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ARTICLE

How Do University Students Perceive the Nature of Science?

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Abstract
The paper presents an empirical study on university students' perceptions of nature of science (NOS). NOS is framed in terms of the cognitive, epistemic, and social-institutional systems of science based on the Family Resemblance Approach (FRA) (Erduran and Dagher 2014; Irzik and Nola 2014; Irzik and Nola, SCED 20:591–607, 2011). FRA includes the following categories: aims and values of science, scientific practices, scientific methods, scientific knowledge, and social-institutional aspects of science. A study was conducted with 15 university students from science and non-science majors at a public university in Turkey. Individual interviews were conducted, and qualitative data analysis was carried out. The educational adaptation of FRA was previously referred to as RFN (or the Reconceptualised FRA to NOS) (Kaya and Erduran, SCED, 25(9–10):1115–1133, 2016). In this study, categories of RFN were identified in students' responses. The results show that non-science majors (e.g., philosophy, sociology) have an enhanced perception of NOS in comparison to science majors (e.g., physics, computer engineering). It is also observed that university students were not explicitly aware of different aspects of NOS and their perceptions do not represent a holistic account. The study suggests that RFN can be used as a framework to explore university students' perceptions of NOS and their perceptions of NOS are linked to their domain-specific educational background.

1 Introduction

Over the last decades, the concept of nature of science (NOS) has become predominant in the context of science education. Science educators and educational researchers

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provided a range of different approaches to explain NOS (e.g., Abd-El-Khalick and Lederman 2000; Allchin 2013; Erduran and Dagher 2014; Matthews 2012). One of the most influential perspectives on the definition of NOS in science education context was proposed by Abd-El-Khalick and Lederman (2000). They offered the “consensus view” and discussed the major tenets of NOS by focusing on the history and philosophy of science (McComas 1998; Osborne et al. 2003). Several alternative approaches to the consensus view were provided to underline different aspects of NOS (e.g., Allchin 2013; Duschl and Grandy 2011; Erduran and Dagher 2014; Irzik and Nola 2014; Matthews 2012). Additional concepts such as process of inquiry, aims and values, methods of science and scientific knowledge, politics, economy, professional structures, advertising, and commerce of science are highlighted through these alternative arguments. In this fashion, alternative perspectives covered the cognitive, epistemic and social systems of science and allowed researchers and science educators to gain broader understandings of what science is about.

Driver, Leach, Miller, and Scott (1996) emphasized the potential benefits of learning and understanding of NOS for students. They claimed that understanding NOS helps students to raise awareness about socio-scientific issues, understand the process of science, comprehend norms of scientific society, and appreciate science as one of the main elements of society and culture. In this direction, one of science education’s most important objectives is not only learning the content of science, but also the nature of science. This mode of science education trains scientifically literate citizens who have an awareness about essential and integral components of science (Osborne et al. 2003). Therefore, in the context of higher education, it is important to train scientifically literate students who can explain different aspects of science holistically. Since university graduates from different majors (science and non-science majors) potentially become the future teachers, economists, physicists, politicians, philosophers, sociologists, or engineers of our society, it is important for them to make sense general NOS concepts in order to become informed and competent professionals who can make higher-level decisions on science-related issues in daily life settings. For instance, we should expect future science teachers who can explain the nature of scientific knowledge and variety of scientific methods to students or a health official who can inform public about the controversial issues of vaccine use or food safety by using scientific evidence. In short, providing task-specific awareness about the different aspects of science is essential for all members of society.

In line with the points mentioned above, it is significant for us to work with university students in order to determine their NOS perceptions, provide effective instructional strategies to improve their understanding of NOS, and develop scientifically literate future college graduates and scientists (Liu and Tsai 2008). It is also important to work with university students from different majors in order to understand the differences in their NOS perceptions. This allows us to provide alternative solutions that will increase their understanding of different aspects of science. In that sense, considering NOS perceptions of both science (students who have natural science-based courses, such as engineering, physics, and chemistry) and non-science majors (students who have social science-based courses, such as philosophy, sociology, primary education) can provide a broad and versatile picture in terms of illustrating university students’ general view of science. In literature, although there are several empirical studies on university students’ perceptions and understandings of NOS (e.g., Abell and Smith 1994; Griffiths and Barry

1993; Liu and Tsai 2008; Miller et al. 2010; Parker et al. 2008), there is limited research addressing the majors of the university students and their perceptions of NOS with respect to cognitive, epistemic, and social-institutional aspects of science.

In this paper, we report the findings from a funded project. This funded study addresses the question of how university students from science and non-science majors perceive the NOS in terms of aims and values, scientific practices, methods, scientific knowledge, and social-institutional systems of science. In other words, we aimed to investigate university students perceptions of different aspects of NOS by considering the impact of their domain-specific courses (Ryder and Leach 1999). We chose Erduran and Dagher's (2014) Family Resemblance Approach (FRA) to NOS as a theoretical base of the study. FRA is one of the recent and comprehensive accounts of NOS (Erduran and Dagher 2014; Irzık and Nola 2014). Kaya and Erduran (2016) produced the terminology of "Reconceptualized Family Resemblance Approach to Nature of Science" or RFN in order to underline the distinction between the educational applications of FRA and its philosophical counterparts. RFN relates to the same framework of FRA to NOS in science education (Erduran and Dagher 2014). In comparison to previous approaches (e.g., consensus view, whole science), RFN is a holistic perspective that promotes the understanding of science as the conception of dynamic cognitive, epistemic, and social-institutional systems. It includes a set of categories that are aims and values, scientific practices, methods, scientific knowledge, and social-institutional aspects of science. In that way, the framework presents a meta-level perspective. The framework has been studied in a number of empirical studies in different contexts (e.g., BouJaoude et al. 2017; Karabaş 2017; Kaya et al. 2019). However, there is still a limited number of research to explain university students' perceptions of NOS with respect to the categories of RFN. Therefore, this study will make an empirical contribution to the limited amount of literature on NOS in the higher education context. Overall, we have two equally significant interests: to apply RFN framework in order to understand how university students think about NOS and to compare science and non-science majors' perceptions of NOS.

The paper is organised in five major sections. First, we defined the problem and purpose of the study, then we explained the significance of the study. Second, we briefly defined and characterized RFN and provided background information about the context of higher education in Turkey. We also identified the terms of "science" and "non-science" majors by giving details about the program contents of the departments. Third, we provided the methodology of the study through the introduction of the participants, data sources, and analysis procedures. Fourth, we presented the findings by describing the landscape of the data and sharing general trends. Finally, we put an emphasis on discussion and implications for advancing equitable science teaching and learning experiences across higher level education settings.

The next section provides information about a holistic account for the characterization of NOS. We introduced the formation process, the main visual of the framework, and the different categories of RFN as a theoretical foundation of the study.

2 Theoretical Framework

2.1 Family Resemblance Approach (FRA) to Nature of Science (NOS)

The FRA to NOS provides a conception which classifies the categories of science in a holistic and inclusive system (Erduran and Dagher 2014). Basically, the roots of FRA to NOS relies on

Irzik and Nola's (2014) adapted Wittgenstein's generic notion of the family resemblance idea. Irzık and Nola (2014) applied Wittgenstein's idea of family resemblance to NOS by considering different branches of science as the members of a "family" who acquired similar and specific characteristics. While Irzık and Nola (2014) adapted Wittgenstein's idea of family resemblance to NOS, Erduran and Dagher (2014) adapted Irzik and Nola's framework for science education by adding visual images, three different categories about societal and cultural factors of science, and pedagogical and educational strategies about NOS.

With the intent of illustrating the educational adaptations of FRA for science education purposes, Kaya and Erduran (2016) coined the term of Reconceptualized FRA to NOS, RFN. They distinguished the educational adaptations of FRA from its philosophical counterparts (Kaya et al. 2019). While RFN relates to the same framework of FRA to NOS which is developed by Erduran and Dagher (2014), it also represents the framework's empirical adaptation in teacher education (Kaya et al. 2019).

Erduran and Dagher (2014) considered science as a set of cognitive, epistemic and social-institutional systems. The categories in each system provide a sound rationale in terms of understanding what science is about and what kind of implications can be taught in various ways during science lessons. Erduran and Dagher (2014) noted the family resemblance approach to NOS not as one of many ways to learn and teach about NOS, but as a comprehensive and sophisticated perspective for framing NOS-related issues for science education context. The categories of FRA to NOS cover a set of ideas about science which are not meant to be distinct and exclusive (Dagher and Erduran 2017). Rather, they relate to one another in an interactive and dynamic way. FRA also characterizes scientific domains and it helps learners to understand their unique and shared attributes. In other words, the framework can accommodate for both domain-specific and domain-general features of science (Erduran and Dagher 2014). Another notable feature of Erduran and Dagher's (2014) work is about introducing visual images to summarize and comprehend some key ideas about NOS. Erduran and Dagher (2014) claimed that benefiting visual images can potentially help science educators in terms of providing pedagogical and instructional content about NOS (e.g., Fig. 1). In that way, the perspective presents a unique approach in terms of providing a collective, visual, and holistic treatment of science.

The interplay between the categories of FRA to NOS are visualized by Erduran and Dagher (2014) through "FRA Wheel" (see Fig. 1). They considered that understanding NOS in the context of science education requires an appreciation of a collective and holistic account of science which is illustrated through the eleven categories in the wheel. The wheel represents all cognitive, epistemic, and social-institutional categories of science. While the inner circle of the wheel represents the cognitive and epistemic categories of science, the second and third circles represent the social-institutional categories of science. The cognitive and epistemic categories of science are aims and values of science, scientific practices, methods and methodological rules of science, and scientific knowledge. The social-institutional categories of NOS are specified as scientific ethos, social certification and dissemination, social values, professional activities, political power structures, social organization and interactions, and financial systems. The wheel provides a notable contribution in terms of representing interactive, visual, and holistic account of NOS.

Aims and values of science are considered in relation to epistemic, cognitive, social, cultural, political, ethical, and moral perspectives (Erduran and Dagher 2014). The authors explained the epistemic and cognitive aims and values of science through the concepts of critical examination, accuracy, objectivity, novelty, and empirical adequacy. The social and

Fig. 1 FRA Wheel: Science as a cognitive-epistemic and social-institutional system (Erduran and Dagher 2014, p. 28)

cultural values are also considered an essential part of the growth of scientific knowledge (Allchin 1999; Longino 1995). Social aims and values are explained through the terms of human needs, honesty, equality of intellectual authority, and decentralizing power.

Scientific practices do not only include epistemic practices but also cover social-institutional and cultural practices of science (Erduran and Dagher 2014; Jimenez-Aleixandre et al. 2000). They used a pedagogical tool called "Benzene Ring Heuristic" to promote learning and teaching of the scientific practices. The heuristic includes epistemic, cognitive, and social-institutional practices to provide a holistic and nuanced interpretation. Epistemic and cognitive scientific practices are reflected by real world, explanations, model, prediction, activities, and data. Social and institutional practices are explained by the concepts of representation, discourse, reasoning, and social certification. They (2014) also underlined that scientific practices such as observation, experimentation, and classification all contribute to scientists' data collection process. These practices utilize a variety of scientific methods to gather historical, observational, and experimental data. Epistemic and cognitive practices, such as modeling, explaining, and predicting, are connected to discursive practices involving reasoning and argumentation.

Methods and methodological rules of science are explained through various scientific methods, which are elaborated by evidence in order to provide explanatory consilience (Erduran and Dagher 2014). By focusing on scientific methods, Erduran and Dagher (2014) referred to the variety of systematic approaches and methodological rules that scientists use to reach reliable knowledge. They claimed that scientists engage in disciplined inquiry by using a variety of investigative, observational, and analytical methods to form scientific and reliable evidence while constructing models, laws, and theories in a given science discipline, which also shape and guide particular methodological rules. They also pointed out the deficiencies of the popular and stereotypical depiction of the scientific method. The depiction includes the scientific steps that ask questions, do background research, construct and test hypothesis by conducting experiments, analyze the data, and draw conclusions about the problem. This type of characterization is deeply problematic and unadaptable in some contexts (such as in the fields of astronomy and geology) and scientific domains where it is impossible to conduct experiments (Dagher and BouJaoude 2005; Driver et al. 1996). Therefore, Erduran and Dagher (2014) presented observational and experimental types of scientific methods through manipulative, non-manipulative, hypothesis testing, and non-hypothesis testing methods. These four forms of scientific methods and methodological rules indicate how different methodologies work synergistically together to gain a variety of evidence and provide explanatory consilience.

Scientific knowledge is considered as a concept that grows by development and extension of theories, laws, and models (TLM) to explain a phenomenon about the universe (Erduran and Dagher 2014). In that sense, theories, laws, and models are different forms of knowledge and they work together to generate and validate new sets of knowledge by providing coherent explanations about specific concepts. Explanations also act as a glue to form relationships among the TLM components (Sandoval and Reiser 2004). The combination of theories, laws, and models provides an opportunity to articulate different forms of knowledge. The key point in the discussion is that scientific knowledge in the form of TLM comes in taxonomies. Different sense and categories of theories, laws, and models prevent confusion about the knowledge formation, diversification, and comparable differences of one another (Erduran and Dagher 2014). Moreover, TLM framework reflects the certain structures of the different disciplines. All branches of science use theories, laws, and models as the three different forms of knowledge. Additionally, TLM is a domain-specific concept (Duschl 1994; Lakatos 1978). For instance, atomic theory, the periodic law of elements, and molecular models contribute to the understanding of the structure of matter (Erduran and Dagher 2014). These various knowledge forms provide a base for understanding and explaining the concept of atom.

Social and institutional systems of science cover societal, financial, political, cultural, and contextual aspects of science (e.g., Akgun and Kaya 2019; National Research Council, 2012; Zeidler et al. 2005). Erduran and Dagher (2014) emphasized the concepts of professional activities, social certification and dissemination, scientific ethos, social values, social organizations and interactions, political power structures, and financial systems of science to explain social and institutional systems of science. For instance, while they clarified the process of social certification and dissemination through the presentation of findings at conferences, producing manuscripts, and publishing articles in reviewed journals, they explained social values through the concepts of social utility, respect for the environment, and freedom.

Overall, FRA is a holistic perspective that promotes the understanding of science with the conceptions of cognitive, epistemic, and social-institutional systems of science. In that way, the framework presents a meta-level perspective for science education. Classification of the categories of science provides a whole and inclusive system. Moreover, the categories present the characteristic of domain specificity, which means each category focuses on the similarities and differences of various branches of science instead of considering science as one general concept. This conceptualization can be considered as an account that potentially motivates students and provides visual teaching tools for teachers in a coordinated fashion (Erduran and Dagher 2014).

Besides mentioning the theoretical value and definition of FRA, understanding how the components of FRA is key for appreciating its practical value, viability, and applicability for guiding instruction and curricula is also essential. From a curriculum perspective, FRA implies the necessity of reconceptualizing concepts by integrating categories into each other, such as integrating aims and values of science into scientific methods, discovering practices while engaging with methods, or considering financial systems and political power structures when they influence the direction of the science (Dagher and Erduran 2017; Erduran and Dagher 2014). Additionally, in order to support the integration of different categories of NOS, Erduran and Dagher (2014) provide a set of visual tools, which they call "generative images of science." These images potentially help teachers in terms of guiding students about the choices of research questions and methods, organizational structures of the research, and cultural and societal values that influence scientific activities (Erduran and Dagher 2014). These visual tools can also support students' meta-level understanding of NOS (Kaya et al. 2019). Overall, FRA and in particular RFN represents an organizational and pedagogical scheme for relating different categories of NOS in a coherent fashion. It allows appreciation and understanding of how different categories of science can work together as a whole system.

In terms of the studies using RFN, the framework provides a comprehensive approach to implementing broader understandings of NOS in K–16 curricula. It also provides fruitful research opportunities by providing new sets of questions and methodologies for science education. For example, RFN has been studied empirically in the analysis of curriculum frameworks (Erduran and Dagher 2014; Kaya and Erduran 2016), textbook analysis (BouJaoude et al. 2017; McDonald and Abd-El-Khalick 2017), teacher education (Kaya et al. 2019; Saribas and Ceyhan 2015), and elementary science education contexts (Alayoglu 2018; Karabaş 2017). RFN has also informed discussions with science faculty in higher education contexts (Dagher 2015), and the framework has been taught in graduate-level courses in Turkey and Taiwan. One of the visual tools within the RFN that covers scientific practices, namely, the Benzene Ring Heuristic, has been used with pre-service science teachers (Erduran et al. 2018; Erduran et al. 2015) and in workshops in Lebanon and Turkey (Dagher and Erduran 2017; Erduran et al. 2015). In these studies, it is observed that RFN provides a practical and effective vision for NOS-related science content and evidence-based practices in science education. However, although the RFN framework has been studied in several different contexts, there are still a limited number of research projects addressing university students' perceptions of NOS within the framework of RFN. Therefore, we aim to make an empirical contribution to the limited literature in terms of reflecting university students' understandings of NOS within the RFN framework.

The next section provides insight on the previous research regarding university students' perceptions of NOS. Since the main concern is to understand university students' perceptions of NOS in relation to their majors, it is beneficial to cover different perspectives and findings from previous studies.

2.2 Research on University Students' Perceptions of NOS

Several lines of research have examined university students' perceptions of NOS in terms of epistemic and cognitive aspects of science (e.g., Griffiths and Barry 1993; Hofer 2000; Liu and Tsai 2008; Parker et al. 2008; Schommer 1993). Most of these studies concluded that students' academic majors and courses in their programs might influence their learning experiences and these experiences are connected to their epistemological perceptions of NOS. Moreover, these studies suggested that university students' epistemological perceptions of NOS vary with respect to their disciplines and domain-specific experiences. Such claims build upon the argument that academic disciplines have different epistemological practices and knowledge structures.

For example, Liu and Tsai (2008) examined whether science and non-science major students have different scientific epistemological views. A multidimensional instrument developed by the authors was used to assess differences in university students' epistemological views of NOS. They found that science majors have less sophisticated perceptions in terms of theory-laden and cultural-dependent aspects of science than non-science majors. The study also implies that science majors might be involved longer in an epistemic environment which described scientific knowledge as universal and objective. Miller, Montplaisir, Offerdahl, Cheng and Ketterling (2010) also investigated the NOS views of science and non-science undergraduate students through introductory environmental science and upper-level animal behavior courses. Their analysis results revealed that students from both science and non-science majors are relatively informed about scientific theories and observations. However, they have uninformed views about the differences between scientific theories and laws, and the existence of diverse scientific methods. Parker et al. (2008) explored atmospheric science students' views about NOS by asking questions such as "What science is about and how it works?" and "What are the aims, products, and methods of science?". According to the results, most university students who are majoring in science maintain the misconception that science establishes facts and proves accurate truths (Parker et al. 2008). The results of these two studies support the indicated idea that the students, especially from science majors, have less sophisticated ideas in the epistemic and cultural-dependent aspects of science than non-science majors. These studies also revealed the differences in scientific epistemological perceptions of students across different majors (Miller et al. 2010; Parker et al. 2008).

More recently, Leung, Wong and Yung (2016) examined the non-science majors' capacities of evaluating scientific news. Findings of the study showed that participants tended to focus more on cognitive dimensions of science rather than social or epistemological dimensions in their evaluation. News reports on socio-scientific issues tended to reveal more responses in terms of explaining the social aspect of science than news reports about scientific research. In other words, non-science majors have a high capacity to draw upon the cognitive aspects of science despite their limited science background. Overall, result of these previous studies suggests that students' majors affect their epistemological perception of NOS. Hence, the academic experiences of students may play an important role in impacting students' perceptions.

Finally, the studies in literature are mainly shaped by two points of criteria. First, the researchers mostly used consensus view or previous NOS conceptions in order to build their studies' conceptual frameworks. Therefore, students mostly considered science in terms of different tenets of NOS (such as tentativeness of scientific knowledge, observations and inferences, and scientific theories and laws) (Lederman et al. 2002). Second, they mostly emphasized students' perceptions of epistemological and cognitive aspects of NOS. There is a limited focus in terms of understanding students' perceptions about social, institutional, financial, and political aspects of science (Leung et al. 2016). In other words, while learners' views about the nature of scientific knowledge became prominent in most of the research, there is limited focus on students' perceptions about social, financial, political, cultural, and institutional aspects of science. This study elucidates a new and different point of view in terms of focusing on not only epistemic and cognitive aspects of science, but also social, financial, political, cultural, and institutional aspects of science by comparing university students' academic backgrounds through their majors.

The next section provides information about the context of higher education in Turkey. Since the students from a university in Turkey are the participants of this study, and academic majors of the students are one of the main variables, it is crucial to illustrate the content of academic programs and general course objectives of the selected majors, departments, and faculties in Turkey.

2.3 Background of the Higher Education in Turkey

The Council of Higher Education (YÖK) has a responsibility to construct the academic, administrative, and institutional aspects of higher education in Turkey (YÖK 2014). All higher education institutions have combined under the roof of YÖK. All academies, universities, and educational institutions follow the program and course structures determined by the council (YÖK 1998). As it is declared on the websites of the faculties for the selected university and instructions of YÖK, each faculty offers students some required and elective courses during their undergraduate program. The required courses are mostly mass courses and most of the students from each major have to enroll in these courses. At the same time, elective courses are selectional courses in which students are free to choose according to their academic program. These elective courses are mostly related to humanities, social sciences, or natural sciences (YÖK 2014).

In this study, the participants were the university students from 12 different departments that are bounded to faculty of arts and sciences, faculty of education, and faculty of engineering. We classified these departments as science and non-science majors with respect to their course contents and program structures. We classified these five departments which are philosophy, sociology, psychology, foreign language education, and pre-school education as non-science majors. We also labeled these seven departments which are physics, chemistry, science education, computer education and educational technology, industrial engineering, computer engineering, and chemical engineering as science majors.

Students from non-science majors do not enroll in any obligatory theoretical or laboratory-based natural science courses, such as physics, biology, or chemistry (YÖK 2014). On the contrary, students mostly enroll in history, psychology, humanities, language, philosophy, research-based courses, and academic orientation-based courses (Faculty of Arts and Sciences 2020). For instance, students from non-science majors enrolled in courses such as "Research Methods in Applied Linguistics," "Culture and Society," "Politics, Religion, and Social Change," "Sociology of Gender," "Philosophy of Science," "Scientific Reasoning," "Applied Ethics," and "Epistemology." As it is indicated in the website of the departments, the goals of these particular courses are to introduce students with the meaning and function of economic, political, and social dynamics of society, and to help them discover the forms of power, authority, and control in different social and cultural settings (Faculty of Arts and Sciences 2020). For example, while one of the sociology courses of "Culture and Society" investigates the relationship between culture and society with special emphasis on context and change, the course of "Sociology of Gender" provides inquiry on the relation between gender and social structure by examining the position of women in society and their access to the economic and political spheres, and focusing on contemporary moral issues, ethics, and moral justification. These particular courses may provide a perspective about the social context of science and may help students increase their limited perceptions about how the scientific enterprise works, and how social structures, and issues affect the development of science. Furthermore, engaging students in social aspects of science (e.g., gender, culture, and race issues) may promote ethical awareness and understanding of students. Overall, offering courses which cover balanced, realistic, and holistic accounts of science may provide a better understanding of the nature of science for students in terms of acknowledging not only epistemic and cognitive systems of science, but also social-institutional systems. Furthermore, “Philosophy of Science” and “Scientific Reasoning” courses are offered by the department of philosophy. The goals of these courses are understanding the goals of science and explaining the concepts of scientific explanation, theory construction, the use of models, confirmation of hypotheses, scientific inquiry and reasoning, and hypothetical-deductive and statistical methods. These particular courses are also connected to our NOS account and categories of the RFN. Through these epistemological courses, non-science majors may get exposed to the nature of scientific knowledge and scientific methods, social and cultural values of science, the existence of social organizations, and political and economic aspects of science. The contents of the courses in the non-science majors mostly intersect with the categories of RFN. In that sense, working with these non-science majors is crucial to understand these students’ perceptions and the effect of taking such courses which are related epistemic, cognitive, and mostly social-institutional aspects of RFN.

On the other hand, students from science majors enroll in theory and laboratory-based natural science courses, which mainly cover the concepts of physics, biology, chemistry, and math. These students also can enroll in a limited number of humanity and social science-based elective courses. For instance, “Quantum Physics,” “Classical Mechanics,” “Basic Concepts in Modern Physics,” “Fundamentals of Chemistry,” “Organic Chemistry Laboratory,” and “Modeling and Optimization” are some of the courses that science majors enroll in (Faculty of Engineering 2020). The main goals of these courses are to help students to understand the process of collecting and analyzing empirical data through observation and experimentation, to make inferences about findings, design, and conduct experiments, and to interpret data to meet desired needs within realistic restraints such as environmental, health, safety, and sustainability issues. When we look at the content and goals of these particular courses, students from science majors mostly learn or consider the cognitive and epistemic aspects of science through the focus of scientific knowledge, practices, and methods. They primarily have an opportunity to apply knowledge of mathematics, science, engineering, and technology, rather than focusing on societal, cultural, economic, and political aspects of science.

3 Methodology

3.1 Research Design

This study is a funded project that includes qualitative and quantitative methods. For this particular paper, we focused on the qualitative findings of the study. We used qualitative research methods to investigate university students’ perceptions of cognitive-epistemic and social-institutional systems of nature of science. We conducted individual interviews to provide interpretations about students’ perceptions of the nature of science and its categories (see appendix A for interview questions). Moreover, to reflect the sampling procedure and selection criteria of the interviewees, we presented the quantitative findings by focusing on students’ “RFN Questionnaire” scores. The questionnaire was developed by Kaya et al. (2019) was administered to a large sample in the study.

3.2 Participants

The study was conducted at a highly ranked public university that provides education in the language of English in Turkey. A total of 15 students from science majors (e.g., physics, science education, industrial engineering) and non-science majors (e.g., philosophy, sociology, primary education) participated in the study. All interviewees were 3rd and 4th year university students. Since 3rd and 4th year students have completed their introductory courses in their domain-specific areas, it was meaningful to work with these relatively experienced students. In other words, since they have a background knowledge about their domain-specific areas to some extent, they shared their experiences about their courses and talked about their perceptions by considering the categories of science easily. Thus, they made some connections between the categories of science and their majors. Additionally, the rationale behind working with university students from different majors was to analyze the effect of students' course contents on their perceptions of the different categories of NOS. While non-science majors dominantly had humanities, politics, economics, history, philosophy, and psychology-related courses, science majors primarily have theory and laboratory-based natural science courses. The study was conducted in the fall semester of the 2017–2018 academic year.

Using convenience sampling procedures (Fink 1995), we selected the interviewees from the sample of 637 university students with respect to their "RFN Questionnaire" scores. Students' questionnaire scores were classified as low, moderate, and high in terms of their NOS understandings. The detailed information about the formation of these levels and students' questionnaire scores will be provided in Section 3.3.

During the participant selection process, we considered two main criteria. First, we used students' levels of NOS understanding, as determined by their RFN scores. After collecting questionnaire data and analyzing the results through their questionnaire scores, we randomly selected five students from each level of NOS understanding (15 in total). We contacted these randomly selected students through their email addresses, which were gathered through the questionnaire before. Second, we considered students' majors during the selection process. We randomly selected eight students from science majors and seven students from non-science majors. Since the students' majors reflect different academic background and different fields of study, we aimed to provide representative spectrum by focusing on students' NOS perceptions from different majors.

Table 1 represents the number of students who participated in the study with respect to their majors, faculties, and departments. We also provided students' RFN questionnaire scores to illustrate the number of students who scored low, moderate, and high with respect to their majors. In non-science majors, three students scored moderate, two students scored high, and two students scored low. For science majors, three students scored high, two students scored moderate, and three students scored low.

While 15 students may be considered a small sample size, this size allowed us to conduct in-depth qualitative analysis, which complemented our quantitative data. These two forms of data showed consistency between their results in terms of students' questionnaire scores and NOS perceptions. However, since our goal was to present qualitative findings in this particular paper, we gathered further information on these 15 students' perceptions of NOS by utilizing an in-depth interview process. In that sense, we kept the sample size limited in order to provide a deeper and comprehensive profile for these selected students. Therefore, since the intention of this study was not to do an exhaustive statistical analysis on university students' understanding, but rather to provide some

Table 1 Frequency distributions for the majors, faculties, and departments with students' questionnaire scores ($N = 15$)

Major	Faculty	Department	Number	Total number	Questionnaire score
Non-science	Arts and Sciences	Philosophy	1		274
		Sociology	1		300
		Psychology	1		262
	Education	Foreign Language Education	2	7	237, 235
		Primary Education	2		269, 249
	Engineering	–			
Science	Arts and Sciences	Physics	1		237
		Chemistry	1		235
	Education	Science Education	1		302
		Computer Education and Educational Technology	1	8	235
	Engineering	Industrial Engineering	2		265, 301
		Computer Engineering	1		262
		Chemical Engineering	1		296

explanations in terms of their domain-specific experiences with respect to their NOS understanding levels, working with 5 students from each level proved sufficient. Further, we did not attempt to generalize these findings by using the sample of 15 students. By comparing science and non-science majors, our main concern was to identify some trends and tendencies for these selected cases and context. Bearing in mind the novelty of the RFN perspective in higher education context, the findings can be considered preliminary results indicating how this approach can be used to understand university students' perceptions of NOS. Future studies should be conducted with larger samples of university students in order to illustrate the variety of experiences these students had.

3.3 Data Sources

The data source is primarily qualitative in nature. The qualitative data of the study includes in-depth interviews with individual university students. However, we used the quantitative data source of "RFN Questionnaire" to select participants for this study. We described the interview approach and questionnaire in the following paragraphs.

A 70-item and 5-point Likert scale "RFN Questionnaire" was used to measure university students' understanding of NOS through RFN framework (Kaya et al. 2019). The RFN Questionnaire reflects five RFN categories which are aims and values, practices, methods, knowledge, and social-institutional systems of science.

Table 2 presents the information about the questionnaire. The example items and number of items for each RFN category in the questionnaire are indicated. The items both reflect the categories of RFN and educational applications of each RFN category. For example, there are nine items for the scientific methods category in the questionnaire. The example item for the aims and values category is that "All scientific disciplines such as physics, biology and chemistry produce values that can contribute to society." The total score of the questionnaire (which is the sum of five RFN categories) ranged from 70 to 350. The reliability coefficient was calculated as 0.80. The questionnaire also includes six demographic items related to participants' department, faculty, age, term or grade, gender, and email address.

Table 2 Item information for the RFN Questionnaire

Category	Example item	Number of items for each RFN category
Aims and values	All scientific disciplines such as physics, biology, and chemistry produce values that can contribute to society.	7
Scientific practices	Analysis and interpretation of data are components of scientific practices.	13
Scientific methods	There is a universal scientific method that all scientists use all over the world.	9
Scientific knowledge	Theories, laws, and models work together to produce scientific knowledge.	9
Social-institutional systems	Science takes place in institutions such as universities and research centers.	16
Educational applications	Science lessons should include financial (economical) aspects of science.	16

According to the participants' minimum and maximum total scores of the RFN Questionnaire, we determined the score intervals in order to assign participants' level of NOS understanding. Table 3 reflects the score intervals for each level of NOS understanding. It also presents the number and percentages of the students from each level.

The total "RFN Questionnaire" scores ranged from 210 to 302 with the mean value of 258.44. Since the difference between maximum and minimum total score was 101 points and students' NOS scores aggregated mainly in three groups, the cutoff point between each category is determined as 34. Additionally, in terms of science and non-science students, we can indicate that their low, moderate, and high scores were also closed to each other and reflect the similar profile. For instance, while the highest total score for science majors was 302, the highest score for the non-science majors was 298. Therefore, there was not an explicit gap between majors' score distributions in each level. Making this classification was significant in terms of selecting representative participants from each level of NOS understanding. In other words, we selected students for the interviewing process according to their NOS scores in order to provide representativeness in terms of their NOS understandings.

Interviews were conducted to elicit university students' perceptions of NOS and categories of RFN in order to see the effect of science and non-science majors' course structures on students' perceptions. We asked nine interview questions indicating each RFN category (i.e., aims and values, scientific practices, scientific methods, scientific knowledge, and social-institutional systems) to students in two parts. Besides, we used two contextually relevant texts (see the supplementary materials, Text 1 and Text 2 for the content of the texts) during the interviews. In the first part of the interview, students answered five questions directly referring to the RFN categories. We asked students if they are familiar with these concepts and whether they can provide some examples about these categories. The sample interview question for this

Table 3 Students' NOS understanding in terms of RFN Questionnaire scores ($N = 637$)

NOS understanding	Score interval	*n*	%
Low	200–235 points	30	4.7
Moderate	236–270 points	489	76.8
High	271–305 points	118	18.5

section is “What comes to your mind when I say aims and values of science? Could you give any examples?” In the second part, students read contextually related Text 1 and Text 2 and they answered the last four interview questions. We used these texts in order to facilitate students’ expressions about their ideas and RFN categories in an easier and more concrete way. For instance, we posed the question of “When you read the Text 1, which key terms or concepts were raised in your mind in terms of the political power structures of science?”. Through the questions, students exemplified and deepened their ideas and cleared up their thoughts about the different categories of science. While Text 1 mainly focuses on the scientists’ work on gut bacteria and working mechanisms of the brain (Jones 2014), Text 2 provides a content about operational and hierarchical dynamics of NASA, and the relationship between NASA and political and economic power structures (Moseman 2015).

More specifically, in Text 1, Jones (2014) underlined the actions of attending conferences, presenting new scientific evidence, working as a researcher at the university, and using observations and experimentation in the scientific process. In that way, the text provided students a real context to think more about the role of research, variety of scientific methods, values of science, professional activities, sharing knowledge with scientific community, and the concept of paradigm shift. Text 2 focuses on institutional categories of RFN through the concepts of political power structures, social organizations and interactions, and financial systems. Operational and hierarchical dynamics of NASA, financial struggles of the organization to make a scientific research, and effects of political figures and power structures on science are mentioned throughout the text (Moseman 2015). In brief, while Text 1 addresses cognitive, epistemic, and social aspects of the RFN through the concepts of scientific methods and practices, aims and values, and dissemination processes, Text 2 addresses mainly institutional systems of science through the concepts of political power structures, financial systems, and social organizations. The text was quite beneficial for students in terms of expressing their opinions about political and financial dynamics of science.

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

3.4 Data Analysis

The items of the “RFN Questionnaire” were in English, and interview questions for the interview sessions were in Turkish. Since university students were Turkish and they expressed themselves verbally better in their native language, we conducted interview sessions in Turkish. We audio-recorded each interview with the permission of the participants and then we transcribed the audio-taped interviews immediately after each interview session. After transcribing and determining main themes, codes, and quotations in Turkish, we translated all the data to English. During this process, we used thematic analysis technique in order to identify themes, codes, and patterns in the data which are crucial or interesting, and we produced themes in order to address our research question (Clarke and Braun 2013).

We produced five themes (i.e. aims and values, practices etc.) and related codes to create some trends about the participants’ perceptions of NOS in relation to RFN categories. For instance, Erduran and Dagher (2014) explained the category of scientific practices through Benzene Ring Heuristic and set of practices, such as data collection, discussion, real world, and prediction. Therefore, we used scientific practices as one of our themes and we used the components of the Benzene Ring Heuristic as some of our codes for scientific practices theme. However, we also formed additional codes for the theme of scientific practices with respect to students' responses, such as constructed hypothesis. Besides, in relation to analysis process, two researchers independently applied coding procedure and high degree of agreement were provided. After finalizing the coding phase, all codes were agreed upon by researchers.

4 Results

Participants' perceptions about aims and values, scientific practices, methods and methodological rules, scientific knowledge, and social-institutional systems of science are presented in this section. For each RFN category, we tried to reflect students' perceptions of NOS by presenting their responses for the two different parts of the interview. In other words, students' responses in relation to RFN-based, and Text 1- and Text 2-based interview questions are presented throughout the section. Students' majors (science and non-science) and levels of NOS understanding (low, moderate, and high) are also highlighted in order to analyze and compare their perceptions.

Aims and Values of Science The interview results indicate that science and non-science majors' perceptions of aims and values of science were distinctive. Table 4 represents students' responses about aims and values of science through their most frequent answers and their explanations. Their answers are framed through the codes with respect to students' definitions and conceptions about the aims and values of science and Text 1. The response rates for each code in terms of students' majors (i.e., science and non-science) and their levels of NOS understandings (i.e., high, moderate, and low) are also illustrated. Thus, clear vision is provided to see the similarities and differences between science and non-science majors' perceptions of aims and values of science, and the consistency between the scores of "RFN Questionnaire" and interview results.

According to the Table 4, science and non-science majors mostly considered aims of science as serving to humanity, understanding the universe, and making people's daily life. For instance, 75% of the science majors and 57% of the non-science majors held the common view of science has an aim of serving to humanity and making easier the people's daily life easier. They underlined the idea that science should meet the demands of mankind and provide a better future for humanity through making progress in different fields of life, such as in medicine and technology. It was also observed that while 80% of the students who scored high and moderate expressed their ideas about aims of science by focusing on these two points, only 40% of the students scored low focused on the concept of serving to humanity while explaining the aims of science. Another common code was understanding the universe which is appointed by 75% of the science and 85% of the non-science students. Science majors, especially the majors of engineering, pointed out the practical and applicational aims of science.

For instance, about 62% of the science majors claimed that science has an aim of providing a progression in technology by highlighting the practical and applicational sides of science without the consideration of theoretical standpoints, norms, and explanations about the scientific subjects. The response rates for this perspective also showed that while students who scored high tend to explain the aim of science with

Table 4 The codes for students' perceptions of aims and values of science ($N = 15$)

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

its practical and applicational use, students who scored low show no tendency to consider such point.

Moreover, while more than half of the non-science majors held the view that science has an aim of searching for the truth without any pragmatist concern, only 12% of the science majors advocated that opinion. According to these participants, science can be done to satisfy one's curiosity about any subject matter without the concern of serving to humanity. In other words, science should aim to explain specific subject matter and provide evidence. For instance, a student from non-science major who scored moderate from the department of psychology stated that:

> I think aims and values of science are simply explaining a phenomenon and understanding the basic components and characteristics of it. I think that science is not necessarily pragmatic. My perspective is possibly connected to my discipline. I mean the aim of science is explaining a phenomenon. For instance, explaining the concept of separation of the visual [or the image] from the retina is an aim. When we consider that, we cannot see a pragmatist approach here. There is an aim of explanation.

This student seems aware of the epistemic and cognitive aims of science. Since the participant considered the main aims of science as discovering and explaining a phenomenon, the student possibly gives an importance to explanatory power and empirical adequacy of science to provide the growth of scientific knowledge. Besides aims of science, participants offered a bunch of different ideas about the values of science. For instance, almost all students from both majors claimed that ethics is one of the important concepts to explain values of science. Students generally held the view that ethics is related to the rights of the animals and human beings in scientific processes and experiments, and it represents the value of no harm to nature and living creatures when doing science. Additionally, while half of the science majors asserted that science has a value because of its dependence on scientific knowledge which has falsifiable, uncertain, and non-dogmatic nature, and use of effective and objective scientific methods in scientific processes, only 14% of the non-science majors gave credit to these specific points. It is also observed that this view is adopted only by majority of students who scored high and moderate.

On the other hand, students' responses for Text 1-related questions were quite similar with their initial answers. After reading Text 1, students mostly pointed out the concepts of serving to humanity, making easier the daily life and ethics to explain aims and values of science. However, 25% of science and 14% of non-science students mentioned the pragmatic values of science only after reading Text 1. They considered the benefit- or profit-oriented scientific studies or productions. Ethical issues and concerns in terms of violating the rights of animals are also considered by students after reading the text. Students' responses reflected their dilemmas, because they thought that while the study is really beneficial for people with autism, it is also harmful for laboratory mouse. This situation leads contradictions for some students in terms of the rights of animals and made them think about the principle of no harm while doing science. The non-science student from the department of primary education who scored moderate had a verbal response:

> In the text, I see the aim of serving to people. Researchers worked on autism and found something to help people with autism. They worked with mice which is questionable, but some positive results were obtained for humanity. I think the opportunity of helping people with autism and using science for a good reason are incredible.

Scientific Practices The interview results show that participants from science and non-science majors consider scientific practices as the activities that are used in scientific process. The codes and explanations about students' responses for scientific practices and Text 1-related interview questions are given in Table 5.

As the most prevalent code in Table 5, more than 70% of science and non-science majors considered testing as one of the scientific practices that is used in experimentation process to gather information about the natural world. Furthermore, the half of the science majors and 57% of the non-science majors believe that constructing a hypothesis is one of the essential steps of the scientific practices. For instance, a science major student who scored high from the department of chemical engineering explained his view by focusing on constructing hypothesis and testing:

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

The response shows that the student tends to consider scientific practices as scientific methods. Since this student conducted experiments and tried to reach results at the end of the testing process in their chemistry lab, these experiences may shape the student's view about the practices of science. However, we can also say that this student directly considers manipulative and experimental methods of science. We cannot see any focus for the alternative methods which are non-manipulative and observational scientific methods. At this junction, in the light of the response rates for the codes of testing and constructing hypothesis, it can be inferred that most of the students cannot discriminate the concepts of scientific practices and scientific methods explicitly. They uttered that these two categories are as the same or similar concepts. On the other hand, participants from science majors, especially the department of science education, declared that prediction, modeling, data collection, and discussion are some of the components of the scientific practices.

These students explained some components of the scientific practices and made connections with Benzene Ring Heuristic (BRH). For instance, a science major student who scored high from the department of science education stated that:

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

Additionally, the practices of using models and simulations, and observation are only indicated by students who scored high. These two practices also constructed the main difference between non-science and science majors in terms of their perspectives of scientific practices. While half of the science majors explained scientific practices by using models and developing simulations, any of the non-science majors considered these points. Similarly, while 72% of the non-science majors described observation as one of the scientific practices, only 13% of science majors expressed that observations are scientific practices.

Students considered the concepts of constructing hypothesis, testing, observation, prediction, and discussion as scientific practices after they read Text 1. For example, they mentioned

Table 5 The codes for students' perceptions of scientific practices ($N = 15$)

Code	Explanation of the code	Science N_{sci}: 8		Non-science $N_{non\text{-}sci}$: 7		High N_h: 5		Moderate N_m: 5		Low N_l: 5	
		#	%	#	%	#	%	#	%	#	%
Constructing hypothesis	A step that carried out after determining a problem about specific topic and made for explaining and testing the problem	4	50	4	57	4	80	4	80	0	0
Testing	Use of experiments to gather information about the natural world and assess whether the constructed hypothesis was correct or not	7	87	5	72	5	100	4	80	3	60
Data collection	Practical and systematic steps to gather and measure information from different sources	3	38	5	72	4	80	3	60	1	20
Observation	Use all the senses to examine people or object in natural settings	1	13	5	72	4	80	1	20	1	20
Prediction	One of the fundamental steps of the scientific method to generate a hypothesis and see what will happen	2	25	1	14	2	40	1	20	0	0
Using simulations and models	Systems that try to explain the real world through simplification and performing an experiment that cannot be done in the real world	4	50	0	0	4	80	0	0	0	0
Discussion	The process of talking about something to exchange ideas and make a decision	2	25	0	0	2	40	0	0	0	0
Real world (only after Text 1)	Using the concepts, objects, creatures, and incidences of real world to determine a problem and work with it	2	25	0	0	2	40	0	0	0	0
Social certification and dissemination (only after Text 1)	The processes of presenting results and publishing articles after the use of scientific practices in the scientific process	4	50	4	57	2	40	4	80	2	40

constructing hypothesis about gut bacteria and brain, making experiments to collect data from mice, and making predictions to explain the impact of probiotics for people with autism. However, the concepts of real world and social certification and dissemination process were raised by students after they read the text.

Methods and Methodological Rules of Science Science and non-science majors' perceptions about methods and methodological rules of science are indicated through Table 6. All the science majors and 85% of the non-science majors' considered testing as one of the scientific methods. According to them, testing is an experimentation process to gather information about the real world and to construct hypothesis about a phenomenon. Moreover, almost half of the science and non-science majors held the view that determining a problem, constructing hypothesis and data collection processes are essential scientific methods. In this sense, students' responses and codes for the methods show similarity with the category of scientific practices. Most of the students considered that these two categories are similar or nearly the same concepts.

Additionally, students' responses show that they tend to explain scientific methods in an ordered and stereotypical way. They described the scientific process and methods with the sequence of determining a problem or asking a question about nature, constructing hypothesis about that problem, collecting data to test the hypothesis, and reaching some conclusions at the end of the process. In other words, students are aware of general rationale and working mechanism of a scientific study; however, they also tend to explain scientific methods within the stereotypic depiction of the scientific methods which is explained by Erduran and Dagher (2014). Research methods are another prevalent conception for both science and non-science majors while explaining scientific methods. Students from both majors mentioned some steps of the research, such as conducting surveys and interviews, reviewing the literature, determining sampling procedures, and using statistical methods for data analysis. While they were explaining their perceptions about scientific methods, they provided some examples and explanations about methods that they are using in their labs, courses, and internships. For instance, a non-science major who scored moderate from the department of primary education stated that:

> When I think about the scientific methods, research methods come to my mind. That's because I am taking a course about the research methods right now. For instance, we use surveys and we make observations. We review the literature and choose our target population.

This student identified research methods as scientific methods. Moreover, all students from both majors and each level of understanding of NOS pointed out that there are different kinds of scientific methods which are used in different domains and disciplines of science. For example, a student from non-science major and the department of psychology who scored moderate uttered:

> When I was working on a behavioral study, there were certain and different procedures that I followed. If I am working on neuroscience, there are some procedures that I should follow. For example, for this study, a survey was applied to us. This method is convenient for this study, but when we were working on visual perception, we used psychophysics experimentation and tried to understand about people's behaviors. I mean, the methods that we use can be different according to our working fields.

Table 6 The codes for students' perceptions of methods and methodological rules of science ($N = 15$)

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

She mentioned the different scientific methods by focusing the methods of educational sciences and behavioral sciences. By doing that, she also reflected her experience with respect to her major.

On the other hand, students also explained the scientific methods by considering Text 1. Different from the other categories, students' conceptions about methods did not change after they read the text. They highlighted the concepts of constructing hypothesis, testing, research methods, data collection, and observation by mentioning the effects of gut bacteria on autism, doing experiments on mice, and making observations of people with autism. In that sense, Text 1 assisted students to put their initial ideas in a real context through the given study. For instance, a student from non-science major and the department of sociology who scored high stated that:

> Constructing hypothesis, data collection and making experiments came to my mind when I read the text. These are the methods of science, I think.

Overall, while majority of the students from both majors thought that constructing hypothesis, testing, and research methods are different kinds of scientific methods, only a small portion of non-science students mentioned observation as one of the scientific methods.

Scientific Knowledge Students reflect their perceptions about the definition, forms, and tentative nature of scientific knowledge through several interview questions. The codes and explanations about students' perception of scientific knowledge in terms of initial and Text 1-related interview questions are given through Table 7.

Students described the concept of scientific knowledge by its characteristics of being tested, credible, objective, and falsifiable in nature. While all the non-science majors characterized the scientific knowledge as tested and credible, only 63% of the science majors mentioned these two characteristics. Students also considered scientific knowledge as a fact or information which is acquired through a set of experiments or tests. Moreover, objectivity was another notion that was raised by students. Twenty-eight percent of the non-science majors underlined that scientific knowledge has an objective and unbiased nature. These students claimed that scientific knowledge is not a subjective entity and it is not affected from people's beliefs and ideas. As a last point, only 28% of the non-science majors talked about the falsifiable characteristic of the scientific knowledge. Students suggested that scientific knowledge is refutable. In that sense, the response rates for these codes show that non-science majors focused some additional points while characterizing the nature of scientific knowledge.

On the other hand, all students uttered that scientific knowledge has a tentative structure and it may change over time. While 43% of the non-science majors have an awareness about tentative nature of knowledge and touched upon the concepts of context dependence and paradigm shift, only 25% of the science majors covered these points. According to these students, social, cultural, and contextual dynamics of the society may lead some changes in the structure of scientific knowledge, and this change can be explained by paradigm shift. For instance, a non-science student from the department of philosophy who scored high demonstrated a sophisticated view that:

> I want to use the term of paradigm shift here. Scientific knowledge can change with paradigm shifts. For instance, people believed that human's mental health was depended on the activity of the brain previously, but now it seems that the mental

Table 7 The codes for students' perceptions of scientific knowledge ($N = 15$)

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

> health also depend on the bacteria activities in our gut. So, the scientific knowledge can develop and change.

The participant used a philosophical standpoint to express changing nature of scientific knowledge. His response reflects the process of paradigm shift and focuses on how scientific knowledge has a tentative nature and can develop and change in time.

Finally, students reflected their perceptions about the different forms of scientific knowledge. About 85% of the non-science majors and half of the science majors found a relation between the forms of scientific knowledge and different branches of science. In other words, these students indicated that scientific knowledge may be classified in different forms in terms of different disciplines of science, such in natural sciences and in social sciences. For instance, a student claimed that scientific knowledge can have different forms in physics, biology, and chemistry. However, this kind of approach did not completely reflect the different forms of scientific knowledge which are theories, laws, and models in terms of RFN. Nevertheless, this student made an implicit expression about the domain specificity of the scientific knowledge which is valuable. On the contrary, half of the science majors, especially engineering students, held better perception in terms of explaining different forms of scientific knowledge. These students focused on the concepts of hypothesis, theory, and law. However, none of these participants considered the models as one of the forms of scientific knowledge. The following statement of a science major student from industrial engineering who scored high:

> Yes, there are different forms of scientific knowledge. For example, hypothesis, law, theory… Laws and theories also depend on scientific facts and scientific basis.

Finally, students also explained the characteristics of scientific knowledge in relation to Text 1 by using the concepts of tested and supported knowledge. They explained the scientific knowledge as a fact that can be reached by the set of experiments on mice and depended on previous scientific evidence about microbiome and gut bacteria.

Social-Institutional Systems of Science Students represented their ideas about the social-institutional systems of science through the interview questions which cover professional activities, effects of social and cultural values in science, and the concepts of social certification and dissemination, financial systems, social organizations, and political power structures.

Besides Text 1, Text 2 was also given to students for this category to provide them a real-world context about social-institutional systems of science. Table 8 contains the codes and explanations of students in terms of social-institutional systems of science, and Text 1- and Text 2-related interview questions.

About 63% of the science majors and 58% of the non-science majors reflected their perceptions about professional activities of science by attending symposiums and conferences, writing articles to journals, collaborative academic activities among scientists, sharing findings with society, and working in laboratories. In terms of social certification and dissemination process, all non-science and 75% of the science majors held the view that presenting findings to public, peer-reviewing process for scientists and researchers, attending conferences, and sharing findings through articles, journals, social media, TV, several internet and popular culture sources are the components of social certification and dissemination process. Both majors also explicitly asserted that social and cultural values and the context of societies have some major impacts on scientific progress and societies' attitudes towards science. They also underlined the concepts of gender, race, and religion as relevant variables which have an

Table 8 The codes for students' perceptions of social-institutional systems of science ($N = 15$)

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

impact on science. For example, a non-science major student from primary education department who scored moderate stated that:

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

This student directly mentioned the effect of social and cultural values and ideologies of the governments on scientific process. In addition, more than 85% of the students from both majors mentioned scientific organizations, such as universities, and research and development companies for institutional systems of science. According to them, these institutions are managed by hierarchical structure and they provide opportunities for scientists and researchers to make science.

Political power structures and financial systems are the last points that students mentioned to describe social-institutional systems of science. Almost all students from both majors and students from each level of NOS understanding depicted that strategies of the governments and political figures of the nation's play a significant role in science.

In other words, governmental strategies, such as investing warfare technologies and increasing or decreasing the number of financial sources and funds for scientific research, can determine the aims and direction of science. For the financial systems, students mostly focused on the importance of money to do science. The terms of budgets, funds, investments, and government's strategies on economic resources were raised by students during the interview sessions. In short, all students are explicitly aware of the effect of politics and finances on science. Most importantly, they also made a connection between these concepts. For instance, one non-science student who scored moderate from psychology department mentions the effect of political figures in science:

> Scientific process can be directly affected by political powers. For instance, social psychology is a field that can be used by politicians effectively. Milgram experiment came to my mind now. It's about revealing people's perceptions about the authorities and it was conducted after the World War II. The experiment shows the effect of politicians in wars on people's perceptions and science process. I mean politicians and governments can use scientific facts to rule and create an order. They use science and science is affected by them.

The participant mentioned Milgram experiment in order to highlight people's perceptions about authority and power of the political figures while determining direction of science. She also claimed that selections and decisions of the high-power figures determine the direction of science and the future the nations. This quote is also valuable, because student made some connections from her field to highlight the effect of political power structures in science. She explicitly used one of the most known experiments from the field of psychology to explain her point of view. Another illuminating quotation is provided by a science major student who scored high from the department of computer engineering:

> Of course, these concepts affect science. If the government does not support science, science does not develop. For instance, let's look at South Korea. In that country,

government directly supports science and provides a fund for scientific technologies. By their support, Samsung and Hyundai became such a big and important companies. They outperformed Turkey in the last 30 years. In that sense, the strategies of the government influence the science.

The student gave a concrete example to explain the effect of political figures and financial sources in developmental process of science. He also pointed out the interrelation between the political power structures and financial systems, because if the political figures do not provide a fund for scientific organizations, scientific progress cannot be achieved.

In addition to these points, almost all students from both majors enthusiastically shared their ideas about professional activities, social organizations and interactions, political power structures, and financial systems after they read Text 1 and Text 2. Students expressed their ideas in a better and comprehensive way while talking about the social organizations and interactions of science through the texts. They mentioned the scientific organization of NASA, its hierarchical and power structures, effects of political figures on science, and the importance of the money to make science. In that way, participants' abstract initial ideas became more organized and holistic after they read especially Text 2.

Overall, at the end of the interview sessions, most of the university students from different majors claimed that these five categories of RFN are efficient to explain different aspects of science holistically and there is a clear connection among the categories. Even some students used some analogies in order to show the relationship among the categories of NOS. For instance, one student from science education associated the categories of RFN with the root, arms, and leaves of the tree. While she considered the root of the tree as RFN itself, she thought that the arms of the tree stand for the five main categories of RFN, such as aims and values, and scientific practices. She also considered the leaves of the tree which are connected to the arms as sub-concepts of these categories. For instance, she stated that real world and data collection can be considered as the leaves on the arm of scientific practices.

5 Discussion

The study aimed to investigate science and non-science majors' perceptions of NOS and the results suggested that non-science majors illustrated a better perception for the categories of aims and values, scientific knowledge, methods, and social-institutional systems of science. Their responses were more sophisticated and elaborated compared to science majors. The qualitative analysis results also indicated that students who scored high have a broader perception about RFN categories in comparison to students who scored low. In other words, qualitative analysis results were consistent with the scores of RFN questionnaire. This coherency is important and valuable in terms of reflecting the selected interviewees' perceptions of NOS as expected from their questionnaire scores.

Moreover, when we examined the students' perceptions in more details through the created trends, we observed that non-science majors' expressions of cognitive and epistemic aims of science, existence of different scientific methods, and descriptions about the nature of scientific knowledge designated the quality of their perception. Additionally, these students found a relationship between the social and cultural values of science and growth of scientific knowledge. They also raised concepts of imagination and creativity while explaining science. However, science majors reflected slightly more enhanced perception while expressing the different forms of scientific knowledge and components of scientific practices. In relation to different forms of knowledge, these students labeled law, hypothesis, and theory as the forms of scientific knowledge. Although they did not provide a detailed and comprehensive explanation about how these forms differ and work together in order to form the process of knowledge generation, they tried to categorize these forms with their prior knowledge. Finally, science majors also explained most of the components of the scientific practices explicitly.

The possible reasons behind these qualitative results can be related to students' course contents and structures of their majors. As it is stated in the directions of "The Council of Higher Education (YÖK)" and the university's specialized curriculum for science and non-science majors, students from non-science majors enrolled in variety of history, psychology, humanities, language, philosophy, and research and academic orientation related courses (Faculty of Arts and Sciences 2020). These courses potentially provide students a perspective about the variety of scientific methods, functions and meanings of economic, political, and social dynamics of the society, the forms of power, control, and authority in different social and cultural settings, and the concepts of gender and social structure in science. Similarly, the possible causes of science majors' better ideas about scientific practices are related to their natural science and technology-based practical and pedagogical courses which they are enrolled in their undergraduate program. For instance, students from science education department enrolled in a pedagogical course in their program which covers the scientific practices with respect to Erduran and Dagher's (2014) framework and introduces students with the components of scientific practices through Benzene Ring Heuristic. In that sense, the quality of students' answers about the components of scientific practices (such as using real world, prediction, and discourse) may be connected to their domain-specific course-based experiences.

In addition, some of the findings of this study are in line with the results of previous studies on university students' perceptions of NOS (e.g., BouJaoude 1996; Liu and Tsai 2008). Consistent with Liu and Tsai's (2008) and Parker et al. (2008) findings, this study showed that students from the science majors did not reflect better perceptions about science than non-science majors. Although the current study did not reveal explicit divergence for each RFN category in students' perceptions, results mostly indicated that science majors have less sophisticated perceptions than non-science majors on different aspects of science. For example, Liu and Tsai's (2008) study also suggested that non-science majors' perceptions were more sophisticated in comparison to science majors in terms of considering the nature of scientific knowledge, and social and cultural values of science which are in line with our results. However, some previous findings have reported that non-science majors tended to focus more on the cognitive aspects of science within the consideration of theoretical and empirical adequacy rather than the social aspect of science (Leung et al. 2016). These findings are inconsistent with our results. In our study, non-science majors expressed their ideas about cognitive and epistemic aspects of science clearly. However, their representations about social, cultural, political, and financial aspects of science were broader compared to science majors. Before conducting this study, we assumed that science majors could have an enhanced perception about science, since they had experienced more deeper discourse about science disciplines by considering previous studies. Therefore, findings of this study provided a different perspective to our expectations. Overall, the result of these previous studies claimed that there is a relation between students' major and their epistemological perception of NOS. The academic experiences of students may play an important role in impacting students' perceptions (Leung et al. 2016; Liu and Tsai 2008).

Overall, the findings suggest that majority of the university students can express epistemic, cognitive, and social-institutional aspects of the nature of science only to some extent. Secondly, students' course contents might affect their perceptions towards science in the higher education settings. In that sense, providing a course program or designating an alternative curriculum which covers courses in relation to nature of science, sociology and philosophy of science, epistemology, and methods of science can be beneficial especially for science majors. Introducing students with nature of science through RFN categories may help university students to grasp the different aspects of NOS. The study hopefully has some contributions in terms of providing further thought for the questions of why university students need to learn the concept of NOS and how university students' NOS understanding can be measured in terms of RFN framework and in relation to different majors of the university. In particular, the study shows the link between university students' perception of NOS and their majors according to their disciplinal backgrounds. Finally, future research can be conducted in different public and private universities. Increasing the sample size and diversifying the groups of science and non-science majors can be beneficial to get more representative results and comprehensive further studies. Using alternative texts and RFN-related contents for the interview process, conducting workshops and intervention studies may be also helpful to provide different points of views and perspectives for the further studies.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix A INTERVIEW QUESTIONS

1. What comes to your mind when I say aims and values of science? Can you give any examples?
2. What comes to your mind when I say scientific practices? Can you give any examples?
3. What comes to your mind when I say scientific methods? Can you give any examples?

   – What do you think about the methods of science? Are there different kinds of scientific methods or not? Please explain.

4. What comes to your mind when I say scientific knowledge? Can you give any examples?

   – What do you think about the characteristics of the scientific knowledge?
   – What are the forms of scientific knowledge? Please explain.
   – Do you think that scientific knowledge changes? Why?

5. What comes to your mind when I say social and institutional aspects of science? Can you give any examples?

   – What do you think about the professional activities that are practiced in scientific process?
   – What do you think about the role of social and cultural values on science?
   – What do you think about the social certification and dissemination process of science? In other words, how scientists share their work with public?
   – What do you think about the relationship between science and financial systems?
   – What do you think about the relationship between science and political power structures?

6. Please read the Text 1. When you read the text:

   – Which key terms and concepts raised in your mind in terms of the aims and values of science? Please explain.
   – Which key terms and concepts raised in your mind in terms of the scientific practices of science? Please explain.
   – Which key terms and concepts raised in your mind in terms of the methods and methodological rules of science? Please explain.
   – Which key terms and concepts raised in your mind in terms of scientific knowledge? Please explain.
   – Which key terms and concepts raised in your mind in terms of the social-institutional systems of science? Please explain.

7. Please read Text 2. When you read the text, which key terms and concepts raised in your mind in terms of the social-institutional categories of science? Please explain.
8. Overall, when you consider the discussion we made and texts you read, what do you think about the relationship between these five categories?
9. To what extent do you think these five categories explain science as whole?

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