

Perceptions of Nature of Science Emerging in Group Discussions: A Comparative Account of Pre-Service Teachers from Turkey and England

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**Abstract**

The paper presents a study about pre-service science teachers' perceptions of Nature of Science (NOS). Although there is substantial amount of research on NOS in science teacher education, international comparative accounts particularly of in-depth qualitative data emerging from group discussions are fairly minimal. The primary aim of the research was to determine the changes of pre-service science teachers' NOS perceptions following group discussions in two different national contexts: Turkey and England. Two groups of pre-service teachers from Turkey were contrasted with two groups of pre-service teachers from England. The group discussions were structured with a set of steps. In the first step, the participants were asked to reflect about NOS and record their key ideas on sticky notes. Subsequently they were presented with a framework of NOS represented in an image, and they were asked to situate their own ideas from the sticky notes onto this image. Verbal data from group discussions were investigated by qualitative methodology using thematic analysis. The findings suggest that both groups of pre-service teachers initially focused on epistemic-cognitive aspects of NOS but their ideas became more nuanced in providing some examples about social and institutional dimensions of NOS following the introduction of the NOS image. The study contributes to the understanding of how pre-service teachers view NOS and illustrates how NOS can potentially be incorporated in science teacher education.

**Keywords:** comparative study, focus group discussions, nature of science, pre-service science teachers

## Introduction

Nature of science (NOS) is a significant area of research in science education (e.g. e.g. Abd-El-Khalick & Lederman, 2000; Allchin, 2013; Erduran & Dagher, 2014; Matthews, 2012) as well as curriculum policy (e.g. NGSS Lead States, 2013). As proponents of the so-called “consensus view”, Abd-El-Khalick and Lederman (2000) discussed the tenets of NOS by focusing on the concepts of epistemology of science and development of scientific knowledge. Allchin (2011), on the other hand, focused on the epistemic values of science, such as scientific enterprise, motivation, funding, and peer review. Matthews (2012) underlined the features of science by focusing on epistemological, psychological, technological, historical, social, and economic perspectives of science. Most recently, Erduran and Dagher (2014) produced a book-length account of NOS based on the Family Resemblance Approach (FRA) which characterizes science as a cognitive, epistemic and social-institutional system. This perspective provides a meta-level, holistic and comprehensive account to explain NOS.

Early accounts of NOS including those represented by Driver, Leach, Millar, and Scott (1996) highlighted the potential benefits of understanding and learning NOS for students. They underlined that understanding NOS helps students to appreciate and understand the process of science, raise awareness about socio-scientific issues, comprehend the norms of scientific society, appreciate science as one of the main elements of contemporary society and culture, and learn science content in a deeper way. It has been emphasised, thus, that science education should promote not only the acquisition of the content of science, but also NOS for developing scientifically literate citizens, educators and teachers (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). Pre-service teachers are part of the key stakeholders whose perceptions and perceptions of NOS are important in the science education sector. As such, much research has

been carried out to find out how to support the learning to teach NOS by pre-service science teachers (e.g. Akerson & Hanuscin, 2007; Bianchini & Colburn, 2000).

Studies on NOS based on the FRA has been studied empirically in the contexts of elementary science education, teacher education, and textbook and curriculum analysis contexts (e.g. Alayoglu, 2018; Authors, 2019; BaouJoude, Dagher & Refai, 2017; Cullinane, 2018; Erduran, Dagher, & McDonald, 2019; Karabas, 2017; Sarıbaş & Ceyhan, 2015). However, although many studies emphasize the necessity of learning and teaching NOS in teacher education, there is still limited research on pre-service science teachers' perceptions of NOS framed from the FRA perspective.

In this paper, the findings from an international comparative study and funded research and development project are presented. This study aimed to investigate and compare pre-service science teachers' perceptions of cognitive, epistemic and social-institutional systems of science through Family Resemblance Approach (FRA) to NOS in the contexts of England and Turkey. FRA is a relatively new concept in NOS research in science education. Hence, part of our intention in this paper is to understand the utility of this framework in terms of elucidating teachers' views of NOS. An FRA-based NOS framework may potentially provide detail to understanding pre-service teachers' perceptions of NOS because FRA consists of a fairly sophisticated and a diverse set of components that span different aspects of NOS. These aspects range methods and knowledge (i.e. epistemic components) to social ethos and political power structures (ie. social and institutional aspects). The comparative study can illustrate the similarities and differences between pre-service science teachers' perceptions of NOS potentially in a more nuanced manner in different contexts.

### **Family Resemblance Approach to NOS**

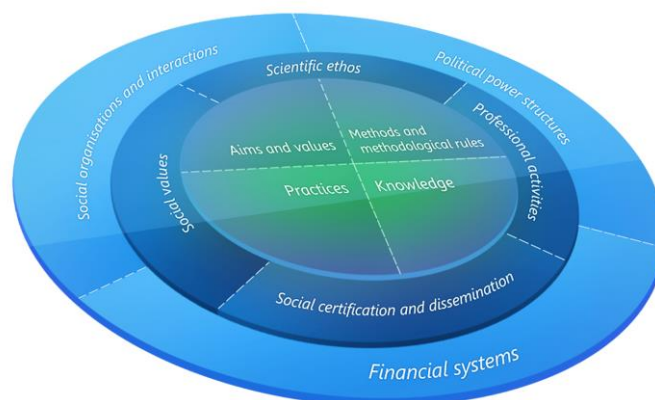
A recent perspective on NOS is based on the Family Resemblance Approach, (Erduran & Dagher, 2014; Irzik & Nola, 2014, 2011) also referred to as Reconceptualised Family Resemblance Approach to NOS (RFN) by some authors (Authors, 2014). Considerable number of studies on NOS in science education have now focused on FRA as an underlying framework (e.g. Authors, 2019; McDonald, 2017; Park et al., 2020). In their book-length account of FRA to NOS, Erduran and Dagher (2014) defines NOS as a cognitive-epistemic and social-institutional system. Epistemic cognitive systems consist of 4 categories which are aims and values, scientific practices, scientific knowledge and methods and methodological rules. Aims and values refers to the key cognitive and epistemic objectives of science such as accuracy, objectivity, empirical adequacy, and critical examination, and also the key social objectives of science, such as addressing human needs, decentralizing power, honesty, and equality of intellectual authority. Scientific practices refer to the set of epistemic-cognitive practices such as real world, prediction, explanation, data, and model. Scientific knowledge refers to the work of theories, laws and models together to generate new scientific knowledge.

On the other hand, social-institutional aspects of science consist of 7 categories. These are social values, scientific ethos, social certification and dissemination, professional activities, political power structures, financial systems, and social organisations and interactions. Social values refer to some values that scientists paid attention such as freedom, respect for the environment, and social utility. Scientific ethos means the norms that scientists employ in their work as well as in interaction with colleagues such as respect for intellectual authority, non-discrimination, animal care.

Social certification and dissemination represent the social mechanisms through which scientists review, evaluate and validate scientific knowledge for instance through peer review systems of journals. Professional activities are the series of activities that scientists engaged in such as attending conferences, presenting findings, reviewing papers. Political power structures

are the dynamics of power that exist between scientists and within science cultures such as gender, race, policies of governments, or hierarchies of scientist. Financial systems refer to the relationship between science and economy such as the effects of developments of technology, commodification and commercialization of science. Finally, social organisations and interactions refer to institutional settings such as universities and research institutes that scientists work in.

Erduran and Dagher (2014) argue that FRA is a holistic account of NOS. These authors have developed images to depict the different aspects of NOS including an overarching figure that is inclusive of all categories of FRA. The FRA Wheel (see Figure 1) illustrates, at-a-glance, the interaction of all components of the cognitive-epistemic and social-institutional systems.



**Figure 1.** FRA Wheel: science as a cognitive epistemic and social-institutional system (Erduran & Dagher, 2014, p.28).

The following brief review of the literature will demonstrate how researchers have engaged with NOS in pre-service teacher education.

### **Pre-service science teachers' perceptions of NOS**

There are considerable amount of research focusing on pre-service teachers' understanding and perceptions of NOS (e.g. Akerson et al., 2009; Akerson, Abd-El-Khalick, & Lederman, 2000; Lederman et al., 2002; Schwartz, Lederman, & Crawford, 2004; Lederman & Zeidler, 1987; McDonald, 2010; Yacoubian & BouJaoude, 2010). For example, in the USA, Akerson et al., (2009) conducted a study to investigate the development of a community of learners through a professional development program to improve pre-service teachers' perceptions of NOS and teaching practice. They used a questionnaire and interviews to determine the change in the perception of pre-service teachers. They found that teachers became more aware of their changes in perceptions about NOS and that intervention provided them with the context to discuss the challenges related to their professional practice. Although FRA perspectives on NOS are still fairly recent, there are some also empirical studies conducted with pre-service science teachers (Authors, 2018b; Authors, 2019; Authors, 2019b; Cullinane, 2018; Saribaş & Ceyhan, 2015).

Apart from research studies conducted in particular country contexts, there has been some work on international comparative accounts of pre-service science teachers' perceptions and understanding of NOS. Broadly speaking, comparative studies of pre-service in science education has a long history (Cobern, 1989; Liang et al., 2009; Park, 2012; Zhao, et. al., 2008). In the context of research on NOS in science education Cobern (1989), compared American and Nigerian pre-service science teachers' understanding about NOS. They used Nature of Science Survey (NOSS) to generate the data source and found that the Nigerian students were much more inclined to see science as a way of producing useful technology and they perceived scientists as nationalistic about their work. On the other hand, Park (2012) aimed to identify students' perceptions of learning activities, assessment formats, and content on their understanding of the NOS by comparing and examining constructs created by Canadian and Korean students. They found statistically significance difference for the effect of country

across all of their perceptions except for the concepts of culturally embedded science and the perceptions of short-answer test formats. The results showed that Canadian students perceived that they engaged with relatively more student-directed activities while Korean students perceived that they had more teacher-directed science lab activities.

Liang et al., (2009) conducted a study with pre-service science teachers' from United States, Turkey and China to compare their perceptions about the nature of scientific knowledge development with respect to six aspects: observations and inferences, tentativeness, scientific theories and laws, social and cultural embeddedness, creativity and imagination, and scientific methods. They reached the conclusion that pre-service science teachers have better understanding of the tentative NOS aspect but less understanding of the nature of and relationship between scientific theories and scientific laws. The Chinese sample had the highest score as compared to the scores of the others; the USA sample showed more developed views on observation and inference; and Turkish sample relatively more traditional views in all six NOS aspects.

In the empirical study described in the rest of this paper, pre-service science teachers from Turkey and England have been contrasted through a qualitative analysis in order to gain an in-depth understanding of how they consider NOS as a cognitive-epistemic and social-epistemic system. In order to provide a contrast of national contexts in Turkey and England, the following section derived from our work elsewhere (Authors, 2019) provides an overview of how teacher education is structured in each country.

### **Teacher education in England and Turkey**

In the United Kingdom (which includes England, Scotland, Wales and Northern Ireland) there are broadly two approaches to teacher training: university-led teacher training and school-led teacher training. The university-led teacher training involves the one-year

postgraduate qualification, such as a PGCE (Postgraduate Certificate of Education) or PGDE (Postgraduate Diploma of Education, Scotland only) which are a common route into teaching across the UK. In Scotland, Northern Ireland and Republic of Ireland a candidate must complete a postgraduate course in order to become a teacher. In the case of the school-led teacher training course, an applicant is typically selected by a school, or group of schools. He or she is then in school from day one, and most of the training will be based in that school. A lot of school-led courses also offer a postgraduate qualification. School Direct is a one-year Teacher Training route available in England. School-Centred Initial Teacher Training (SCITT) is provided by groups of schools and colleges in England. In Wales, the Graduate Teacher Programme (GTP) gives people the opportunity to qualify as a teacher while working. Teach First is an employment-based route in England and Wales, aimed at recent graduates.

In Turkey, on the other hand, teacher education is carried out by university education faculties. Teacher candidates are trained based on a concurrent model in which they have both subject matter and teaching courses together. The courses include subject matter knowledge and skills in the proportion of 50-60%, knowledge and skills of the teaching profession in the proportion of 25-30% and general culture lessons with the proportion of 15-20%. Students commonly take teaching-related pedagogy courses including educational psychology, curriculum planning and teaching, measurement and evaluation, and classroom management. Pre-service teachers mostly have teaching practice in the fourth year.

The brief overview of teacher education provision in England and Turkey illustrates the systemic variation between the two countries. The content of the programmes themselves can vary enormously. In England, in England after finishing a 3-year undergraduate program, pre-service teachers complete a year of pedagogical training that aims to develop professional skills of teachers through both university courses on lesson planning and preparation, assessment, recording and reporting, responding to individual learning needs, classroom and behaviour

management. There is also a significant element of teaching practice, accounting typically about two thirds of the training being located in schools through the mentorship of an experienced teacher. On the other hand, pre-service teachers in Turkey, train for teaching qualification throughout their undergraduate education in 4 years. They take most of their pedagogically oriented courses and complete their internship during the last two years. The pre-service teachers also get exposed to teaching practice in the final year of the program. Pre-service science teachers take courses which cover curriculum and professional studies and classroom management. A significant difference is that the Turkish students get exposed to more traditional courses such as psychology in their teacher training. Overall, the pedagogical training courses in Turkey are distributed over several years, whereas in England these courses are typically covered within one-year in the PGCE programme offered by universities.

In summary, the teacher education provision in England and Turkey varies significantly in terms of the system and programme level arrangements. There are also the obvious cultural and social differences between these countries. Although valuable to understand, it is beyond the scope of this paper to consider all possible contrasts that are inherent in the country profiles where the empirical research to be described were based. Our primary objective in this paper is to focus on how pre-service science teachers in each country view NOS and how their perceptions compare in light of a relatively recent account of NOS based on the FRA. In other words, we are interested how a new account of NOS can potentially elucidate how pre-service teachers in different countries view NOS.

## **Methodology**

### **Research questions**

The empirical study was guided by the following research questions:

1. How do English and Turkish pre-service science teachers perceive NOS as characterised from an FRA perspective?

2. How do English and Turkish pre-service science teachers' perceptions compare?

As indicated earlier, given that FRA is a relatively new concept in NOS research in science education, part of our intention in the empirical investigation was to understand the utility of this framework in terms of elucidating views about NOS. An FRA-based NOS framework may potentially provide detail to understanding pre-service teachers' perceptions of NOS because FRA consists of a fairly sophisticated and a diverse set of components that span different aspects of NOS. These aspects range methods and knowledge (i.e. epistemic components) to social ethos and political power structures (ie. social and institutional aspects). The comparative element contributes to the agenda of testing the potential of the FRA framework by highlighting the similarities and differences between pre-service science teachers' perceptions of NOS potentially in a more nuanced manner in different contexts. The focus on the national contexts was based on the observation that the English and Turkish systems of teacher education present a very stark comparison (e.g. duration of teacher preparation programmes), and hence might lend themselves to very different outcomes in terms of pre-service teachers' views. We wanted to gain understanding of how pre-service teachers in these different national contexts and educational systems view NOS and how the FRA approach can potentially be used as a tool to do so. Some aspects of these teacher education systems are reviewed in order to illustrate the contrast.

### **Context of the study**

Pre-service teachers participating in the study were both based in universities in England and Turkey. Apart from the contrast already presented between teacher education approaches in both countries, one major difference between the teacher education programmes at the two

universities is related to History and Philosophy of Science (HPS) content taught to teacher candidates. This is particularly relevant to the theme of NOS in this paper given HPS provides a framework for unpacking NOS. Whereas there are options at the Turkish university on some HPS related courses, there is none at the English university.

### **Design of the study**

The methodology of the study follows a multiple-case study design (Yin, 2003). Multiple-case design allows researchers to use collective case studies focusing on themes that might emerge across the groups. The cases from England and Turkey are selected to develop better understanding about pre-service science teachers' views of NOS and to illustrate potential similarities and differences between them. The results are expected to provide a more powerful account about NOS views than what a single case can provide (Gerring, 2007). In order to establish external validity, the same strategy of conducting group discussions has been replicated in both Turkey and England contexts. Group focus discussions were chosen as the means of data collection because they yield extensive data in a confined timeframe (Hennink, 2014). Additionally, focus group discussions can be used in order to expose pre-service science teachers' conservations as well as their opinions and expressions about NOS in depth.

### **Sample**

In line with the purposes of this study, a total of 14 pre-service teachers were chosen based on convenient sampling. The participants had informed consent, and they were 9 (8 females, 1 male) pre-service teachers from a public university in Turkey and 5 (3 females, 2 males) pre-service teachers from a public university in England. The participants from Turkey were in their fourth and final year of bachelor education in the science education program. The

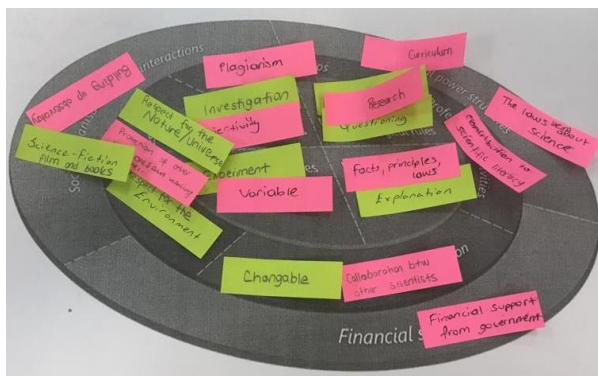
participants from England were enrolled in the PGCE programme of a major public university. In both of these settings participants were randomly split into two groups.

### **Focus Group Discussions**

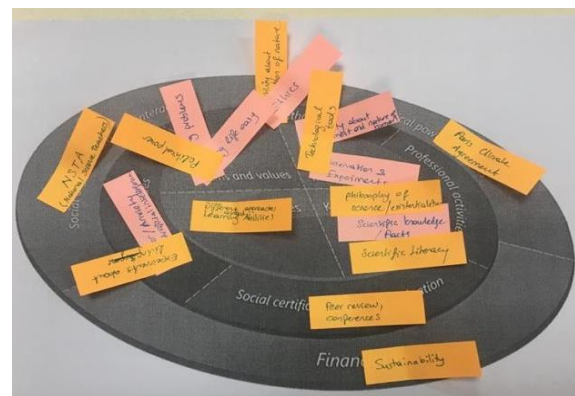
Group discussions lasted about an hour for each group in each context. Since one specific issue was selected during the discussion, the duration was appropriate to investigate selected topics in detail. The group discussions of the two contexts were conducted in different places but in similar formal and preorganized settings. Empty and silent classrooms were selected to ensure that the participants' attention is dedicated to the task at hand. Groups in each context sat around different tables and discussed face to face. The group discussions were conducted in pre-service science teachers' native languages in both contexts so; Turkish was the medium of discussions for groups in Turkey and English for groups in England. However, since the medium of instruction in the Turkish university is actually English, the pre-service teachers are fairly comfortable with using English in written resources. Hence the written part of the group work in the Turkish context also operated in English.

The discussions were conducted in three main parts. There was an initial question posed to them by the interviewer: *"What do you think nature of science is about?"* Each group member produced some keywords about the characteristics of science and then they wrote down their ideas on sticky notes. After the end of this part of the discussion, the instructor distributed the figure of "FRA Wheel" and definition table of the categories. As the second step, instructor expected students to consider the wheel and definitions of the categories and asked the participants to place their sticky notes on to the sections of the FRA Wheel where they thought suitable (see Figure 2). Hence, the pre-service teacher participants reconsidered their ideas about NOS, and they placed their sticky notes into the related sections of the FRA Wheel.

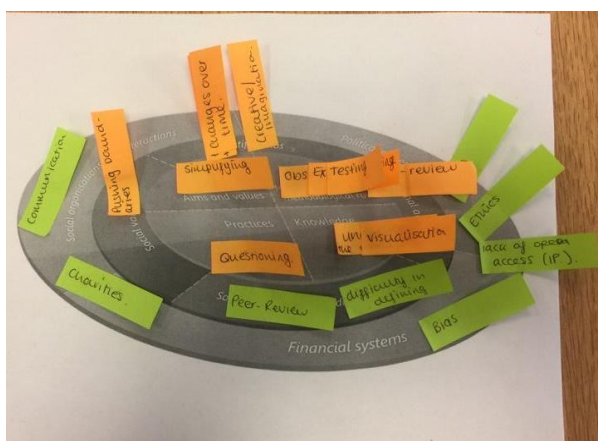
As a final step, the interviewer asked the participants to use different coloured sticky notes to produce a new set of statements to write further ideas for each category on the FRA Wheel. With the help of the table of definitions, the participants produced new ideas about what they thought NOS is about and they wrote down these new ideas and placed them on FRA Wheel. In this fashion, the participants reflected on their initial and FRA-based ideas captured on different coloured sticky notes on the FRA Wheel. Hence their initial and subsequent ideas were clearly visible not only to themselves but also to the whole group for further discussion.



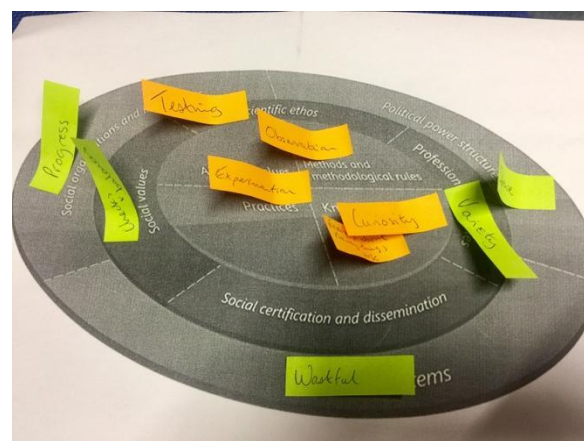
(a) Turkey Group 1



(b) Turkey Group 2



(c) England Group 1



(d) England Group 2

**Figure 2.** The FRA Wheels used by the participants during the group discussions: (a) Group 1 from Turkey, (b) Group 2 from Turkey, (c) Group 1 from England and (d) Group 2 from England.

## Data sources

Data sources are interviews of group discussions. During the discussions, “FRA Wheel” (see Figure 1) and the table of definitions of the categories (see Table 2) were used to support the discussions. Table 1 provides the definitions of the FRA categories which are aims and values, science, scientific knowledge, scientific practices, methods and methodological rules and social-institutional systems. It also explains 7 subcategories of the social-institutional category separately. These categories are theoretically defined by nature in Erduran and Dagher’s (2014) framework although these authors have also provided examples from curriculum standards to illustrate how they can be exemplified in empirical data.

In this study, we have used these categories both (a) from a top-down approach in terms of the use of the FRA wheel as a tool in the focus group discussions and (b) also in a bottom up fashion in interpreting the data generated on sticky notes by the participants. A picture of the FRA wheel was distributed to the participants to trigger their thinking about NOS. Through the wheel and the table of definitions, participants were encouraged to think about other aspects of science that they had not included in their original discussion. Hence, they produced additional keywords and statements which were not previously considered. In this fashion, the FRA Wheel served as a pedagogical tool to organize participants’ ideas.

**Table 1.** Definitions of FRA Categories (adapted from Erduran & Dagher, 2014).

<b>Categories</b>	<b>Definition</b>
Aims and values	The key cognitive and epistemic objectives of science, such as accuracy and objectivity
Scientific practices	The set of epistemic and cognitive practices that lead to scientific knowledge through social certification
Methods	The manipulative, as well as non-manipulative techniques that underpin scientific investigations
Knowledge	Theories laws and explanations that underpin the outcomes of the scientific inquiry
Scientific ethos	The norms that scientists employ in their work as well as in interaction with colleagues

Social certification and dissemination	The social mechanisms through which scientists review, evaluate and validate scientific knowledge for instance through peer review systems of journals.
Social values	Values such as freedom, respect for the environment, and social utility
Professional activities	How scientists engage in professional settings such as attending conferences and doing publication reviews
Social organisations and interactions	How science is arranged in institutional settings such as universities and research institutes.
Financial systems	The underlying financial dimensions of science including the funding mechanisms
Political power structures	The dynamics of power that exist between scientists and within science cultures

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### Data Analysis

Thematic analysis (Cresswell, 2007) on audiotaped discussions was used to investigate pre-service science teachers' views of NOS. In the analysis of multiple case studies, typically a thematic cross-case analysis is conducted after with-in case analyses (Yin, 2003). Accordingly, a within case analysis was conducted for each group by using 12 different FRA categories as the predetermined themes of the coding. For example, when a preservice science teacher made a verbal comment in the audio-recording such as the following, we traced the FRA categories to see which might be the most relevant:

*A lot of people would do it for the money, but the majority of scientists would do it out of curiosity, out of interest.*

In this case, the reference to words such as "out of curiosity" and "out of interest" suggest an underpinning message about the aims and values of doing science. Hence, we would categorise it as an instance of "Aims and Values" category of FRA. In some cases, the nuance in the local meaning of some key words made a difference in which FRA category they were assigned to. For instance, if the participants were talking about the purpose and goal of science

to be 'inquiry', this word would be assigned to the *Aims and Values* category, whereas if they were mentioning inquiry as a process that scientists follow in order to do investigations, it would be classified as an instance of *Scientific Practices* category.

Subsequently, the codes were identified as pre- and post-FRA intervention in the discussion. After forming a description of each case's account of NOS, a cross-case analysis was conducted in order to compare the Turkish and English pre-service teachers' perceptions of NOS. Similarly, the keywords that were generated by the pre-service teachers and placed on the FRA Wheels were compared and contrasted as well. The internal consistency (Hennink, 2014) of the codes was investigated. Four researchers independently applied the coding procedure and determined the ratio for internal consistency. The analysis showed that the ratio for the inter-rater reliability was 89%. This value indicates to a high degree of agreement between the four researchers.

### **Results and Findings**

When the FRA Wheels from each group are examined (see Figure 2), it is observed that participants from Turkey added more keywords to the category of aims and values of science. But it should be acknowledged that the participants from England generally tended to add less keywords to the FRA Wheel during their discussions beyond the category of aims and values of science. Examining the FRA Wheels showed that participants from both countries added fewer keywords to the category of scientific practices than they had mentioned during the discussions. Moreover, keywords such as experimentation and observation were attributed to scientific methods although within the FRA framework they are characterised as scientific practices. This might indicate that after taking part in the group discussions the difference between scientific practices and scientific methods was still not clear for the participants.

Participants from all groups added more key words to the scientific methods category than any other category.

Different forms of scientific knowledge (i.e. theories, models, laws) and the relationship between them was not noted in the keywords of the participants from either of the contexts except for one group of participants from Turkey who only wrote down laws. Another observation from the examination of the FRA Wheels was that for the social-institutional categories, there was an increase in the number of keywords produced by participants of all group in both contexts from the beginnings of the discussions until the FRA Wheel and the category definitions were introduced. For example, the participants from the second group in England had not produced keywords in relation to social-institutional aspects of science. But they added some keywords later, after the introduction the FRA Wheel and the definitions.

In the following subsections, the pre- and post-FRA codes, and related quotes for each context will be presented. The full list of the codes is provided in the Appendix. Considering the small sample size, it is not possible to do a quantitative comparison between the codes. In any case, the research questions were not about the extent of the impact of the group discussion following the use of the FRA wheel. Rather, they focused on what affordances the FRA wheel can provide to explore pre-service science teachers' perceptions of NOS. In this sense, the FRA wheel can be said to be both a methodological tool but can also be an instructional resource, facilitating discussions about NOS.

There are shorthand notations in parenthesis at the end of each quotation to denote the data source. For example, (TR-G2-C-POST) indicates that the quotation was taken from a response given by participant C in the second group from Turkey in the part of the discussion that took part after seeing the FRA Wheel and definitions of the categories. The italicized words throughout the text indicate the codes attributed to the participants' statements.

## Aims and Values of Science

The analysis of verbal data from group discussions indicates that group discussions affected pre-service teachers' perceptions about *aims and values* in both country contexts. When they first began their discussions, participants from both of the contexts focused on common issues about NOS such as *understanding the real world* and *curiosity*. At this initial phase, according to the participants from England, other aims of science could be *simplifying ideas*, *experimentation* and *need for scientific literacy*. Participants from Turkey have also stated other aims of science as *serving humanity*, *finding solutions to problems*, *searching for truth*, *gathering information*, *investigation*, and *questioning*.

After seeing the FRA Wheel and the related definitions, the participants started to talk about other issues such as *gaining political power* in the context of Turkey, and *technological progress* and *financial motivation* in the context of England. The example of the latter may be found in the following quotation,

*A lot of people would do it for the money, but the majority of scientists would do it out of curiosity, out of interest.* (EN-G2-B-POST)

Although *accuracy* was a common value mentioned by participants, in both contexts there were limited mention of values related to science. Participants from Turkey have also mentioned about the explanatory power of scientific knowledge and its independence from subjective norms which was labelled as *objectivity* in coding data. The participants from England discussed about *everchanging and evolving nature of science*, *creativity*, *imagination*, and *cultural boundaries* in relation to the values in science. All in all, participants from the two contexts focused on different aims and values of science but there was no marked difference between the sophistication level of participants' perceptions of aims and values of science. For example, the discussion was not nuanced or extensive in terms of how these concepts might be inter-related.

## Scientific Practices

In terms of discussions related to scientific practices, while participants from Turkey were familiar with wide range of scientific practices, participants from England were able to make more in-depth explanations. In Turkey, participants highlighted the concepts of *data collection*, *observation*, *explanation*, *model* and *experimentation* to explain their perceptions about *scientific practices*. These issues are wide ranging and pertinent to the scientific practices as presented in FRA framework. Likewise, the participants' definition of scientific practices is also in line with that of FRA to NOS as seen in the following quote:

*Scientific practices are those practices which are used to reach scientific knowledge that is verified by a group or community.* (TR-G2-C, POST)

The participants from England presented more nuanced characterisation of scientific practices in comparison to participants from Turkey. Similar to their Turkish counterparts, they have also focused on *experimentation*, *observation* and *model* from the elements of scientific practices. However, these participants have discussed scientific practices from a broader and more in-depth point of view by also mentioning *classification*, *prediction* and *making inferences*. They also pointed out the *explanatory* and *predictive capacity of models*, and *domain specificity of scientific practices*. In the following quote the participant expresses that models are used to understand and predict phenomena,

*I used to think modeling as a good technique because you can use it to expect lots of things but then things don't behave according to models. Your model is something you generated to help people understand.*  
(EN-G2-B-PRE)

The perception of thos participant is in line with the way that scientific practices are defined in the FRA framework of Erduran & Dagher (2014). As in the above excerpt, in the theoretical account of FRA acknowledges models as a significant form of scientific knowledge and emphasises their predictive and explanatory power.

## Methods and Methodological Rules of Science

Results indicate that in both contexts, *observation*, *experimentation* and *questioning* are proposed as different kinds of scientific methods. Although participants from both countries viewed the scientific methods to be pluralistic, participants from Turkey illustrated a more naïve understanding. For example, while they agreed that the fact that there can be non-experimental methods, they could not clearly describe what differentiates them.

After the introduction of the FRA Wheel and the definitions, the participants from Turkey started to mention about *forming hypothesis*, but they did not explicitly refer to testing of hypotheses. However, they mentioned *manipulation*. Perceptions of the participants from England were more advanced, since these participants clearly pointed out *testing of hypotheses*, manipulative and non-manipulative practices, such as *observation* and *experimentation*, and the *domain specificity of scientific methods*. For example, one participant from England pointed out that:

*Some branches of science are very much observation particularly biology. They are not experimenting on the creatures they are watching. ... So, it is sort of experiment, but it is not. It is much more observation. Talking about space science and theories of space science, they are not measuring what's going on in a black hole, but they are measuring what's around it and look at what's around it and they think know what's going on. You can't experiment on it. (EN-G2-A-PRE)*

The way that the English pre-service teacher explains the diversity of scientific methods is noteworthy. The participant is not only referring to experimental or manipulative methods of science, but also highlighting the use of observations and inferences. Moreover, in the same group discussion, there was development in the characterisation of scientific practices. They mentioned more complex issues such as domain specificity and variety of scientific methods explicitly.

## Scientific Knowledge

The data analysis indicates that in both country contexts participants considered the branches of science as different forms of scientific knowledge. During the initial stages of the discussion, participants from Turkey described the nature of scientific knowledge through the concepts of *tentativeness*, *uncertainty*, and *evidence-based*, while participants from England only mentioned about *tentativeness*. On the other hand, only the participants from England mentioned *growth of scientific knowledge* through both *paradigm shift* and *gradual knowledge accumulation* patterns. For example, a participant from England pointed out that:

... who knows 50 years down the line. maybe the whole concept of the electrons, protons will change. (EN-G2-B-PRE)

The participant's explanation about the growth of scientific knowledge is noteworthy. The participant clearly underlines the tentative nature of scientific knowledge and its growth mechanism through the philosophical concept of paradigm shift. These are fairly sophisticated concepts for pre-service teachers.

After considering the FRA Wheel and the definitions of the categories, the participants from Turkey started to talk about *hypotheses*, *theories*, *laws*, *facts* and *principles* as different types of scientific knowledge. However, participants from England did not touch upon these concepts, although they were eager to talk about more meta-level characterisations of scientific knowledge such as paradigms. Additionally, one participant from England claimed that theories are not supported by evidence which indicates a naïve understanding of the concept. Participants from England argued about significance of *visualization* and *models* for science, and participants from both contexts were familiar with models as a scientific tool. On the other hand, none of the participants from either country explicitly stated models as one type of scientific knowledge. Similarly, none of the participants from either of the contexts talked about the relationship between different forms of scientific knowledge namely theories, laws and models.

It was found that both English and Turkish pre-service teachers have some alternative conceptions about scientific knowledge category of NOS. Pre-service teachers from Turkey identified types of scientific knowledge as different branches of science such as physics, biology, chemistry, psychology, history, linguistics, science, and mathematics, rather than theories, laws or models. Although this way of characterising scientific knowledge is not necessarily a misconception, it points to a fairly broad characterisation of knowledge without any nuance about the forms or types of scientific knowledge. Pre-service teachers from England, on the other hand, did emphasise the role of theories in scientific knowledge although the association was in the context of stressing the non-technical or non-practical ways of doing science, not necessarily about theories themselves.

### **Social Institutional Aspects of Science**

It was observed that both English and Turkish pre-service teachers mentioned social-institutional aspects of science before FRA Wheel was introduced. Participants from Turkey generally focused on social values, scientific ethos, political power structures, and social organizations and interactions components of science. *Respect for the environment, serving to humanity, ethics, peer review, popular science sources, animal care, threat for humanity, cultural boundaries, political boundaries, and using science for political purposes* were some of the codes obtained from groups in Turkey before introducing the FRA Wheel. For example, one of the participants in Turkey mentioned some threats for humanity by generating atom bombs and fatal consequences of Madam Curie's studies with radiation as examples:

- A: Threats comes to my mind when I say science.*
- C: Yes, atom bombs. They are the results of science.*
- D: Madam Curie.*
- C: Radiation. (TR-G2-A, C, D-PRE)*

In a similar way, the participants from England have also focused on social values, and scientific ethos components of FRA. On the other hand, they have also addressed professional

activities, and social certification and dissemination. *Respect to environment, human rights, ethics, the role of scientist, using science for political purposes, people's beliefs, cultural constraints, and political restrictions* were some other codes obtained from England for the social-institutional context of NOS. For example, participants from England mentioned peer review and scientific standards for social certification and dissemination of science as follows:

*C: It is peer review, isn't it? It is like one person thinks and got results to show me and someone else can kind of reproduce it or debate...*

*A: Reproduce, what are the other words?*

*B: All those things that make it sort of like....*

*C: People don't agree with it.*

*B: Acceptable by scientific standard. (EN-G1-A, B, C-PRE)*

After the introduction of the FRA Wheel, the discussions became more sophisticated for each group and country context. The groups from Turkey mentioned *contribution to scientific literacy, peer review, academic publishing, conferences, seminars, and informing public* as professional activities of science. They referred to issues of *collaboration between scientists, peer review, conferences, writing and sharing articles, sharing scientific finding, and academic publishing* for social certification and dissemination components of science. Furthermore, they developed their initial ideas for social values, and scientific ethos components of FRA. They also referred to concepts such as *curiosity, governmental restrictions, plagiarism, avoiding bias, and ideological and religious constraints* for social values, and scientific ethos. These concepts are not part of the theoretical characterisation of FRA and were not included in the definitions presented to the groups.

It is interesting to note that after introducing the FRA Wheel, groups in Turkey also mentioned financial systems as *financial support from government, budget, sustainable development, providing financial income, and governmental restrictions*. They have talked about the significance of political power structures while introducing the science with related codes such as *curriculum, sustainable development, political figures, international agreements, and governmental restrictions*. Finally, after the introduction of FRA Wheel,

groups in Turkey mentioned *institutions, research centers, and planetariums* as social organizations of science. For example, one participant from Turkey suggested NSTA as an example for social organizations as:

*National Science Teacher Association (NSTA) came to my mind as one of the examples for social organizations. The communication between the scientists in such organizations is important. They work together and they publish articles. By that way, public and especially students can reach the latest studies and access the information.*  
(TR-G2-A-POST)

Participants in England have generally addressed more diverse issues and they covered almost all components of FRA Wheel. However, unlike the Turkish pre-service teachers, after introducing FRA Wheel, the English pre-service teachers generally did not refer to issues related to social values and scientific ethos. For example, they just mentioned *imagination, curiosity, and testing* for scientific ethos of science. On the other hand, it was seen that they started to generate ideas about other social-institutional aspects of science after introducing FRA Wheel. Participants in England mentioned *peer review, scientific communication, using scientific language, understandable language, conferences, and working in labs* as professional activities of science. They identified social certification and dissemination component of science referring to codes such as *sharing scientific finding, scientific communication, using scientific language, understandable language, intellectual property, peer review, citation, credibility of scientific knowledge, and fake news*. The English groups talked about *money, grants, financial motivation, financial bias, companies, commercialization of science, charities, intellectual property, and financial motivation* as financial aspects of science. It was interesting that *ethics, financial bias, open access for science, conspiracy theories, interests of political lobbies, political influence, external influence, and checks and balances* were the issues mentioned for the political power aspects of NOS by participants from England after the introduction of the FRA Wheel. Finally, *companies, labs, institutes, interactions between institutions and charities* were some of the other codes generated from the data of the English

pre-service teachers in reference to social organizations and interactions component of science. For example, one of the participants from England explained the effects of companies and financial effects on science mentioned his experience as follows:

*...Yeah massive. I was in a company that invested a lot in malaria in particular but it is kind of like they are gonna end up making those drugs. What's the point, because they won't be able to fool them so that is another one way. It is like that is the point these companies put huge amount of money and not got it out but it is interesting about it and stuff like how that may influence particularly who then ends up being a leader stuff like that. Cause if that got good business and are able to sell themselves to their team, they are going to do quite well. (EN-G1-B-POST)*

In conclusion, throughout group discussions, participants from Turkey and England addressed different issues for almost all components of social-institutional aspects of science after the introduction of the FRA Wheel, suggesting that the wheel was useful in facilitating discussion. However, while participants from Turkey focused only on governmental restrictions, and ideological and religious constraints, participants from England tended to emphasise other social-institutional aspects, including companies, charities, commercialization of science, intellectual property rights and open access. Similarly, communication between scientists, and social organizations and interactions were discussed in both cases, but only participants in England mentioned about the interaction between different institutions.

Overall, the findings from the investigation of the FRA Wheels suggest that throughout the discussions the issues discussed by the participants from both Turkey and England became more diversified. Analysis of the transcriptions of focus group discussions also supported this finding. For example, in terms of the aims and values of science only after seeing the FRA Wheel and definitions, participants mentioned political aims. This may be in relation to realising one of the outer components of the FRA Wheel: political power structures. On the other hand, in both of the contexts cognitive-epistemic values of science were mentioned in a limited sense. Participants from both contexts mentioned pertinent issues in relation to the scientific practices in terms of the FRA framework.

On the other hand, participants from England discussed scientific practice more deeply mentioning issues related to domain-specificity of scientific practices, and explanatory and predictive capacity of models. In terms of the category of methods, while participants initially referred to limited number of concepts, such as observation, hypothesis and questioning to explain different kind of scientific methods, after introducing the FRA Wheel and definitions, they started to explicitly talk about the variety of scientific methods with respect to different domains of science. Similarly, while participants initially only considered the tentative nature of scientific knowledge and different forms of scientific knowledge in terms of different branches of science, after seeing the FRA wheel, they acknowledged different forms of scientific knowledge through talking about theories, laws and models explicitly.

Moreover, it is interesting that before the introduction of the FRA Wheel, some of the categories of social-institutional system were not mentioned by either English or Turkish participants. Both sets of participants generally addressed scientific ethos and social values categories while defining science before the FRA Wheel. However, throughout the group discussions, participants focused on different issues for almost each component of social systems. For example, groups in Turkey explained political power structures aspects such as management of sustainable development, while groups in England focused on codes of open access for science and conspiracy theories.

### **Conclusions & Discussion**

The study reported in this paper aimed to examine and compare the NOS perceptions of pre-service science teachers from England and Turkey. The group discussions were conducted to explore participants' perceptions based on an account of NOS as a cognitive-epistemic and social-institutional system. Conceptualization of this broad view of science was guided by Erduran and Dagher's (2014) FRA framework. The findings suggest that there are

commonalities and differences between the perceptions of the participants from England and Turkey. Moreover, the focused group discussions following an intervention involving a visual tool and definitions of FRA might have a positive influence on participants' perceptions of NOS.

The English and Turkish pre-service teachers held similar perceptions in the sense that they were fairly limited in terms of how they characterised the social organizations and interactions, financial systems and political power structures categories of FRA. Likewise, as the analysis of how the groups engaged with the FRA Wheels suggested, there was an increase in the number of keywords participants from either of the contexts produced in relation to social-scientific categories. In terms of the development of scientific knowledge, participants from both contexts emphasized that scientific knowledge was tentative in nature and therefore could change in time. On the other hand, participants from both countries did not account for models as a type of scientific knowledge or mention the complementary nature of different types of scientific knowledge. Likewise, participants from both England and Turkey had alternative conceptions about scientific knowledge. Participants from Turkey viewed different branches of science as different types of scientific knowledge.

There were also divergences in the NOS perceptions of the participants. For instance, participants from England had a more sophisticated view of scientific methods since they could explicitly discuss with accurate terminology such as constructing hypothesis. In contrast, participants from Turkey discussed a broader range of scientific practices. Pre-service teachers from Turkey had taken a course on scientific practices in the prior years. This might have been the reason why there was such a difference between the breadth of NOS perceptions of the participants. Furthermore, the Turkish pre-service teachers mentioned many ideas about the social-institutional aspects of science prior to the introduction of the FRA Wheel while the English students expressed no examples of the *financial systems, political power structures*

and *social-organisations and interactions categories* of FRA prior to seeing the wheel. It is possible that the Turkish participants would have been introduced to these issues through the History and Philosophy of Science course offered at their university whereas the English participants would not have had such exposure.

There have been changes in participants' consideration of social-institutional aspects of science throughout the group discussions. For instance, initially while thinking about what science is about participants from either of the countries limitedly mentioned social-institutional aspects of science. Likewise, pre-service teachers did not mention aims of science in relation to financial motivations of the scientists. But, after seeing the FRA Wheel, realizing the social-institutional categories, participants included these in their discussions. Moreover, after seeing the FRA Wheel and the definitions of the categories participants also talked about the types of scientific knowledge. Therefore, the participants' discussions became broader in this regard as well.

Given the empirical study did not investigate further the participants' motivations in making the comments that they did during the group discussion, it is difficult to draw out major inferences about what accounts for the variation between the two groups. In all likelihood, a range of factors, including the participants' own personal and academic backgrounds, their teacher education programmes as well as more widely the social, linguistic and cultural contexts would potentially play a role in how they approached the content of the tasks and the discussions. For example, the data on Turkish participants' reference to religion and government suggest a strong cultural element of how they are positioned in their national context. Similarly, the reference to charities and open access science by the English pre-service teachers suggest that these factors are fairly pronounced in their cultural context. Further studies with bigger sample sizes of participants are needed to draw out any correlations

between how these variables may be involved in the emphasis on different aspects of NOS as well as the details of the nuances between how each aspect is characterised in each context.

The broadening of the perceptions of the participants from both England and Turkey in the short duration of the focus group discussions suggest that the use of visual tools about NOS and opportunities for discussion may be crucial elements in the design of teacher education interventions with the aim of facilitating comprehensive account of NOS. In Saribas and Ceyhan's (2015) study, the effect of the visual tool on scientific practices developed by Erduran and Dagher (2014) was investigated. As a result of introducing this visual tool, researchers found the use of visuals to be supportive of pre-service teachers' representations of NOS. Likewise, in their teacher education intervention study, Authors (2019) also reached the conclusion that teacher education may benefit from group discussions and using images in support of instruction and to improve the pre-service teachers' understanding and perceptions of NOS.

Given the limited duration of the group discussions in the current study, the pre-service teachers did not have the opportunity to learn further about the FRA categories but rather they had integrated their prior knowledge to supplement their views of NOS. In actual teacher education interventions, it would be important to resurface the pre-service science teachers' prior knowledge about NOS by giving them opportunities to think about and articulate their understanding of NOS in a more extended fashion. However, the study suggests that even an hour of discussion with their peers, guided by pedagogical tools such as the FRA Wheel can help pre-service teachers expand their perceptions of NOS by helping them to organize their prior knowledge in a conceptual framework. Furthermore, given our overall purpose of using FRA, a relatively new framework on NOS, to see its affordances on elucidating pre-service teachers' views, our analysis did not include a fairly in-depth investigation on how these pre-service teachers' demographics and academic backgrounds might have influenced their views.

Future studies can potentially do more in-depth analyses as well as quantitative studies in order to determine any correlations between the participants' cultural and academic backgrounds as well as their personal interests. Such investigations can potentially help with the design of teacher education programmes that would support pre-service teachers by considering the relevance of the content.

Overall, the results suggest that group discussions can have an influence on pre-service teachers' perceptions of NOS. Using visual tools might also contribute to the effectiveness of these discussions by serving as an organizer to the teacher candidates' NOS knowledge. Pre-service teachers from England and Turkey were able to express their perceptions of all categories of FRA although in different ways and to a different extent. However, the study provides evidence for the relevance of FRA for supporting teacher education. As such, the study contributes to the emerging research literature on FRA in NOS in science education (e.g. Erduran & Dagher, 2014; Irzik & Nola, 2011; MacDonald, 2017; Park et al., 2020). FRA wheel can also be said to have some methodological utility in guiding analysis of verbal transactions as well as an instructional resource, facilitating discussions about NOS. Given the limited data set in this study, it is not possible to draw out any inferences about how the country level teacher education provision might have contributed to the differences in the English and Turkish pre-service teachers' perceptions of NOS. Future research could potentially involve correlational studies based on participants' educational background, details of their teacher education programmes as well as their exposure to NOS in order to explain the reasons for these differences with a larger sample of participants from each country. Further investigations focusing on classroom practice can also complement research on pre-service teachers' perceptions of NOS to identify how such perceptions might impact their teaching practice.

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