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Investigation of Science Teachers' Views of Epistemic, Cognitive, and Social-Institutional Aspects of Science

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Abstract

This study examined science teachers' views on the Reconceptualized Family Resemblance Approach to Nature of Science (RFN). Semi-structured individual online interviews including questions related to all categories of the RFN were conducted with eight science teachers to explore their views on the epistemic, cognitive, and social-institutional aspects of science. The results indicated that while some teachers held informed views on certain cognitive-epistemic aspects, others maintained naïve views on scientific practices and methods. For example, they did not differentiate practices and methods and described methods as step-by-step activities. The teachers also emphasized that scientific knowledge could develop and change over time, but they did not discuss the theory, law, or model as types of scientific knowledge. Although nearly all teachers addressed each social-institutional aspect, most were unable to elaborate on their ideas as outlined in RFN. Some also held naïve views on professional activities. It is believed that incorporating explicitly the Reconceptualized Family Resemblance Approach to Nature of Science, which includes epistemic, cognitive, and social-institutional aspects of science and offers a holistic view of science into teacher education programs could significantly enhance teachers' understanding of the Nature of Science.

Introduction

Over the past several decades, many science educators have studied the Nature of Science (NOS), which is a key issue (Leden & Hansson, 2019). To produce students that are scientifically literate, it is vital to understand NOS (Holbrook & Rannikmae, 2007). In addition to being knowledgeable about the subject matter of science, being scientifically literate enables people to comprehend how scientific knowledge is produced (Lederman et al., 2014). However, some people still lack the knowledge necessary to explain how a scientific enterprise operates. The people who have the right to speak out on scientific or political concerns and contribute their thoughts to the decision-making process may suffer as a result of the lack of understanding of NOS.

Studies carried out with a variety of student groups have produced comparable findings about students' insufficient understanding of NOS or their naive knowledge of it (Cofré et al., 2019; Dogan, 2011; Lederman & O'Malley, 1990; Ryan & Aikenhead, 1992). One of the reasons why the students don't have sufficient NOS understanding may be teachers. The teachers' views on the nature of science affect their science instruction and the way how they transform the knowledge to their students (Lederman & Abd-El-Khalick, 2000). In order to successfully teach NOS in the classroom, Lederman (1992) suggested that instructors' conceptual grasp of the nature of science must be developed. Teachers cannot teach students in subjects they themselves do not fully comprehend (Ball & McDiarmid, 1990). At this point, it can be very important to examine the teacher's views on NOS. Some of the research that was done to explore or improve the NOS views of science teachers revealed that the views of the science teachers are insufficient, traditional, or mixed. (Dogan & Abd-El-Khalick, 2007).

The relevance of teaching and learning NOS has been emphasized in several frameworks proposed by philosophers and science educators (Abd-El-Khalick et al., 1998; Allchin, 2011; Matthews, 2012; Irzik & Nola, 2011; 2014). In the current study, one of the recent frameworks proposed by Erduran and Dagher (2014) with the insight of the Irzik and Nola's (2011; 2014) version of Family Resemblance Approach to NOS and named as "Reconceptualized Family Resemblance Approach to NOS [RFN] by Kaya and Erduran (2016) was used. RFN explains science as a cognitive, epistemic, and social-institutional system, which is why this framework was chosen for this study. By considering the domain-specificity and domain-general characteristics of science, RFN can be a potent framework that can be utilized in learning and teaching the nature of science holistically (Erduran & Dagher, 2014).

While the importance of teachers' role in teaching the nature of science in science classrooms is recognized, little is known about teachers' RFN-based nature of science views. Although some studies have looked at pre-service science teachers' understanding of the nature of science, (e.g., Barak et al., 2023; Cullinane & Erduran, 2022; 2023; Çam, 2023; Erduran et al., 2023; Erduran & Kaya, 2018; Ju et al., 2023; Kaya et al., 2019; Saribas & Ceyhan, 2015; Takriti et al., 2023; Voss et al., 2023) the number of the studies conducted with in-service teachers are very scarce (Aksoz, 2019; Demirel et al., 2023; Kurt & Kaya, 2024). Before we expect teachers to consider the NOS holistically in their classrooms, first, we need to know what science teachers' views on NOS are. This study can be the basis of the experimental studies examining the teachers' views, understandings, and perceptions of RFN in the future. Thus, the purpose of this study is to investigate how science teachers view NOS based on RFN. We focused on each aspect of science defined by RFN to evaluate science teachers' views on NOS holistically. The research question, as given below, served as the study's compass:

What are the science teachers' views on epistemic-cognitive and social-institutional aspects of science?

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

One of the NOS frameworks, the Family Resemblance Approach to Nature of Science (FRA to NOS), was put forth by Irzik and Nola (2011; 2014) based on Wittgenstein's (1958) general notion of family resemblance idea. This approach has philosophical roots and provides some explanations for how science might be viewed and how this can benefit teaching and learning of science. According to FRA to NOS, there are various aspects of science that are shared by various science disciplines, including chemistry, astronomy, biology, and physics, as well as some that are unique to each discipline.

In other words, FRA to NOS offering a unifying and flexible framework emphasizes the domain specific and domain general aspects of science. By examining, criticizing, and introducing new categories, Erduran and Dagher (2014) reconceptualized the theoretical viewpoint proposed by Irzik and Nola (2011; 2014). To distinguish Erduran and Dagher's (2014) FRA to NOS from prior presentations of the family resemblance ideas, the phrase "Reconceptualized Family Resemblance Approach to NOS [RFN]" was then coined (Kaya & Erduran, 2016). Throughout this study, the abbreviations RFN or NOS were used to represent the Erduran and Dagher's (2014) version of Family Resemblance Approach to Nature of Science (FRA to NOS).

According to Erduran and Dagher (2014), students are more likely to be motivated to learn science if they are exposed to various epistemic, cognitive, and social-institutional components of science by expanding the characterization of NOS. Erduran and Dagher (2014) tried to put the views put forward by FRA to NOS on a pedagogical basis. In order to create practical tool sets that science educators and researchers can use in NOS teaching and learning, they created various pedagogical visuals on the categories based on the concept of "family". One of the generative images produced by Erduran and Dagher (2014) is called "FRA Wheel". The wheel presented in Figure 1 includes epistemic, cognitive, and social-institutional aspects of science and represents science "as a holistic, dynamic, interactive and comprehensive system" (Erduran & Dagher, 2014, p.29).

Figure 1. FRA Wheel: Science as a Cognitive, Epistemic, and Social-Institutional System (Erduran & Dagher, 2014, p.28).

With categories stressing cognitive, epistemic, and social-institutional components of science, the FRA Wheel (see Figure 1) provides a comprehensive explanation of the nature of science. The wheel is formed by the intertwining of 3 circles. The inner circle of the wheel includes the cognitive-epistemic aspects of science, while the middle and outer circles contain the social-institutional aspects that support the growth of scientific knowledge.

The cognitive-epistemic aspects of science are described by RFN as being the aims and values of science, methods and methodological rules, scientific practices, and scientific knowledge that are positioned in the inner circle of the FRA Wheel. The cognitive-epistemic aims and values of science include objectivity, novelty, and accuracy. They also contain social aims and values such as meeting human needs and decentralizing power (Erduran & Dagher, 2014). A set of cognitive-epistemic procedures known as scientific practices, such as observation, model, and argumentation, produce scientific knowledge through social validation. Both manipulative and non-manipulative methods are utilized in scientific investigations, according to method and methodological rules. Additionally, it highlights science's domain-specific and domain-general characteristics. Lastly, the scientific knowledge category stresses the growth of scientific knowledge and describes theory, law, and model as the results of scientific studies.

The social-institutional aspects of science are explained by RFN and are put in the middle and outer circles of the FRA Wheel. The middle circle includes social certification and dissemination, professional activities, scientific ethos, and social values; the outer circle includes social organizations and interactions, financial systems, and political power structures. RFN defines social-institutional aspects of science as wheels. Social certification and dissemination category emphasizes that scientists share their results of the scientific studies at conferences, produce reviewed, criticized, and evaluated manuscripts published in peer-reviewed journals. Professional activities include a range of activities that scientists do in addition to producing knowledge such as attending conferences, sharing findings, writing manuscripts, seeking funding as well producing knowledge. The standards that scientists are required to uphold when interacting with one another and in their scientific investigations such as intellectual honesty, being skeptical, confidentiality etc. are known as the scientific ethos. Respect for the environment, social utility, and freedom are examples of social values defined by RFN. In addition, social organizations and interactions explain that scientists conduct their investigations in institutions like universities, research centers which are socially constructed and emphasize the interactions among those institutions. Financial systems explain how science is mediated by economic factors. Finally, political power structures help us understand how the scientific enterprise functions in a social and political context that supports its own values and interests, as well as how those dynamics impact science.

RFN has been used as an analytical framework on some NOS studies since 2014. There are some curricula analyzes (Kaya et al., 2025; Kurt & Kaya, 2025; Mork et al., 2022; Pimenta et al., 2025; Yeh et al., 2019), and school textbook analyzes (Korsager et al., 2022; Okan & Kaya, 2023a; Reinisch & Fricke, 2022). Also, some of the studies which are rely on RFN conducted with scientists (Wu & Erduran, 2022), middle school students (Akbayrak & Kaya, 2020; Çilekrenkli & Kaya, 2023; Goren & Kaya, 2023) and university students (Akgun & Kaya, 2020; Petersen et al., 2020). Even though RFN was used as a theoretical framework in pre-service teacher education in various contexts (Barak et al., 2022; Cullinane & Erduran, 2022; 2023; Kaya et al., 2019) there are limited studies conducted with in-service science teachers (Aksoz, 2019; Azninda & Sunarti, 2021; Kaya & Erduran, 2024; Kurt & Kaya, 2024). Teachers play a crucial role in educating students about the nature of science. In this context, knowing how the science teachers view nature of science may help us to see the general picture and improve their views in future studies. In this context, pre- and in-service teachers' views on NOS in science education literature are presented in the next section.

Nature of Science Views of Science Teachers

According to Lederman (1992), teachers' views on NOS have an impact on how well they can teach about the nature of science in the classroom. Teachers must possess sufficient knowledge of the nature of science ideas in order to adequately explain them to students. The studies investigating the pre-service teachers and in-service teachers' views of nature of science generally revealed that both groups of teachers have mixed and incoherent views and conceptions about NOS (Dogan & Abd-El-Khalick, 2008; Tairab, 2001).

Zion et al. (2020) designed a course for in-service science teachers that combined explicit-reflective instruction on the Nature of Science (NOS) with an open inquiry approach. They concluded that only a small number of participants showed changes in their understanding of theories, laws, and scientific methods. The researchers argue that this limited shift in understanding of Nature of Science (NOS) and the Scientific Inquiry Process (NOSI) has resulted in many teachers continuing to experience difficulties with key aspects of NOS and NOSI even after engaging in open inquiry. Buaraphan (2010) also found that teachers generally have traditional views to explain the role of a scientist and they have constructivist views about scientific knowledge. However, most teachers held both traditional and constructivist views rather than a single view on some categories of NOS, such as scientific theories, scientific method, and scientific laws. Many studies conducted in the past years support the conclusion of those studies by stating that teachers expressed their NOS views from a traditional point of view, or they have mixed views (Haidar, 2001; Lederman & Niess, 1997; Koulaidis & Ogborn, 1989).

Using a method based on textbook analysis, Chanetsa and Ramnarain (2023) showed that areas such as creative aspects of NOS, scientific knowledge, scientific methods and ethical practices can be improved. However, they found that the development of scientific methods remains the most challenging area. Similar results regarding the scientific methods are found in different studies with pre-service science teachers. Besides, Dursun and Ozmen (2018), examined the nature of science views of the Turkish pre-service science teachers. In contrast to their deficient views on the epistemological status of hypotheses, theories, laws, and scientific knowledge, it was discovered that pre-service teachers maintained realistic and acceptable ideas regarding the changeability of scientific knowledge and the definition of science. Some other studies conducted in Türkiye also showed that the teachers have both informed and inadequate views on NOS (Ayvacı & Muradoğlu, 2021; Cebesoy & Karışan, 2018; Koksal & Cakıroglu, 2010).

Studies examining in-service teachers' RFN views are very limited (Aksoz, 2019; Azninda & Sunarti, 2021). Aksoz (2019) looked at how science teachers perceive and understand the aims and values of science as well as social-institutional categories of NOS. The quantitative analysis findings indicated that there is no discernible difference among the teachers' views according to teaching experience, education level and school type. Also, qualitative results showed that teachers have some naïve understanding on some social-institutional aspects of science such as professional activities. Otherwise, Demirel et al. (2023) found that teachers who graduated from master's or PhD showed more informed views regarding NOS. Besides, Azninda and Sunarti (2021) examined both science teachers' and non-science teachers' views on RFN. While quantitative results showed that two groups of teachers do not significantly differ from one another, the qualitative results showed that they held different views on each category of RFN.

RFN portrays science as cognitive, epistemic, and social-institutional systems and pays attention to holistic dynamics of each aspect to understand scientific enterprise (Erduran & Dagher, 2014). In this context, it is important to examine in detail the views of science teachers on each RFN category. This may help us to understand how teachers view the epistemic-cognitive aspects of science such as scientific knowledge, scientific methods, scientific practices, as well as social-institutional aspects including social values, professional activities, social certification and dissemination, political power structures. It enables us to offer suggestions on the points on which in-service teacher education should be improved. In this context, this study examined how actively working Turkish science teachers perceive the epistemic, cognitive, and social-institutional aspects of science and presented suggestions for in-service training in line with the results.

Method

Research Design and Participants

The 2018 vision of the Ministry of National Education (MoNE) in Türkiye aims to raise scientifically literate citizens. The most recent study by Okan & Kaya (2023a) investigated whether NOS is included in the latest version of the Turkish science curriculum by using RFN. The authors found that the Turkish science curriculum (MoNE, 2018) emphasizes cognitive-epistemic categories more than social-institutional categories. Later on, 2024 Turkish century education model science curriculum was prepared by the Ministry of National Education. It includes topics such as understanding the nature of science, comprehending the basic characteristics of science and scientists, and questioning the reliability of information sources. The new curriculum emphasizes that students should understand the nature of science, scientific ethics and scientific thinking skills (MoNE, 2024).

To explore the nature of science views of the science teachers, a collective case study approach investigating a “phenomenon, population, or general condition" (Stake, 2000) was chosen for this research. All participants in this study use the current curriculum in their classrooms. The eight science teachers who were conveniently chosen for the study based on their availability and willingness in participating make up the study group. Being an active science teacher is the essential requirement for participation in this study. All teachers in this study follow the same science curriculum and use textbooks which have been approved by the Ministry of National Education in their classrooms.

The selection of eight teachers for the interviews is due to the qualitative nature of this exploratory study. The decision to interview eight teachers was also informed by the principle of data saturation in qualitative research methodologies. This approach was adopted to ensure that the number of participants was sufficient to allow exploration of their perspectives on NOS without overwhelming the research with unnecessary information. Data saturation was reached when no new themes or insights emerged from the interviews, indicating that the sample size was sufficient to meet the research objectives (Creswell, 2013). Each teacher who participated in the study committed to having a basic understanding of NOS by indicating that they had encountered NOS in various ways during university courses, in academic papers, seminars or educational textbooks. Identifying this prerequisite not only ensures that all teachers have prior knowledge of NOS, but also allows us to explore how nuanced and comprehensive their understanding really is.

For a wide range of representation, participants were selected based on some variables such as gender, school type and teaching experience. The rationale behind the use of variation sampling by researchers is not to generalize the findings. Instead, the aim is to illustrate the common patterns in that diversity (Patton, 1990). In the final case, 5 teachers work in public schools and 3 teachers work in private schools. In addition, half of the participants were male and half were female. While 3 of the teachers have 0-5 years of teaching experience, 3 of them have 5-10 years of teaching experience and 2 of them have 10 years or more of teaching experience.

This methodological choice recognizes that while the findings offer valuable insights, they are a starting point for further research rather than definitive conclusions. This study aims to provide a baseline understanding upon which future research can build to examine the consistency of these insights in larger populations of teachers with larger and more diverse samples, to determine the extent to which teachers are able to explain which categories of RFN and which categories they have insufficient or naïve understanding of.

Interview Protocol and Data Collection

The interviews were conducted with the participants to investigate their views of Reconceptualized Family Resemblance Approach to Nature of Science. RFN guided the development of the interview protocol and provided a structured framework for analyzing the participants' responses. The authors prepared specific questions based on RFN to examine teachers' views on each RFN category. Subsequently, the purpose and research questions of the study were sent to two other researchers actively involved in RFN studies in order to test the validity of the questions. Within this scope, they reviewed the interview questions and provided their suggestions. After reaching a consensus, the final version of the questions was determined (see Appendix), and a pilot study was conducted with two teachers to assess the questions’ clarity and validity. Following the pilot study, the interview questions were used in the main study without further revisions. The last version of interview protocol includes 8 main and 10 sub-questions which are the questions referring to RFN categories explicitly. For instance, when discussing scientific knowledge, the teachers were asked “What is scientific knowledge? Do you think scientific knowledge can change? Please explain.” After this question, some sub-questions were administered to get deeper answers from teachers if they were not able to elaborate more. Online interviews which lasted approximately 60 minutes were conducted with the participants at different times. Through the questions, teachers have started to think on different categories of science and have expressed what comes to their mind when they hear the categories of science explicitly.

Data Analysis

The interview data was examined using thematic analysis. Some steps such as familiarization, coding, generating, and fitting into themes, were followed during the analysis (Terry et al., 2017). Before starting the analysis of each participant’s data, some familiarization methods including transcribing audio, reading through transcriptions, and looking at the whole data in a deeper way were followed. After transcribing, the irrelevant portions of the responses were removed, and the data was then separated into the expressive components, giving each code a name. Using the participants' responses to each question as a guide, the initial codes were created. Later, to build cohesion between the codes, similar ones from the created codes were renamed. Eleven categories of RFN in total were used as predetermined themes and codes were created under each theme to see the general trends in teachers' views of epistemic, cognitive, and social-institutional dimensions of science. In addition, two researchers coded the same data independently and there was a 92% agreement rate between the coders, which is very high.

Results

In this section, the results of science teachers' views on the nature of science were presented under two main subsections: cognitive-epistemic aspects of science and social-institutional aspects of science. Within these subsections, findings related to 11 themes derived from the Reconceptualized Family Resemblance Approach to Nature of Science (RFN) were discussed. Alongside the presentation of these themes, the frequency values of the related codes were also provided. To support the results, direct quotations from the participants were included. For confidentiality, participants were referred to using pseudonyms such as P1, P2, and so on.

Cognitive - Epistemic Aspects of Science

Aims and Values of Science

Almost all teachers talked about the aims of science by focusing on people's lives. 'Understanding universe' (f=4), 'ease of life' (f=3), 'curiosity' (f=3) are the most repeated codes by the teachers. The following is how one of the teachers described the aims and values of science.

> P1: Well, then the aim may be to make sense of the universe, it may be to facilitate human life, after all, we learn something in the light of science and use it for ourselves, we use it for our own interests.

This excerpt emphasizes that the teacher sees the aims of science as understanding the universe and ease of life. In addition, some teachers emphasized that science has 'monetary' (f=1), and 'moral' (f=1) aims. Also, some other codes were mentioned once such as 'development of technology', 'discovery', 'empirical adequacy' in some of the teachers' interview data. When asked to describe the values of science, the majority of science teachers were not able to explain their views. Only two science teachers emphasized the values of science as 'social utility'. On the contrary, one teacher presented some of the social values as values of science such as 'animal care', 'respect for environment', 'honesty', and 'doing no harm'. The general results of aims and values indicated that science teachers are generally focused on the social aims and values of science rather than epistemic and cognitive aims and values such as objectivity, novelty, accuracy, critical examination or taking challenges seriously.

Methods and Methodological Rules

While talking about the methods and methodological rules most of the science teachers mentioned ‘experimentation’ (f=2), ‘observation’ (f=3), ‘research’ (f=2), ‘interpretation’ (f=2), ‘data collection’ (f=2), ‘construction of hypothesis’ (f=3), and ‘hypothesis testing’ (f=2) as some of the methods in science. None of the teachers talked about the non-manipulative testing or non-hypothesis testing methods explicitly. While they are elaborating their views on methods most of them stated hypothesis construction and testing should be in scientific investigations. "Do you think that all branches of science use the same methods?" was the question posed to the teachers. Almost all mentioned 'domain specific' and 'domain general' characteristics of science under this question. One of the quotations is given below.

> P8: Of course, not all branches of science respond with the same scientific method, because the difference between the branches of science would mean that they would actually use different scientific methods in order to create their own sciences in a way...

This excerpt indicates that the science teacher is aware that scientists can use different methods based on their branches and aims. However, she is not able to elaborate her views on which types of methods are used in different science disciplines. Although the science teachers think on the domain specific features of science, some of them (f=3) have some misconceptions about the methods of science as step-by-step activities such as ‘asking questions’, ‘construction of hypothesis’, ‘experimentation’, ‘hypothesis testing’, ‘supporting claims’, ‘manipulative testing’ and ‘verification by trying’. All those codes show that even though all science teachers think that there are various methods in science, they still give step-by-step activities as the methods used in science. It may show us that some of the science teachers were not able to elaborate their views on how those methods can be varied based on different disciplines.

Scientific Practices

When scientific practices were asked to science teachers, five of them claimed to have never heard of this term. Some science teachers identified the scientific practices as ‘easy method’ (f=1), ‘doing practices’ (f=1), ‘doing something frequently’ (f=1), and ‘practical science’ (f=1). Those teachers were not able to explain the scientific practices since they might have a confusion about the keyword “practice”. However, the other three teachers touched on ‘asking questions’ ‘observation’, ‘data collection’, ‘evaluation of data’, ‘representation’, ‘experimentation’, and ‘using appropriate tools’ as scientific practices. When we look at the general views of teachers on practices it can be concluded that while some of them are able to build connections between different types of practices, some of them have some naïve understanding of that concept.

Scientific Knowledge

When asked to define scientific knowledge, teachers failed to mention laws, theories, or models as examples of scientific knowledge, but one teacher explained scientific knowledge as ‘explanation of phenomena’. All of the teachers claimed that scientific knowledge is supported by scientific data and explanations. Additionally, many of the teachers highlighted the refutable nature of scientific knowledge. Additionally, almost all teachers said that scientific knowledge may change based on new evidence or new interpretations of the same data over time. Based on the teachers' explanations it can be said that they typically concentrated on the 'credible' (f=6), 'falsifiable' (f=2), and 'tentative' (f=7) features of scientific knowledge. The credibility of science was described by one of the teachers in the excerpt that follows.

> P7: What distinguishes scientific knowledge from other knowledge is that if it is scientific knowledge, if this is really something that has been proven to us now, I know that behind it, all those observations and hypotheses that have been verified as a result of research, I know that there is something reliable, so I think it is reliable information...

The science teacher thought scientific knowledge should be grounded on research findings and this makes scientific knowledge reliable. Also, most of the teachers mentioned 'development of scientific knowledge with technological advancements' (f=4) while they were explaining how scientific knowledge can change. Some of the teachers didn't elaborate their views on the development of scientific knowledge but some of them share stories from the history of science to explain how scientific knowledge can change or improve. For instance, one teacher explained how scientific knowledge (SK) can change over time by supporting his ideas with a historical vignette which is about the particle model of light according to Newton, and the wave model of light according to Huygens. Also, he implicitly mentioned law and model while he is talking about this story, but he was not able to explain those are the types of SK explicitly. Considering this, it may be claimed that teachers lack awareness of the various types of scientific information, including theories, laws, and models. However, all science teachers have a common view that scientific knowledge is not permanent since it can be changed over time with development of technology or new discoveries. While some of them elaborate their views in a sophisticated way, some of them didn't give different examples to explain how SK changed.

As a summary, the science teachers generally explained their views on cognitive-epistemic aspects of science but some of them have naïve understanding on some categories such as scientific practices and methods and methodological rules. The teachers generally talked about the social aims and values of science rather than epistemic and cognitive ones. Also, all science teachers emphasize the development of scientific knowledge whereas almost all are not aware that theory, law, and model are the forms of SK.

Social-Institutional Aspects of Science

Social Certification and Dissemination

Most of the teachers explained 'publication'(f=5), 'broadcasting'(f=4), and 'conferences'(f=5) as dissemination ways. One of them explained the dissemination ways as follows.

> P7: Of course, if we look at the present day, they can share communication tools, television, radio, telephones or in different ways such as conferences, symposia...

Then, the science teachers were asked why scientific knowledge should be disseminated. Only 3 teachers explained the aims of dissemination which are 'sharing with public and scientists'(f=3), 'making publicly understandable information'(f=1), and 'providing international collaboration'(f=1). In addition to this, only 4 teachers talked about the certification criteria and there was no consensus among the teachers. Almost all of them explained certification ways with different criteria. For example, while one of them thought certification can be provided 'peer review' (f=2), another mentioned that there should be 'empirical adequacy' (f=1) to certify knowledge. Among all teachers only one teacher explained this category in a sophisticated way by explaining the step-by-step process of dissemination and certification of scientific knowledge. Overall, it can be said that while most of the teachers explained the dissemination ways with different examples, some of them were not able to answer and elaborate their ideas about certification criteria and aims of dissemination.

Professional Activities

When asked what types of professional activity scientists can pursue, the teachers provided some activities. 'Participating in conferences'(f=3), 'publication' (f=3), and 'research' (f=3) are some of the professional activities which were mentioned three times by the teachers. One of the teachers is aware that just producing knowledge is not enough and scientists should be engaged in a series of professional activities.

On the other hand, one of the teachers did not want to answer this question because he said that he does not have any idea on this topic. In addition, some of the teachers (f=2) have naïve beliefs about what professional activities that scientists engage in are. One teacher explained professional activities as motivational activities such as having pets and traveling whereas another teacher thought that professional activities are being professional on job. In addition to them, one of them mentioned some of the characteristics of scientists such as being skeptical, being patient, perseverance etc. and highlighted the practices that scientists use such as observation and discovery instead of talking about the professional activities of scientists. Briefly, while some of the teachers touched upon various professional activities that scientists perform, most of them perceived professional activities as just doing research or participating in conferences and they are not able to elaborate their views on them.

Scientific Ethos

'Intellectual property'(f=3), 'transparency' (f=3) and 'doing no harm' (f=3) are the codes mentioned by three teachers whereas 'social utility' (f=2), 'animal care' (f=2), 'objectivity' (f=2), and 'intellectual honesty' (f=2) were mentioned twice by the teachers as scientific ethos. The science teachers think that the results of the studies should be presented transparently, and the scientists should be honest and objective while interpreting the results of the studies. Also, some of them mentioned that the studies should not be conducted on the animals and should not harm the environment or human beings. One of the teachers explained her views on scientific ethos by highlighting intellectual property as follows.

> P1: ... For example, I said articles. It could possibly be plagiarism. ...In other words, using a sentence taken from someone as if it were your own sentence. For example, they may be contrary to scientific ethos...

Looking at the quote given, it can be said that the teacher expressed an opinion about ‘intellectual property’ which is one of the scientific ethos (SE). Besides, ‘respect’ (f=1), ‘collaboration’ (f=1), and ‘equality of intellectual authority’ (f=1) were mentioned once during the interviews to get science teachers’ views on SE. Briefly, some of the teachers emphasized various ethical issues by supporting their ideas with historical stories and current news, whereas some of them are withdrawn to share and elaborate their views on SE.

Social Values

The teachers were asked about the social values of science. ‘Social utility’ was mentioned three times by the teachers as one of the social values of science. For example, one of the science teachers stated that “science should benefit people, ... science is for humanity” while talking about the values of science whereas another said that “I think for the development of the society, science will make a social contribution...”.

Also, ‘transparency’, ‘intellectual honesty’, ‘doing no harm', 'equality of intellectual honesty’, and ‘freedom' are other codes highlighted once by the teachers as social values of science. One of the teachers mentioned doing no harm as social values but she contradicted her views. The teacher is aware that doing no harm is one of the social values, but she also thinks that the animals can be used for the development of scientific investigations. Besides, one teacher emphasized that the scientists are not free to choose what they want to investigate. Briefly, it can be said that almost all teachers talked about some of the social values especially by focusing on one of them. However, when we consider all the teachers, it is seen that they did not mention all the values individually and they were not able to present sophisticated views on this issue.

Social Organizations and Interactions

Teachers were asked where scientific research is conducted. Five teachers out of eight stated that scientific investigations are conducted in the ‘universities’ and in some of the ‘government institutions’ such as TÜBİTAK (The Scientific and Technological Research Council of Türkiye), BİLSEM, Teknopark (which are some of the scientific institutions in Türkiye). Also, ‘research center’, ‘laboratory’, and ‘school’ are the institutions which were mentioned twice by the teachers whereas ‘hospitals’, ‘science centers’, ‘private campaigns’ and ‘museums’ are other places that were mentioned once. It can be said that all the teachers stated many institutions under this category.

Apart from such social organizations, some teachers (f=2) stated that scientific studies can take place in the workplaces of scientists or in any place independent of the place. Only two teachers explained their ideas on the interactions among the stakeholders and institutions while scientific investigations are conducted. Exclusively, none of them emphasized the dynamics and work distribution in scientific institutions.

Financial Systems

The 'need for money' to carry out scientific research and spread scientific knowledge was acknowledged by all teachers. Due to the possibility of scientific research being halted due to a lack of financing, one of the teachers described how financial systems impact science. All teachers said that the government should fund scientific research and provide financial support when asked where scientists can receive the money for their study.

Some of them (f=3) provided instances of 'governmental funding' opportunities available in Türkiye, like the TÜBİTAK (The Scientific and Technological Research Council of Türkiye) and YLSY (Ministry of National Education Scholarship for Graduate Studies Abroad) scholarships and the state treasury. Besides, some other funding ways such as 'private sector funding, self-funding, and commercialization of science' were mentioned once. In general, science teachers' views on financial systems revolve around the idea of needing money. However, only a few explained how the financial system affects science in a deeper way.

Political Power Structures

According to each teacher, political power structures can have a variety of effects on science. They made a point of highlighting the potential impact of 'ideological constraints' (f=3), 'government constraints' (f=1), 'social construction of gender' (f=2), and 'governmental funding' (f=2) on science. Governments may approve the conduct of scientific research if it is in their 'interest' (f=2), according to some of the teachers. Therefore, conflicts of interest and the benefits of governments may affect how research is developed.

While only one teacher talked about the positive effects of science on politics, the others explained their views on how ideologies and interests of the government affect science negatively. One of the interesting results under this category is that only two female teachers emphasized the effect of social construction of gender on science. One of the female teachers explained her thoughts in the following excerpt.

> P7: ...Here's Alan Turing... ...the person who found a computer... Actually, he is homosexual... So, because this was not accepted at the time, the authorities accepted the man was ill and started giving medicine. ...Huge Alan Turing dies for such a reason. ...I think we should never, ever judge things like this while science is done.

The quotation above indicates that the teacher is aware of the negative influence of social constructions of gender on science. Briefly, it can be concluded that almost all teachers are aware of the effects of the political power structures on science but some of them are not able to explain how it affects in a detailed way. As a summary, it can be said that all science teachers tried to explain their views on social-institutional aspects of science. While some teachers explained the categories in a detailed way, some of them were inadequate to deepen their views. Also, some of the participants held naïve views on professional activities. However, no significant differences were observed based on their demographic information.

Discussion

The current study examined the science teachers' views on nature of science based on Reconceptualized Family

Resemblance Approach to Nature of Science (RFN). The reason to use this framework is that RFN defines science as a holistic, dynamic, interactive, and comprehensive system (Erduran & Dagher, 2014).

The general findings indicated that the science teachers generally have informed views on some aspects of science while some of them have naïve views on some categories such as scientific practices, methods, and professional activities. Even though most of the science teachers explained their views, some of them did not elaborate on their ideas about social categories. This result is in line with one of the studies conducted to examine science and non-science teachers' views of Family Resemblance Approach to NOS (Azninda & Sunarti, 2021).

According to the findings, it could be concluded that most of the teachers showed inadequate views regarding cognitive-epistemic aims and values of science whereas they emphasized generally social aims and values of science. The results are consistent with several of the research that used the Reconceptualized Family Resemblance Approach to NOS (RFN) to look at how university students, in-service science teachers, and pre-service science teachers understand, view, and perceive NOS (Aksoz, 2019; Demirel et al., 2023; Kaya et al, 2019). In order to help science teachers to acquire appropriate views of the nature of science and to define science as a holistic system by being aware of cognitive- epistemic, and social-institutional aspects of science, RFN needs to be explicitly outlined (Erduran & Dagher, 2014) and discussed in the method courses in pre-service teacher education and in-service training programmes.

In the current study, even though all teachers are aware of the domain specific and domain general features of methods and methodological rules which are used in different branches of science, most of them focused on the step-by-step scientific research process. It was found that most of the teachers were not able to categorize methods and practices separately and they used both terms interchangeably and focused on the same things as both methods and practices such as doing experiments, collecting data etc. Some other studies also found similar results regarding this category (Demirel et al., 2023; Ioannidou & Erduran, 2021). This result might be because of the way the methods and methodological rules are represented in the science textbooks since some of the studies showed similar results in the textbooks (Okan & Kaya, 2023a).

Some teachers had naïve views about scientific practices. This may be since the Turkish word for practice indicates something that is simple to use and convenient. Another factor that may have prevented teachers from deepening scientific practices and separating them from scientific methods was the content of the university courses they completed. As a result, the courses that explicitly teach NOS in teacher preparation programs might be changed to provide a comprehensive grasp of scientific practices and dispel some myths about methods and practices used in science (Saribas & Ceyhan, 2015).

The teachers emphasized that scientific knowledge could develop and change over time. But they didn't touch upon the theory, law, and model to mention types of scientific knowledge. This result is also in line with another study conducted with secondary school students and science textbooks (Çilekrenkli & Kaya, 2023; Korsager et al., 2022; Okan & Kaya, 2023b)). This could be as a result of the fact that theories, laws, and models are typically not stressed in schools as forms of scientific knowledge. Teachers' views on scientific knowledge may affect how they teach it in their instructions, and this also affects students' NOS concepts. Teachers should convey the NOS to their students accurately and adequately.

This study showed that although most of the teachers had a view about social-institutional aspects, some teachers were not able to adequately explain their ideas and had naïve understandings for some categories such as professional activities. Considering all these results we can say that other studies examined the teachers' views on social-institutional aspects support each other (Aksoz, 2019; Demirel et al., 2023).

In general, most of the teachers explained the dissemination ways with different examples such as publication, broadcast, and conference, while some of them could not answer and elaborate their ideas about certification criteria and dissemination purposes. Although all teachers mentioned many different institutions and organizations while explaining the social organizations and interactions category, they did not emphasize the dynamics and work distribution in scientific institutions. The teachers' lack of knowledge about the dynamics of scientific institutions and the distribution of work may have led them not to address these issues. In the relationship of scientific organizations with society, external effects such as the impact of scientists' work on society are emphasized while internal processes such as work distribution and team dynamics may be ignored.

Although almost all teachers identified social utility as a social value, they did not show a sufficient view on explaining other social values of science. On the contrary, while some teachers emphasized various ethos such as intellectual property, transparency, doing no harm, social utility, objectivity etc. by supporting their ideas with historical stories and current news, others were hesitant to share and elaborate their views on scientific ethos. This can be as a result of their attentive attention to current global issues.

In addition, almost all teachers are aware of the effects of political power structures and financial systems on science, but some of them are not able to explain in detail how these effects happen. Particularly, some of the participants stated that they did not feel very comfortable talking about many social-institutional categories such as political power structures and financial systems. This might be explained by the representation of those categories in the textbooks and curriculum. Since some of the curriculum and textbook analysis showed that social categories of science were addressed seldom or some of the categories were missed (Caramaschi et al., 2022; Kaya & Erduran, 2016; Kaya et al., 2024; Okan & Kaya, 2023b).

Another reason might be that the traditional teaching focusing on cognitive-epistemic aspects of science still exists in many universities. The science teachers might not talk about these issues in pre-service education courses before that social-institutional aspects might not be as emphasized as cognitive-epistemic aspects. But, in order to further strengthen holistic awareness for each area of science and demonstrate how scientific enterprise operates, the emphasis on each of the nature of science components needs to be presented explicitly in teacher professional development or teacher preparation programs. Our suggestion is also supported by some studies that emphasized the need for providing explicit and reflective science instructions to present the nature of science concepts (Abd-El-Khalick & Akerson, 2009; Edgerly et al., 2022).

Conclusion and Implications

This study was conducted to examine the views of science teachers on cognitive-epistemic and social-institutional aspects of science. The questions asked during the interview are about the cognitive-epistemic aspects of science such as the aims and values of science, methods, scientific practices, and scientific knowledge, as well as social-institutional categories of science including social certification and dissemination, social values, scientific ethos, professional activities, social organizations and interactions, financial systems, and political power structures. It was concluded that while some teachers held informed views on certain categories, others maintained naïve views on scientific practices, methods, and professional activities. Although nearly all teachers addressed each social-institutional aspect, most were unable to elaborate on their ideas as outlined in RFN. All these results indicate that while the teachers have some ideas about all the categories, they struggle to articulate their ideas in depth.

What teachers know about NOS and how they define science may affect the teachers' actions in the classrooms and the way they approach teaching science as a holistic enterprise. Therefore, improving teachers' understanding of the NOS holistically should be considered a crucial element of teacher professional development programs. Teacher educators who deliver in-service professional development programs should address each component of RFN by showing connections between each aspect of science through explicit discussions to encourage science teachers to be able to see science as a holistic system. Based on these results, it can be said that stakeholders and policy makers should provide training to teachers to improve their NOS views and to help them how to integrate NOS in their classrooms. Some of the studies conducted with lower secondary school students showed that integrating both cognitive-epistemic and social-institutional aspects of science into science lessons improved students' understanding of NOS (Çilekrenkli & Kaya, 2023). The teachers' understanding on NOS can affect their instruction (Vazquez et al., 2013) hence it is important that teachers should possess an adequate NOS understanding to improve their students' NOS understanding. Further research can be conducted with a large sample size of science teachers and case studies can be conducted to see how their views on NOS affect their instructions.

The Higher Education Council (HEC) in Türkiye oversees the regulation and policies of higher education institutions, ensuring academic standards and shaping educational policies. Although HEC identified a course called Nature of Science and Teaching in the undergraduate program of science teaching, there is no comprehensive information on which universities offer this course, the content and impact of these courses on students' NOS understanding. During the training of teachers, very little attention is paid to issues related to the nature of science (Çakıcı, 2013). In addition, there are very few professional development studies involving NOS and teaching (Caymaz, 2022). Besides, in the "In-Service Training Activities Planned for the Years 2001-2023" published by the Ministry of National Education, no training on the nature of science was found. This situation shows that science teachers have no in-service training opportunities on this subject. The Reconceptualized Family Resemblance Approach to NOS should be specifically acknowledged and included in science teacher education curricula and science teacher professional development programs to present a holistic understanding of the nature of science.

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Declaration of Interest

The authors report there are no competing interests to declare.

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Appendix. Interview Questions

1. What is your branch? For how long have you been teaching?
2. What is science? How do you define science?
3. What comes to your mind when I say nature of science (NOS)?
4. What do aims and values of science mean to you? Can you give examples of aims and values of science? (AV)
5. What are the scientific methods? Can you give examples of scientific methods? (M)
   - Is there one scientific method that is followed by all scientists? Why?
   - Do all branches of science use the same scientific method? Does this differ? How?
6. What do scientific practices mean to you? Can you give examples of scientific practices? (SP)
7. What is the scientific knowledge? (SK)
   - Do you think scientific knowledge can change? Please explain.
8. What do social and institutional aspects of science mean to you? Can you give any examples?
   - What do you think about the social certification and dissemination? I mean, in what ways can scientists share their work with others? (SCD)
   - What does the scientific ethos mean to you? So, are there any norms that scientists follow when interacting with colleagues or during their own work? What are they? (SE)
   - What do you think of social values of science? What can be the social values of science? (SV)
   - What professional activities do scientists do? (PA)
   - What comes to your mind when I say social organizations and interactions? Where is scientific knowledge produced? (SOI)
   - What do you think about the relationship between science and financial systems? Do scientists need money for their research? (FS)
   - Is there a relationship between science and political power structure? Do you think science is affected by political power structures? (PPS)