örneğin bir bilim insanının aklında bir soru var bunu cevaplamak istiyor. Mesela uzaydaki gök cisimlerini ya da COVID- 19 virüsünün özelliklerini incelemek istiyor olsun. Bu bilim insanı bu soruları yanıtlaması için kullanması gereken yöntemler nelerdir?
   Öğrenci: KOVID olan bir hastadan bilgi alabilirler hastalık boyunca ne yaşadıklarına dair bilgi alabilirler. Bu şekilde virüs ile ilgili bilgi toplamış olurlar ve bu insanları gözlemleme yapmış olurlar. Anlamak için kan tahlili de alabilirler.

7. Metot olarak mikroskop falan kullanıyorlar. Başka yöntemler büyüteç filan kullanıyorlar yani böyle pamuklu bir şey var DNA şeyi var. Onu kapsülünün içine koyuyorsun orada araştırıyorlar. Bir kutuya koyuyorlar onu çıkartıyor.

8. Bilimsel bilgi değişir. Şöyle bilimsel bilgi varsa bayağı bir test ettikten sonra değişiyor. Yani bir de bu bilginin kanıtlanmış olması da gerekiyor. Mesela diyelim ben bir düşünce attım sonra test ettim baktım kanıtladım bilimsel bilgi oldu. Ama ondan sonra deneyerek baktım bilimsel bilgi oldu. Ama bayağı bir deneyip bakıp da farklı bir şey bulunca sonra değişebiliyor.

9. Araştırmacı: Sence bilim insanları araştırmalarının sonuçları hakkında toplumu ve diğer bilim insanlarını bilgilendirmek isterler mi?
   Öğrenci: Çalışmamı diğer bilim insanlarına vermem paylaşmam. Kendime saklarım.
   Araştırmacı: Neden?
   Öğrenci: Kendi şeyim, ben keşfetmişim. Kendi çalışmamı o kadar geliştiririm ki piyasaya bir veririm hem zengin olurum hem ondan sonra insanların sevgisi bana karşı artar. Ne adamdı be derler. Ölünce de şanım artar.

10. Mesela bir çalışma yapıyordur ve dinine uygun olmayan bir şeye denk gelmiştir. Mesela Müslüman birinin çalışmasında Hristiyan birilerini araştırması ve onları anlamaya çalışması zor olabilir. Çalışmasını olumsuz etkiler, çalışması kötü yönde ilerler. Onu değiştirmek zorunda falan bile kalabilir.

11. Mesela çalışan iki bilim insanı birbirlerine bağırmamalardır. Birbirlerine ulaştığı bilimsel bilgiye karşı onları küçümsememelidir. Birlikte daha iyi şeylere ulaşabilirler. Topluca uğraşıp bu konuyu geliştirebilirler.

12. Öğrenci: Bilim insanları konferanslara katılabilirler ve bu yolla insanları çalışmalarıyla ilgili bilgilendirmiş olurlar.
    Araştırma: Peki bilim insanlarının yaptıkları diğer profesyonel aktiviteler nelerdir?
    Öğrenci: Toplantılara katılırlar ve araştırmaları üzerine konuşurlar. Ulaşmak istediği sonucu anlatırlar sonra bulduğu bilgileri anlatırlar.

13. Öğrenci: Mesela onunla ilgili bir testte zorlanıyorsam yani konuyu anlamadığımı düşünüyorum. Bir tekrar daha yapıyorum konunun üstünden bir daha geçiyorum.
    Araştırmacı: Peki bir konuyu öğrenip öğrenemediğini anlaman için testler senin için yeterli oluyor mu yoksa başka yöntemler kullanıyor musun?
    Öğrenci: Evet. Başka bir şey kullanmıyorum. Benim için yetiyor.

14. Araştırmacı: Tamam peki bir konuyu öğrenip öğrenemediği nasıl anlarsın?
    Öğrenci: …… (Cevap Gelmez).
    Araştırmacı: Mesela bir anını düşünebilirsin. Mesela bir durumla karşılaşacaksın veya bir şey olacak ve sen diyeceksin ki ben konuyu anlamamışım. Bunu ne zaman dersin? Yani ne ile karşılaştığı zaman bunu söylersin?
    Öğrenci: Bu tür şeyler bana olmaz ki.
    Araştırmacı: Yani ne öğrendiğini ya da bildiğini düşünmezsin öyle mi?
    Öğrenci: Hiç öyle hissetmem. Düşünmem.

15. Araştırmacı: Peki bir fen dersi ile ilgili öğrenme sürecini bahsetmeni istiyorum. Mesela 7.sınıfın ilk ünite fen konusu güneş sistemi ve galaksiler. Bu konuyu anlamak ve öğrenmek için neler yaptın?
    Öğrenci: Mesela…eee…diğer dersler gibi. Mesela etkinlikler yapıyoruz derste. Ben de onları silip yeniden yapıyorum. Bu kadar.
    Araştırmacı: Peki bir konuyu çalışırken kullandığın stratejiler var mı? Veya konuyu anlamak için yaptığın şeyler?
    Öğrenci: Teknik yok. Sadece okuyorum.
    Araştırmacı: Peki bir konuyu öğrenip öğrenemediğini nasıl anlarsın?
    Öğrenci: Bilmiyorum. Böyle sorular sormadım kendime daha önce.
    Araştırmacı: Yani bir konuyu öğrenip öğrenemediğini bilmiyorsun?

Öğrenci: Dediğim gibi okuyorum.

16. Dersler KOVID den önce daha etkiliydi. Online da zaten çok fazla anlayamıyorum ve zorluk yaşadığımı biliyorum. Ama bu negatif yönleri daha çok çalışarak telafi etmeye çalışıyorum. O yüzden derslerden önce mutlaka okuyorum ve derse hazır olmaya çalışıyorum. Dersten sonra da kitaptan tekrar okuyorum ve o konuyu çalışıyorum. Sonra da o konuyla ilgili test çözüyorum ve anlayıp anlamadığımı kontrol ediyorum.

17. Araştırmacı: Peki çalışmaların için bir planlama yapıyor musun?
    Öğrenci: Evet, yani amacıma göre değişiyor. Mesela öğretmen derslerden sonra ödev veriyor. Onları dersten hemen sonra yaptığım için, onlar için bir plan yapmıyorum. Ama derslerimi çalışırken yapıyorum. Öncelikle konuyu anlamak için zaman ayırıyorum ve sorular test çözüyorum.
    Araştırmacı: Örnek verebilir misin? Mesela mevsimler ve iklim işlediğiniz bir konu. Bu konu için nasıl bir planlama yaptın?
    Öğrenci: İlk başta konuyu tekrar ettim, kitabı okudum ve ne olduğunu anlamaya çalıştım. Diğer kaynaklardan mesela internetten de baktım. Öğretmenin verdiği soruları çözdüm. Bu plan için ilk başta kendi kendime düşündüm. Kedi kendime bu konuyu gerçekten ne kadar anladığımı ve düzgün anlayıp anlamadığımı sordum. Eğer bunu yapamamışsam konuya daha ağırlık verdim ve daha çok çalıştım.

18. Koyarım tabi yani hatta annem ile beraber yaptık. Günlük 2 saat oyun 5-6 saat ders yapıyordum ama tabi yaz tatilinde değil. Daha geçen sene 7. sınıfta böyle bir şey yapmıştım. Ama çok sıkılıyordum ya. Her şeyin sınırı olunca sıkılıyordum. Hiçbir şeyin sınırı olmayacak. İstediğim kadar her şeyi yapacağım. Öyle olacak yoksa bırakıyorum.

19. Mesela mevsimler ve iklim ile ilgili soru çözdüğüm zamanı hatırladım. Dünya'nın Güneş'e göre konumlarını düşünmüştüm. Mesela hangi konumda yaz ve kış oluyordu karıştırdım. Ve şey dedim…eee… haziranda Dünya Güneş' in alt kısmında kalıyordu. Eee.. Aralıkta ise üstte oluyordu. Böyle düşündüm. Sonra kafama bu şekilde kodladım kolayca hatırlayabilmek için. Fakat bunu kodlamadan önce, hatamı fark ettim ve konuyu tekrar ederek bunu düzelttim.

20. Araştırmacı: Peki soru çözdüğün zamanları hatırlamanı istiyorum senden. Soru çözdüğün anlardaki düşünme şeklin ile ilgili neler düşünüyorsun? Örneğin çok zor bir problemle veya durumla karşı karşılaştın. Bu anda ne yaparsın?
    Öğrenci: Eğer problem çok zorsa üzerinde çok düşünmem.
    Araştırmacı: Peki soru çözerken veya bir şeyler yaparken kullandığın stratejiler var mı?
    Öğrenci: Eee...ne stratejileri?
    Araştırmacı: Mesela kendine sorular sorar mısın bu soruları çözerken veya problemlerin alternatif çözümlerini arar mısın?
    Öğrenci: Yok hayır.
    Araştırmacı: Peki bu soruları çözerken veya düşünürken ne yaparsın? İç konuşmanda neler geçer?
    Öğrenci: İçimden konuştuğumu pek sanmıyorum.

21. Araştırmacı: Şimdi kısa süreliğini bir sınav anını canlandırmanı istiyorum. Bu anını hatırlayıp düşün lütfen (yarım dakika sonra).
Öğrenci: Tamam
Araştırmacı: Sınavı bitirdiğini düşünelim. Sınavdan sonra ne yaptığını kontrol eder misin ya da hiç düşünür müsün?
Öğrenci: Yok, hayır. Kontrol etme ihtiyacı hissetmem.
Araştırmacı: Tamam peki sınavlardan ayrı olarak düşünürsek eğer, genel olarak öğrenme sürecinin kontrolünü yapar mısın? Mesela bir konuyu öğrenip öğrenemediğini değerlendirme gibi bir sürecin olur mu?
Öğrenci: Genelde ders çalışmam. Çalışsamsa da yapmam. Neden uğraşayım ki?

22. Benim dayımın teleskobu vardı. Bir kere yıldızları izlemiştik, ayı ve evrelerini gözlemlemiştik. Hilal gördük, dolunay gördük, ayın evrelerini gördük. Bir ay boyunca baktık. Her hafta farklı bir ay çeşidi gördük ve bunları not aldım. Gözlemlerken aklıma şunlar da gelmişti. Ayı neden sürekli farklı şekillerde gördüğümüzü ve buna ne sebep oluyordu onu düşündüm. Sonra bunu öğretmene sordum derste. Bu sayede ayın evreleri konusu daha biz sınıfta işlemeden pekiştirmiş oldum ve konuyu öğrenirken işime çok yaradı. Mesela bu ayın evrelerinin isimlerini ve aralıklarını öncesinde gözlem yapmış olduğumuz için iyi biliyorum. [5th-H-RFN]

23. Şey feni anlamak için bol bol araştırma yapmak önemli bana göre. Bu sene insan vücudunu öğrendik ve kolay bir konu değildi. Bunu anlamak için çok çalıştım. Sadece bunun için değil hem konuları hem de fazlası için araştırma gerekli bence. Çünkü bizim öğrendiğimiz şeyler fenin ve bilimin hepsi değil. Bilim çok daha fazlası. Hatta kitapta bazı yerlerde araştırma yapalım veya videolarda EBA da ve benzeri şeyler de araştırma yapalım diyor. Anlamak için de bol bol araştırma yapıyorum öyle yani.
Araştırmacı: Araştırma derken nasıl bir araştırma mesela örnek verebilir misin?
Öğrenci: Mesela geçen günkü ödev de bir araştırma vardı. Kan pompalama, insanlarda ve hayvanlarda kan pompalama işleyişini araştıracaktık. Bunu araştırdık ama ben mesela hayvanlarda en çok en hızlı kan pompalayan hayvan gibi daha fazla araştırma yaptım, bilim dergisi okudum ve bir araştırma buldum. Zürafa mesela dakikada 75 kere kalbi atıyormuş ve dakikada 180 litre kan pompalıyormuş.

24. Fen dersi ile ilgili yani fen dersi daha çok araştırma yaparak öğrenebileceğimiz bir ders bana göre yani sayısal dersler matematik de öyle. Çok araştırma yaparım mesela kitabın şu kısmında anlamadıysam aileme sorarım yani sorabileceğim çevredeki kişilere sorarım. Hiç kimseden bir cevap bulamazsam internetten bakarım. Mesela fen dersinde insan vücudu önemli ve zor bir konuydu bana göre çünkü ilk defa insan vücuduyla karşılaştım ve öğrenmek için çoğu kaynağa başvurdum ve araştırma yaptım. Mesela EBA olur, classroom gibi, Eğitimhane gibi sonra Vitamin gibi sitelere başvurdum, bu konuyla ilgili yapılan araştırmaları okudum.

25. Bilim insanları beklentilerini bulduğu sonuçlarla kanıtlayabilir yani sonuçlarla aynı da olabilir farklı da olabilir. Mesela beklentilerini karşılayamayabilir çünkü bir insanın düşünceleri sonuçlarla aynı doğrultuda olmadığından farklı çıkabilir. Her bilim insanının düşünme şekli ve yöntemi aynı olmayabilir. Mesela ben konuya başka türlü yaklaşırım ve bu yüzden farklı bir varsayımım olabilir. Fakat bazen deney sonuçlarında beklentilerini de bulabilirler yani düşündüklerini tam karşılığını da

verebilir. Bu kişinin düşünme şekli ve bilmesiyle alakalı. Yani sonuç olarak varsayımlar karşılanabilir daha farklısını da verebilir.

26. Öğrenip öğrenemediğimi…kendime sorular sorarım ve bir başıma tek başıma sorular çözmeye çalışırım. Mesela öğrendiklerimi birisine konuyu anlatmaya ve özetlemeye çalışırım. Eğer bunları yapamazsam kendimin de konuyu iyi anlamadığımı düşünürüm ve daha çok çalışmam gerektiğini anlarım.

27. Herkesin farklı öznel yargısı vardır. Herkes farklı düşüncelere sahip oluyor o yüzden kişisel özelliklerinden dolayı bilimsel çalışmalar etkilenebilir. Mesela farklı bilim insanları vardır, aynı şey hakkında bile farklı düşüncelere sahip olabilirler. Bu mesela ben de bile oluyor. Ben arkadaşlarımın düşüncelerine göre başka bir şey savunabiliyorum. Farklı bir bilim insanı vardır farklı düşünceye sahiptir. Yani kişisel özellik mesela onu etkiler.

28. Şöyle, bu konuyu nasıl öğrendiğimi anlatayım. Ben bir şey öğrenmeye çalıştığım an hocaya işte mesela vücut hücrelerinde ne gerçekleştiğini anlamaya çalıştım, ilk başta onları anlamaya çalıştım. Mesela onları aklımda canlandırdım ve aklımda ezberledim çünkü onun bir tanesi vücut hücresinde gerçekleşti şöyle oldu filan dedim. Onla ilgili örneklere sordum hocaya. Mesela hoca anlattıktan sonra onu araştırdım ve örneklere de baktım. Fakat bu hücrelerdeki mutasyonlar ile ilgili bilmediğim şeyler de vardı mesela. Bunu şöyle düşündüm işte nükleotidlerin yapısı ya da yerinin değişmesi ya da dışarıdan bir şey yüzünden diye düşündüm. Örneklere baktım onlarla ilgili nasıl olduğunu filan düşündüm. Gerçekten de öyle oluyordu öğrendiğim o bilgiye göre de. Ve onlarla ilgili kâğıt çıkartıp not tutuyordum. Orada unutmam gerekenleri yazıyordum.

29. Araştırmacı: Peki devlet bilim insanlarının yaptıkları çalışmaları etkileyebilir mi?
Öğrenci: Etkilemez ya neden etkilesin ki?
Araştırmacı: Peki bilim ve parasal meseleler birbiriyle ilişkili midir?
Öğrenci: Eşyalar için filan evet
Araştırmacı: Peki bu bilimsel çalışmalar ve araştırmalar nerelerde gerçekleşebilir
Öğrenci: eee… evet. İsmi aklımın ucunda ama
Araştırmacı: Düşündüğün yer nasıl? Tarif de edebilirsin.
Öğrenci: ….. (Cevap Gelmez)

30. Araştırmacı: Şimdi kısa süreliğini bir sınav anını canlandırmanı istiyorum. Bu anını hatırlayıp düşün lütfen (yarım dakika sonra).
Öğrenci: Tamam
Araştırmacı: Sınavı bitirdiğini düşünelim. Sınavdan sonra ne yaptığını kontrol eder misin ya da hiç düşünür müsün?
Öğrenci: Yok, hayır. Kontrol etme ihtiyacı hissetmem.
Araştırmacı: Tamam peki sınavlardan ayrı olarak düşünürsek eğer, kendi öğrendiklerini ya da yaptıklarını değerlendirme gibi bir sürecin olur mu?
Öğrenci: eee.. Emin değilim. Genelde ders çalışmam. Çalışsamsa da yapmam. Neden uğraşayım ki?

APPENDIX G: CONSENT FORM

Veli Bilgi ve Onam Formu

Araştırmayı Destekleyen Kurum: Boğaziçi Üniversitesi
Araştırmanın Adı: Ortaokul Öğrencilerinin Bilim Doğası Anlayışları ve Üst biliş Farkındalıkları arasındaki İlişki
Proje Yürütücüsünün Adı: Prof. Dr. Ebru Kaya
E-mail Adresi:……………………. **Telefonu:** ……………….
Araştırmacının Adı: Dilara Gören
E-mail Adresi: …………………… **Telefonu:**……………….

Sayın veli,

Boğaziçi Üniversitesi, Eğitim Fakültesi, Matematik ve Fen Bilimleri Eğitimi Bölümü'nde yüksek lisans yapmaktayım. Ortaokul öğrencilerinin bilim doğası anlayışları ve üst biliş farkındalıkları arasındaki ilişki konulu araştırmayı incelemek üzere tezim kapsamında bu araştırma yürütmekteyim. MEB ve okul müdüründen araştırma için gerekli izinleri ve onayları aldım. Eğer çocuğunuzun bu araştırmaya katılmasına izin verirseniz araştırmaya önemli bir katkı sağlayacaksınız. Formu doldurmadan önce size araştırma ile ilgili bilgi sunmak isterim. Araştırma ile ilgili bilgilerden sonra eğer çocuğunuzun bu çalışmaya katılmasını onaylarsanız bu formu zarf içerisinde fen bilimleri öğretmenine ulaştırınız.

Bu araştırma kapsamında çocuğunuzun bilimin doğası ile ilgili düşünceleri ve üst biliş farkındalıkları ile ilgili iki farklı anket dağıtılacaktır. Bilimin doğası anketi öğrencilerin bilimin ve bilim insanlarının çalışma şeklini (bilimin amaçları, yöntemleri, uygulamaları vb) ile ilgili düşüncelerini anlamak üzere uygulanacaktır. Üst biliş farkındalık testi ise öğrencilerin kendi anladığını ifade etme, planlama ve ders çalışma teknikleri ile ilgili yaklaşımlarını anlamak için uygulanacaktır. Bu anketlerin sonuçlarına bağlı olarak yaklaşık 5 öğrenci ile görüşme yapmam gerekmektedir. Bu görüşmeler öğrencilerin kâğıt üzerinde ifade etmek istedikleri bilgileri daha iyi anlamak amacıyla sözel olarak kendilerini daha iyi açıklamaları için yapılacaktır. Görüşmeler sırasında benim konuşmayı daha iyi anlayabilmem ve hatırlayabilmem için sizin de izniniz doğrultusunda kısa notlar ve ses kaydı almam gerekebilir. Bu görüşmelerin maksimum 1 saat süresinde olması düşünülmektedir ve okul içerisinde okul yönetiminin uygun gördüğü mekânda öğrencilerle bireysel görüşülecektir.

Bu araştırma bilimsel amaçla yapılmaktadır ve katılımcı öğrencilerin gizliliği esas tutularak yapılacaktır. Çalışma öğrenciler için hiçbir risk içermemektedir. Öğrencinin çalışmaya katılıp katılmaması durumu ders notlarını hiçbir şekilde etkilemeyecektir. Yapılan görüşmelerin kayıtlarının korunması amaçlı taşınabilir USB bellekte kaydedilip çalışma bittiğinde silinecektir. Çalışma sonucu elde edilecek veriler öğrencilerin kişisel bilgileri gizli tutularak bilimsel amaçlı yayınlarda kullanılabilir. Bu kapsamda öğrencilerin kişisel bilgileri kesinlikle kullanılmayacak takma isimler veya rastgele numaralar verilerek kullanılacaktır. Araştırma seçilen sınıflarda uygulanacak olup veli onayı alınan öğrencilerin gizliliği korunarak veriler kullanılacaktır. Araştırmaya katılmayacak öğrencilerin verileri kullanılmayacaktır. Araştırmaya katılmak isteğe bağlıdır ve öğrenciler istedikleri zaman çalışmadan çekilme haklarına sahiptirler. Çalışmadan çekilen öğrencilerin verileri (anketler, görüşmeler vb) silinip yok edilecektir. Bu çalışmaya katılmayı kabul eden kişiler için bir ücret veya başka bir ödül söz konusu değildir. Araştırma ile ilgili haklarınızı Boğaziçi Üniversitesi Sosyal ve Beşerî Bilimler İnsan Araştırmaları Etik Kurulu (SBINAREK)'na başvurabilirsiniz. Araştırma ile ilgili ek sorularınızı için proje yürütücüsü olan Boğaziçi Üniversitesi, Matematik ve Fen Bilimleri Eğitimi Bölümü Öğretim Üyesi Prof. Dr. Ebru Kaya ile iletişime geçebilirsiniz. (E-mail: ebru.kaya@boun.edu.tr). Eğer çocuğunuzun bu araştırmaya katılmasını kabul ediyorsanız, lütfen bu formu imzalayıp fen bilimleri öğretmenlerine iletin.

Ben, (öğrenci velisinin adı) ...., yukarıdaki metni okudum ve çocuğumun katılması istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. Çalışma hakkında anlayamadığım yerleri danışıp sorma imkânım oldu. Araştırmaya katılmanın isteğe bağlı olduğunu, çocuğumun istediği zaman sebep belirtmeden çalışmadan çekilme hakkına sahip olduğunu ve bunun sonucu bir olumsuzluk ile karşılaşmayacağını anladım. Çalışmaya katılmayı kabul ediyorum ve karşılığında ödül veya ücret gibi bir beklentim yoktur.

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

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

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

APPENDIX H: PERMISSIONS FOR FIGURES

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