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ARTICLE

From FRA to RFN, or How the Family Resemblance Approach Can Be Transformed for Science Curriculum Analysis on Nature of Science

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Abstract The inclusion of Nature of Science (NOS) in the science curriculum has been advocated around the world for several decades. One way of defining NOS is related to the family resemblance approach (FRA). The family resemblance idea was originally described by Wittgenstein. Subsequently, philosophers and educators have applied Wittgenstein's idea to problems of their own disciplines. For example, Irzik and Nola adapted Wittgenstein's generic definition of the family resemblance idea to NOS, while Erduran and Dagher reconceptualized Irzik and Nola's FRA-to-NOS by synthesizing educational applications by drawing on perspectives from science education research. In this article, we use the terminology of "Reconceptualized FRA-to-NOS (RFN)" to refer to Erduran and Dagher's FRA version which offers an educational account inclusive of knowledge about pedagogical, instructional, curricular and assessment issues in science education. Our motivation for making this distinction is rooted in the need to clarify the various accounts of the family resemblance idea.The key components of the RFN include the aims and values of science, methods and methodological rules, scientific practices, scientific knowledge as well as the social-institutional dimensions of science including the social ethos, certification, and power relations. We investigate the potential of RFN in facilitating curriculum analysis and in determining the gaps related to NOS in the curriculum. We analyze two Turkish science curricula published 7 years apart and illustrate how RFN can contribute not only to the analysis of science curriculum itself but also to trends in science curriculum development. Furthermore, we present an analysis of documents from USA and

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Ireland and contrast them to the Turkish curricula thereby illustrating some trends in the coverage of RFN categories. The results indicate that while both Turkish curricula contain statements that identify science as a cognitive-epistemic system, they underemphasize science as a social-institutional system. The comparison analysis shows results such as the “scientific ethos” category being mentioned by the Irish curriculum while “social organizations and interactions” category being mentioned by the Turkish curriculum. In all documents, there was no overall coherence to NOS as a holistic narrative that would be inclusive of the various RFN categories simultaneously. The article contributes to the framing of NOS from a family resemblance perspective and highlights how RFN categories can be used as analytical tools.

1 Introduction

Nature of science (NOS) has been advocated as a curriculum goal for several decades. For example, the work in the 1960s included seminal pieces by Conant (1961) and Klopfer (1969). According to Klopfer, NOS refers to the processes of scientific inquiry and the developmental nature of knowledge acquisition in science. Some of the work conducted in the 1970s included that of Showalter (1974) who used the adjectives tentative, public, replicable, probabilistic, humanistic, historic, unique, holistic, and empirical to characterize the nature of scientific knowledge. More contemporary accounts of NOS in the science education research literature have been reviewed by Chang et al. (2010) who traced the literature between 1990 and 2007. The key proponents during this period in science education (Abd-El-Khalick 2012; Lederman et al. 2002; McComas and Olson 1998) have outlined a set of statements that characterize what has been referred to as a “consensus view” of NOS. The consensus view of NOS has been applied to curriculum analysis (e.g., Leden and Hansson 2015; McComas 2014; McComas and Olson 1998). For example, using the consensus view of NOS, McComas (2014) reviewed the NOS components of state standards in the USA. Alternative perspectives on NOS have recently emerged and have included the idea of “whole science” (Allchin 2011), “features of science” (Matthews 2012), and the “family resemblance approach (FRA)” (Dagher and Erduran 2016; Erduran 2016; 2014; Erduran and Dagher 2014a; Erduran et al. 2016; Irzik and Nola 2014; Kaya and Erduran 2016) although curriculum investigations based on these alternative approaches are virtually inexistent (e.g., Erduran and Dagher 2014b).

We investigate the use of the FRA for curriculum analysis as an example of how alternative NOS characterizations can contribute to curriculum studies. Our aim is to illustrate the affordance of the FRA in analyzing curriculum statements and thereby informing curriculum development. While the consensus view of NOS (e.g., McComas 2014; Lederman et al. 2002) refers to statements about NOS in terms of particular tenets (e.g., tentativeness of scientific knowledge, difference between observations and inferences, etc.), the FRA consists of classes or categories about NOS (e.g., scientific knowledge, aims and values of science). In this sense, the FRA is a broader and more inclusive framework to capture various aspects of NOS, rather than discrete ideas about NOS tenets. A broader framework may not only capture missing ideas not accounted for by a consensus view analysis but may also set the precedence for curriculum revision if significant aspects of NOS are not addressed in the science curriculum. Previous applications of the FRA to curriculum analysis have been limited but included the examples of the NGSS (Next Generation Science Standards 2013) in the USA (Erduran and Dagher 2014a) and Junior Cycle Draft Specifications (2005) in Ireland (Erduran and Dagher 2014b).

In this article, we analyze two Turkish curricula published 7 years apart (MEB 2013; MEB 2006) and illustrate how the FRA can contribute not only to science curriculum analysis but also to analysis of trends in science curriculum development. Our choice of the Turkish example is related to the observation that there has been a major increase of science education research in Turkey in recent years. According to Lee et al. (2009), Turkey was not in the top 10 countries for 1998–2002 period but ranked 9th for the 2003–2007 time period in terms of the number of papers in top journals. Understanding of the Turkish curricular context might prove useful for other researchers. Our analysis of the Turkish curricula is extended to a comparison with other international curriculum documents from USA and Ireland. The choicse of these countries is based on the fact that there are existing studies (Erduran and Dagher 2014 a, b) which used the family resemblance approach to investigate curricular content. Our ultimate aim is to develop understanding of how the science curriculum content can be improved so that students can appreciate NOS.

2 The Family Resemblance Approach to Nature of Science

The application of FRA to NOS in science education research is relatively new. The original approach proposed by philosophers of science Irzik and Nola (2014, 2011) has been reconceptualized by science educators (Dagher and Erduran 2016; Erduran and Dagher 2014a, b). Some preliminary work has been carried out in the applications of the framework in curricular context (Erduran and Dagher 2014b), and the implications of the FRA for learning pathways on NOS have been considered (Kampourakis 2016). Irzik and Nola (2014) drew on the work of Wittgenstein to describe the idea of family resemblance as follows:

> Consider a set of four characteristics {A, B, C, D}. Then one could imagine four 440 individual items which share any three of these characteristics taken together such as (A&B&C) or (B&C&D) or (A&B&D) or (A&C&D); that is, the various family resemblances are represented as four disjuncts of conjunctions of any three properties chosen from the original set of characteristics. This example of a polythetic model of family resemblances can be generalised as follows. Take any set S of n characteristics; then any individual is a member of the family if and only if it has all of the n characteristics of S, or any (n-1) conjunction of characteristics of S, or any (n-2) conjunction of characteristics of S, or any (n-3) conjunction of characteristics of S and so on. How large n may be and how small (n-x) may be is something that can be left open as befits the idea of a family resemblance which does not wish to impose arbitrary limits and leaves this to a 'case by case' investigation. ... we will employ this polythetic version of family resemblance (in a slightly modified form) in developing our conception of science. (Irzik and Nola 2014, p. 1011).

Irzik and Nola (2014) adapted Wittgenstein's generic definition of family resemblance. These authors' depiction was extended to the characterization of nature of science (hereafter referred to as "FRA-to-NOS" to denote their adaptation). In applying Wittgenstein's family resemblance idea to NOS, Irzik and Nola consider the various branches of science as a "family" with some characteristics that are similar as well as specific. The FRA then can accommodate both the domain-general and the domain-specific features of science. For example, many science domains rely on data collection and observation. Other practices such as experimentation may be restricted in some domains. Irzik and Nola (2014) give the example of astronomy and earth sciences that do not resort to experiments, because neither celestial bodies nor earthquakes can be manipulated in the experimental sense. Irzik and Nola's FRA-to-NOS had several versions. The original FRA-to-NOS (Irzik and Nola 2011a) included four main categories focused on epistemic aspects of science. Irzik and Nola (2011b) introduced institutional and social norms as a fifth component that encompassed Merton's norms, social values and research ethics. In a more recent account, Irzik and Nola (2014) elaborated on the fifth component by transforming it to a social dimension that includes four clearly defined categories: professional activities, scientific ethos, social certification and dissemination, and social values. In summary, Irzik and Nola describe science primarily as a cognitive-epistemic and social system. Within the cognitive-epistemic system, they discuss four categories that include scientific activities/processes, aims and values, scientific methodology and methodological rules, and scientific knowledge. Within the social system, they discuss four aspects that include professional activities, social and ethical norms, community aspects of science work, and the relationships of science with technology and society.

While Irzik and Nola (2014; 2011a, b) adapted Wittgenstein's generic definition of family resemblance idea to NOS, Erduran and Dagher (2014a) reconceptualized Irzik and Nola's FRA-to-NOS for application in science education, producing what will hereafter be referred to as "Reconceptualized FRA-to-NOS" (RFN). In relation to terminology, it is important to note two issues: (a) we are making clarifications about the various versions of the family resemblance idea by different authors, and (b) the disciplinary expertise between the aforementioned authors are radically different (philosophy in the case of Wittgenstein, philosophy of science in the case of Irzik and Nola, and science education in the case of Erduran and Dagher), which suggest different aims and values in their work. Irzik and Nola (2014) referred to "scientific processes" as well as to "activities." These terms were substituted with "practices" in the work of Erduran and Dagher (2014a). Erduran and Dagher (2014a) argue that "using 'scientific practices' in the context of the FRA establishes a healthy distance from the overuse and narrow meanings often associated with scientific process skills in science education, and the generally all-encompassing sense implied by scientific activities." (p. 27). The replacement of the terms is not merely about a change in terminology. It reflects incorporation of findings and observations from science education research.

Erduran and Dagher (2014a) added three categories that they deemed significant for the science curriculum: "social organizations and interactions," "political power structures," and "financial systems" because they impact how science is done and address aspects of scientific work as it is influenced by societal and cultural forces as noted in the field of science studies. Social organizations and interactions have been described in Knorr Cetina's (1999) analysis of the professional and employment status of CERN researchers, along with an analysis of connections of the scientific enterprise to ties in the military and industry by Kaiser (2002) and Kleinman (1998). Political power structures address power relations at the level of gendered ideologies (Fox-Keller 1996; Harding and Hintikka 2003; Pinnick 2005) and colonial science (Bleichmar 2012; McLeod 2000; Schiebinger 2005). The financial system category addresses ways in which states and governments shape scientific research priorities as well as the relationship between science and technology from an economics of science perspective (Diamond 2008; Irzik 2013; Polanyi 2002/1969; Radder 2010). Erduran and Dagher (2014a, b) have referred to the FRA "categories" to specify conceptual classes in relation to NOS. Here, when we use the term "category," we are in line with their use of the term. Throughout the article, when we refer to "characteristics" or "dimensions" of these categories, we are applying generic shorthand for illustrating aspects of these categories.

Dagher and Erduran (2016) highlight that the FRA improves the consensus view of NOS because the extended FRA framework:

1. Acknowledges two concerns raised by Duschl and Grandy (2013) about the consensus view: namely that the natures of scientific practices and scientific knowledge should be part of a broader conception of NOS and that such broader conception appeals to models of growth of knowledge and practices (via FRA categories of scientific knowledge and scientific practices)

2. Satisfies Matthews' (2012) call to break away from declarative statements to thinking about broader concepts but proposes different categories for thinking about these features (via FRA representation of science as a cognitive-epistemic and social-institutional system)

3. Addresses Allchin's concerns about inadequate inclusion of scientific aims and values and the broader social context (via FRA categories of social-institutional aspects such as social ethos and certification)

4. Differs from Clough's view on keeping the consensus view's tenets and turning them into questions but agrees that NOS content ought to be questioned

5. Is compatible with Yacoubian's CT-NOS (2011) approach that is strong on the critical thinking component, an important orientation for implementing the FRA approach instructionally (pp. 5–6)

In both Irzik and Nola's (2014) and Erduran and Dagher's (2014a) accounts of the FRA, there is an emphasis on the meta-level characterization of the key categories related to science from the aims and values of science, to the methods and practices, and to the political power structures underpinning science as a social endeavor. As Dagher and Erduran (2016) argue, such a broad meta-level approach "invites selecting those issues about science that are of immediate relevance to the big ideas under study. The FRA framework alerts us to the missing components about science in science education such that we could make intelligent decisions about which aspect to prioritize when and for what purpose." (p. 7). The visual tool named the "FRA Wheel" captures an image of science as a holistic, dynamic, and comprehensive system with various influences (Erduran and Dagher 2014a). As explained previously, in clarifying the terminology about the FRA, we find it useful to denote Erduran and Dagher's (2014a) version as the RFN to distinguish it from Irzik and Nola's FRA and Wittgenstein's family resemblance idea, although Erduran and Dagher only made the distinction of an "expanded" FRA.

An important aspect of Erduran and Dagher''s (2014) work is that by synthesizing philosophical perspectives offered by Irzik and Nola (2014) with evidence from science education research, these authors have gone beyond a mere expansion of philosophical work with implications for science education. They have reconfigured the content of Irzik and Nola''s FRA account of NOS to suit the purposes of science education. Furthermore, their production of visual tools makes philosophical ideas pedagogically relevant and illustrates how the transformation of the family resemblance idea can be useful for the purposes of curriculum, instruction and assessment. Hence, we envisage their work as "''reconceptualisation''" because of the element of reconfiguration of a philosophical account for a different purpose in a different domain underpinned by its own theoretical and empirical assumptions. While Irzik and Nola's philosophical account is devoid of educational theory and evidence, Erduran and Dagher's educational account synthesizes the philosophical ideas with evidence from science education research. As Bernstein (1996) would put it, each iteration of the "''family resemblance idea''" refers to a field of production where new knowledge is constructed and positioned, where recontextualisations lead to appropriations and repositionings, eventually becoming educational knowledge. In the rest of this article, then, we will refer to Erduran and Dagher's version as the "Reconceptualised Family Resemblance Approach to NOS" or RFN. Overall, in the sense that we distinguish and articulate different conceptual accounts of the FRA, the FRA is a theoretical framework. In the sense that we have adapted Erduran and Dagher's (2014a) version for curriculum analysis, the FRA is a methodological approach. In other words, broadly speaking the FRA can be considered both a theoretical and a methodological approach. In the next section, we will illustrate how we have adapted the RFN to analysis of curricula in Turkey, followed by a comparative curriculum analysis involving documents from the USA and Ireland as examples.

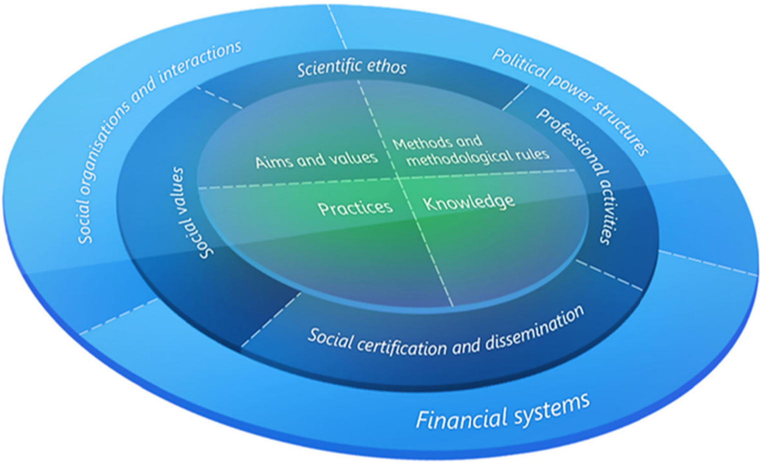

Fig. 1 FRA wheel from Erduran and Dagher (2014a, p. 28)

3 Applying RFN to Curriculum Analysis: Methods and Results

Given the recent emergence of the RFN in science education literature, its application to curriculum analysis is rather scarce. Erduran and Dagher (2014a) gave numerous examples for the potential of FRA in guiding curriculum analysis in their book in the context of US-based NGSS document as well as the English science curriculum. Erduran and Dagher (2014b) have further adapted the FRA to illustrate how curriculum reform can be facilitated by the FRA through analysis of a draft policy specification from Ireland (Erduran and Dagher 2014b). In this article, we analyze two Turkish science curricula published by the Ministry of National Education (abbreviated as MEB in Turkish) with the intention of comparing the results with Erduran and Dagher's (2014b) Irish example. Such a comparison may help clarify how the adaptations of the FRA can contribute to curriculum analysis and development. Comparative curriculum analysis is a method that is employed not only by researchers but also curriculum policy makers in establishing coherence in international standards and identifying where further curriculum development might be needed for enhancing the content of curricula (Ruddock and Sainsbury 2008).

In Turkey, research on NOS has primarily concentrated on the application of the consensus view of NOS (e.g., Aslan and Tasar 2013; Bilican et al. 2014; Cakiroglu et al. 2009). Therefore, we aimed at investigating the coverage of NOS themes in the Turkish middle school science curriculum in its latest (MEB 2013) and previous (MEB 2006) versions from a RFN perspective. In the Turkish context, various dimensions of NOS have been investigated, including the integration of NOS with other strategies such as critical thinking (Irez and Cakir 2006), teachers' views of NOS (Aslan and Tasar 2013), and pre-service teacher education (Koseoglu and Tumay 2010). In the case of textbooks, a number of serious problems have been identified with the way NOS is portrayed in the textbooks (Irez 2009). Science was generally portrayed as collection of facts, not as a dynamic process of generating and testing alternative explanations about nature. Concerns were also raised about the coverage of NOS in the Turkish general science (Kaya and Erduran 2015a) and chemistry curricula (Kaya and Erduran 2015b) in terms of missing and fragmented content. Given the issues raised about the coverage of NOS in the Turkish context, we aimed to investigate recent middle school curricula (MEB 2013; MEB 2006) in order to understand their content on NOS and to provide some potential suggestions for future curriculum development.

3.1 MEB 2006 Curriculum

The middle school science (science and technology) curriculum from 2006 is divided into two sections (MEB, 2006). The first section describes the foundations of the middle school science curriculum such as the vision, the main approach, the main structure, the learning and teaching process, the assessment and so on. The second section presents general and specific outcomes, and learning areas for middle school science and technology courses. There are four learning areas which are “livings things and life”, “matter and change”, “physical events”, and “world and universe”. For students to be able to be scientifically literate in these areas, some learning outcomes in different categories are proposed. These outcomes are classified as “Science-Technology- Society- Environment relations (STSE)”, “Scientific Process Skills (SPS)”, and “Attitude and Values (AV)”. The learning outcomes of each unit in each learning area are presented by integrating them with the learning outcomes about STSE, SPS, and AV. Since the first section of the curriculum (MEB, 2006) covers the vision, main approach, main structure, learning and teaching process including explanations about nature of science in science education, in this article, we focus on the first section on the general introduction for the curriculum aimed at Years 6–8 (age group 12–14) (MEB, 2006). The other section describes the outcomes for specific learning areas. Therefore we did not include this section of the curriculum (MEB, 2006) in our analysis.

3.2 MEB 2013 Curriculum

MEB 2013 science curriculum differs from MEB 2006 science curriculum in terms of the amount of content in the document and the organization of the units, although both cover similar sections. For example, the number of the outcomes in each unit in the MEB 2013 science curriculum is less than those in the MEB 2006 science curriculum. On the other hand, both curricula include a sub-section on nature of science, but again, the amount of content is different in each one with MEB 2013 having less. MEB 2013 is divided into different sections. The first section which is the foundations of the middle school science curriculum describes the vision of the curriculum, the aims of the curriculum, the main approach of the curriculum including the role of teacher-students, the strategies and the methods, and assessment issues. The second section presents four learning areas which are “knowledge,” “skills,” “affective domain,” and “science-technology-society-environment (STSE).” The knowledge area consisted of four sub-areas: “livings and life,” “matter and change,” “physical events,” and “world and universe.” The skill area consisted of scientific process skills and life skills. The affective area consisted of four sub-areas: attitude, motivation, value, and responsibility. The STSE area consists of some sub-areas such as socio-scientific issues, nature of science, the relationship between science and technology, and so on. After presenting these areas, the names of the units, the learning areas under each unit, the number of the learning outcomes, and the number of class hours in each unit are indicated for each grade level (from 3rd grade to 8th grade) in a table. For each grade level, the learning outcomes for each topic and unit are presented. In this article, we focus on the whole document to examine the curriculum aimed for years 3–8 (age group 9–14) (MEB 2013). This science curriculum reflects the ideas about nature of science throughout the document. Both foundation and learning area sections include explanations regarding NOS. That is why we focus whole science curriculum (MEB 2013) in the analysis.

3.3 Coding Curricula

In order to analyze the two versions of Turkish middle school science curricula (MEB 2013; MEB 2006), some keywords were generated. The use of keywords in analyzing curriculum standards has been successfully applied by science education researchers previously. For example, Wang et al. (2012) conducted a research study using keyword analysis based on the comparison of chemistry curriculum standards. Through keyword analysis, they discovered some exemplary features that can reflect the trends in the field of international chemistry curriculum such as performance expectation and the demand of cognitive ability. They noticed the shortcomings of curriculum setting in mainland China and also found three elements that contribute to curriculum structure while searching for the commonalities in content those countries and regions expect students to learn at the primary, lower secondary, and upper secondary schools. In our study, based on document analysis (e.g., Bowen 2009), we generated a set of keywords using Erduran and Dagher's (2014a) definitions of the FRA categories translated into Turkish. For example, for the "social certification and dissemination category," Erduran and Dagher (2014a) defined this category as the social mechanisms through which scientists review, evaluate, and validate scientific knowledge through, e.g., the peer review systems of journals. Therefore, we selected the keywords of "peer-review," "validate," "evaluate," "certification," "dissemination," and "collaboration" as the indicative words of this category. These were used to search the documents for any instances, and examples were selected for further investigation. The keywords are summarized in Table 1.

The analysis was not an exhaustive frequency count of each keyword in the curriculum documents. Rather, the main goal of the analysis was to present any occurrence of exemplars for each category. In other words, we did not count the number of times each RFN category occurred in the curriculum document but rather took the existence of one occurrence as an instance of presence of that category. This is because we are only interested in whether or not each RFN category is exemplified in the curriculum rather than the extent of its coverage. The keyword search of science curricula (MEB 2013; MEB 2006) was conducted by two coders individually. The results found by the two coders were compared and discussed whether the results were consistent. When disagreements emerged, they were resolved through discussion. Eventually, there was agreement between the two coders that the selected instances corresponded to the RFN category and that the translation from Turkish to English was reasonable, given that both coders were native Turkish speakers.

4 Results

4.1 RFN Categories in Turkish Middle School Science Curricula

In Table 2, we present definitions of the RFN categories and examples of curriculum statements in two versions of Turkish science curricula (MEB 2006; MEB 2013). For example, in the case of MEB (2006), the curriculum statement "The aim of science is to understand the world and try to explain it; the aim of technology is to make changes in the natural world in order to meet people's demands and needs" (p. 8) makes an explicit reference to the aims and

Table 1 Keywords used to trace RFN categories in curricula

RFN category	Description	Keywords
Aims and values	The key cognitive and epistemic objectives of science, such as accuracy and objectivity	Aim, value, goal, accuracy, objectivity
Methods	The manipulative as well as non-manipulative techniques that underpin scientific investigations	Method, scientific method, inquiry, process, hypothesis, manipulation of variables
Scientific practices	The set of epistemic and cognitive practices that lead to scientific knowledge through social certification	Observation, experimentation, data, explanation, model, argumentation, classification, prediction
Scientific knowledge	Theories, laws, and explanations that underpin the outcomes of the scientific inquiry	Knowledge, scientific knowledge, formulation of knowledge, theory, law, model
Social certification and dissemination	The social mechanisms through which scientists review, evaluate, and validate scientific knowledge for instance through peer review systems of journals	Peer-review, validate, evaluate, certification, dissemination, collaboration
Scientific ethos	The norms that scientists employ in their work as well as in interaction with colleagues	Scientific norms, ethics, bias, being sceptical, caution against bias
Social values	Values such as freedom, respect for the environment, and social utility	Culture, cultural, social values, society, beliefs, freedom, respect
Professional activities	How scientists engage in professional settings such as attending conferences and doing publication reviews	Conference, article, presentation, writing, publishing, publication
Social organizations and interactions	How science is arranged in institutional settings such as universities and research institutes	University, research center, institution, organization
Financial systems	The underlying financial dimensions of science including the funding mechanisms	Financial, funding, finance, economy, economical, budget
Political power structures	The dynamics of power that exist between scientists and within science cultures	Political power, research team, team leader, team members, researcher, gender, ethnicity, race, nationality

values of science (MEB 2006). An example of the RFN category "social values" is "..to educate constructive, creative and productive individuals who are respectful of human rights and who value initiative, have social responsibility" (p. 2). In the 2006 curriculum, there were instances of categories for which we could not find any examples, including for the category of "professional activities." When such gaps in the curriculum are identified, we can provide some suggestions that might be useful for future curriculum development. For example, as a suggestion to the "professional activities" category, the curriculum could include statements such as "engage in activities such as writing, presenting and communicating results of investigations to other teams."

There are aspects of the RFN category of "scientific practices" in both the 2006 and 2013 documents. However, the 2013 document introduces the concepts of "discussion," "arguments," "evidence," and "justifications" as follows:

> In written and verbal discussions including opposing arguments, teachers' guide and support students in basing their claims on valid evidence and present them with substantiated justifications. (MEB 2013, p. III).

Table 2 RFN categories in Turkish middle school science curricula from 2006 to 2013 (MEB 2006; MEB 2013)

RFN category	Definition	Curriculum statements from 2006 (MEB 2006)	Curriculum statements from 2013 (MEB 2013)
Aims and values	The key cognitive and epistemic objectives of science, such as accuracy and objectivity	"The aim of science is to understand world and try to explain it; the aim of technology is to make changes in natural world in order to supply people's demands and needs" (p. 8)	"The teacher shares the value and importance of science, and the responsibility and excitement of arriving at scientific knowledge with his/her students and s/he leads research processes in the classroom" (p. III)
Methods	The manipulative as well as non-manipulative techniques that underpin scientific investigations	"Scientific methods include the processes of observing, constructing hypothesis, testing, gathering knowledge, interpreting data, and presenting findings" (p. 7)	"Inquiry process is addressed not just as exploration and experimentation but also as explanation and argument" (p. III)
Scientific practices	The set of epistemic and cognitive practices that lead to scientific knowledge through social certification	"- Observe objects and events by using sense organs or observation equipments. - Based on observation, inference, or experiments, suggests possible consequences. - Suggest an experiment to test a hypothesis. - Gather qualitative and quantitative data to test the hypothesis." (p. 77)	"In written and verbal discussions including opposing arguments, teachers' guide and support students in basing their claims on valid evidence and present them with substantiated justifications" (p. III) "The following skills that scientists use while doing science are included: observation, measurement, classification, data collection, hypothesis formation, use of data, construction of models, variation and control of variables, experimentation" (p. V)
Knowledge	Theories, laws, and explanations that underpin the outcomes of the scientific inquiry	"- Give examples for how scientific knowledge change and improve when new evidence are found. - Know the importance of using models to generate scientific knowledge and to present them to other people with the aim of explaining this scientific knowledge" (p. 73)	"To help understand how scientists formulate knowledge, what processes knowledge formulation undergoes and how scientific knowledge is used in new research" (p. II)
Social certification and dissemination	The social mechanisms through which scientists review, evaluate, and validate scientific knowledge for instance through peer review systems of journals	"In the academic discussions in which the participants deal with the issue in detail, a reciprocal dialog and persuasion process happens." (pp. 61–62)	"To enable students' appreciation of how science is developed collaboratively among scientists from different cultures" (p. II)
Scientific ethos		?	?

Table 2 (continued)

RFN category	Definition	Curriculum statements from 2006 (MEB 2006)	Curriculum statements from 2013 (MEB 2013)
	The norms that scientists employ in their work as well as in interaction with colleagues		
Social values	Values such as freedom, respect for the environment, and social utility	".to educate constructive, creative and productive individuals who are respectful of human rights and who value initiative, have social responsibility" (p. 2)	"Scientifically literate person is aware of how social values of the culture and societal structures and beliefs influence how knowledge is cognitively processed" (p. I)
Professional activities	How scientists engage in professional settings such as attending conferences and doing publication reviews	?	?
Social organizations and interactions	How science is arranged in institutional settings such as universities and research institutes	?	"The students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country" (p. 34)
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	?	?

Such emphasis on argumentation and discussion is consistent with Erduran and Dagher's (2014a) characterization of "scientific practices" being inclusive of and mediated by social-certification processes including discourse and argumentation. Such characterization is a marked departure from simply presenting terms such as "observation," "experimentation," and "hypothesis testing" devoid of the mediational processes that enable their occurrence. In this sense, the 2013 curriculum may be considered as an improvement of the earlier 2006 version because of the inclusion of reference to argumentation in general and justification of knowledge claims in particular. While the categories of "financial systems" and "political power structures" are referred to in the curriculum, the "social organizations and interactions" aspect is not mentioned in the 2006 curriculum. Even though there are statements such as "The students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country" (p. 34) in the 2013 curriculum, the RFN category of "social organizations and interactions" is implicit and not clearly articulated. One way of improving such statements is to make explicit the main emphases of the RFN category, for instance by writing that "science is conducted in social organizations such as universities and research centers. The research conducted in these organizations as well as the researchers themselves interact with each other and contribute to the scientific enterprise."

In conclusion, while both MEB 2006 and MEB 2013 contain statements that identify science as a cognitive-epistemic system, they underemphasize science as a social-institutional system. In particular, whereas MEB 2006 contains only two categories of science as a social-institutional system, MEB 2013 contains three categories of science as a social-institutional system out of seven. Overall, MEB 2006 contains statements referring to 6 out of a total of 11 science categories, while MEB 2013 contains statements referring to 7 out of a total of 11 categories. Although MEB 2013 might be considered as an improvement over MEB 2006 in terms of the frequency of categories covered, there are missing RFN statements in both documents which need further improvement.

4.2 The Use of RFN for International Comparative Curriculum Analysis

The preceding analysis of science curriculum documents (MEB 2006; MEB 2013) illustrates how the RFN can guide curriculum analysis. The results of the analysis are consistent with previous research (Erduran and Dagher 2014a, b) in terms of the presence of some categories such as aims and values, knowledge, practices, and methods. In order to investigate the potential of the RFN for international comparative curriculum analysis, we focused on those categories that were not well represented in our analysis as well as those of other researchers (i.e., Erduran and Dagher 2014a, b). In the work of those researchers as well as ours, there is limited reference to the categories of professional activities, financial systems, and political power structures. Hence, we focused on how these categories compare across curriculum documents from Turkey, the USA, and Ireland (see Table 3).

As presented in Table 3, with respect to the "social organizations and interactions" category, only the Turkish curriculum includes a statement of "The students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country" (p. 34). Related to the "scientific ethos" category, there is the statement: "Conduct research relevant to a scientific issue, evaluate different sources of information, understanding that a source may lack detail or show bias" (p. 17). This example of "scientific ethos" is present only in the Irish curriculum, while the US and Turkish curriculum statements did not include any instances of this category. The lack of reference to the "professional activities" category is consistent with the curriculum analysis study by Erduran and Dagher (2014b) who reported the FRA categories in the Irish science curriculum. The "scientific ethos" category is referred to by only the National Council for Curriculum and Assessment (NCCA) in Ireland while "social organizations and interactions" category is referred to by only MEB in Turkey. Overall, the NGSS in the USA referred to only one, whereas the NCCA in Ireland referred to two, and MEB in Turkey referred to three out of the seven categories.

Table 3 Comparison of science curricula from the USA, Ireland, and Turkey for RFN categories about social context of NOS

RFN category	USA NGSS 2013 (Achieve, Inc. 2013b) *Science as a human endeavor [Theme-Appendix H]*	Ireland NCCA 2015 (*Specification for junior cycle science*)	Turkey MEB 2013 (*Science curriculum for middle school education*)
Social certification and dissemination	?	"- Organise and communicate their research and investigative findings in a variety of ways fit for purpose and audience, using relevant scientific terminology and representations (p. 17)	"To enable students' appreciation of how science is developed collaboratively among scientists from different cultures." (p. II)
Scientific ethos	?	"Conduct research relevant to a scientific issue, evaluate different sources of information, understanding that a source may lack detail or show bias" (p. 17)	?
Social values	"Individuals and teams from many nations and cultures have contributed to science and to advances in engineering." "Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings." (Appendix H, p. 6)	?	"Scientifically literate person is aware of how social values of the culture and societal structures and beliefs influence how knowledge is cognitively processed." cau(p. I)
Professional activities	?	?	?
Social organizations and interactions	?	?	"The students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country." (p. 34)
Financial systems	?	?	?
Political power structures	?	?	?

It should be noted that there exist relevant statements for some of the missing categories, but they do not conform to the RFN definitions in our framework. For instance, consider the following examples where the emphasis is our own:

> Globalisation, international *economic* competition, as well as rapid scientific and technological progress will continue to influence our lives. (MEB 2006, p. 5).

> To develop awareness of the interaction between the individual, environment and society as well as sustainable development in society, *economy* and natural resources. (MEB 2013, p. II).

> Many technological solutions are also contributors to a complex set of social and environmental problems. Such problems are increasingly preoccupying the *political* landscape. (MEB 2006, p. 63).

In these examples, even though there is reference to the keywords of "economic" and "political" and at first sight, these might appear as instances of the RFN categories of "financial systems" and "political power structures," they do not capture the meaning of these terms. These categories in Erduran and Dagher's (2014a) characterization emphasized how economic and political factors are inherent to the conduct of science and thus are part of NOS. In other words, they are not factors outside the sphere of the scientific enterprise influencing science from a societal perspective. Rather, they are integral aspects of how science is practiced in organizational and institutional settings. Given that the above characterizations of the economic and political factors do not capture this aspect in relation to NOS, we did not include them in our coding.

A further instance of nuance in the interpretation of the curriculum statements can be considered with some of the categories that we have included as part of the analysis. Consider the following reference to "scientific knowledge": "To help understand how scientists formulate knowledge, what processes knowledge formulation undergoes and how scientific knowledge is used in new research" (MEB 2013, p. II). We have included this example because there is reference to the growth of knowledge processes that is also an aspect of the "scientific knowledge" category as specified by Erduran and Dagher (2014a). However, regarding the generation of scientific knowledge, models are addressed but there is no explanation about how theories, laws, and models are related to each other. Consider the following quote: "Know the importance of using models to generate scientific knowledge and to present them to other people with the aim of explaining this scientific knowledge" (MEB 2006, p. 73).

Hence, even in the case of those positive instances of the RFN categories being present in the curriculum documents, there seems to be a trend in presenting these categories in a rather fragmented set of statements that do not add to a coherent overall vision for that category. This observation is consistent with Erduran and Dagher's (2014b) analysis which indicated that the curriculum provides focus on generic statements about how scientists, for instance, behave in social contexts by directly importing financial and political dimensions of science. The authors argued that the curriculum referred to generic and undifferentiated components that do not necessarily build on an overarching topic or story. They suggested that:

> We believe that students' engagement in science in general and in learning NOS in particular will be enhanced if the various categories are interrelated in meaningful contexts that go beyond disconnected bits of information. In other words, students can be introduced to particular aims and values of science. These in turn dictate what methods and practices are utilized to achieve particular forms of scientific knowledge. These aims, values, practices, methods and knowledge are situated within particular social values, ethos and community norms. There are institutional, financial and political factors that shape, hinder or enhance how science gets done. The presentation of NOS to students in this fashion is likely to make it more meaningful from their point of view, instead of begging questions about why particular aspects are being

highlighted and not others (e.g. why methods and not social contexts). (Erduran and Dagher 2014b, p. 344).

Overall, while we observed most of the RFN categories in the curricula we investigated, it is not entirely clear how the categories contribute to a meaningful whole, an observation consistent with Erduran and Dagher's (2014b) observation. The questions raised in the present article relate to how curriculum statements are related to one another and how they could be considered together in communicating NOS holistically. The contribution of our analysis is that the RFN is not only an analytical tool but it can also serve as a meta-tool in bringing together often disparate pieces of information in curriculum standards. The outcome is that curriculum developers can potentially aim to unify the various statements related to each category so that there is coherence and relevance across them for meaningful learning.

5 Conclusions and Implications

This article presented an investigation of how NOS is articulated in the science curriculum, thereby contributing to existing research literature in this area (e.g., Leden and Hansson 2015; McComas 2014; McComas and Olson 1998). A RFN-based account was used as a tool in the analysis of science curriculum and curriculum development as well as international comparative curriculum analysis. Given FRA-to-NOS is a recent perspective on NOS in science education research (i.e., Irzik and Nola 2014, 2011a, b) with limited applications so far (i.e., Erduran and Dagher 2014a, b), the study provided a rationale for the utility of the FRA in defining and refining work in science education particularly in terms of curriculum studies. The results indicate that some RFN categories had at least one instance referred to in the Turkish curriculum documents (MEB 2013; MEB 2006) although some categories were emphasized at a greater extent than others. While both MEB 2006 and MEB 2013 contain statements that identify science as a cognitive-epistemic system, they underemphasize science as a social-institutional system. Overall, the MEB 2013 curriculum covers more social-institutional system categories as well as all categories when compared to the MEB 2006 curriculum. Although MEB 2013 might be considered as an improvement over MEB 2006 in terms of the frequency of categories covered, there are missing RFN statements in both documents which need further improvement.

Furthermore, the results point out that the RFN categories about the epistemic and cognitive context such as aims and values, scientific practices, and scientific knowledge were included in both curriculum documents. However, the inclusion of the RFN categories related to the social-institutional context was limited in both documents. Even in the case of those positive instances of the RFN categories being present in the curriculum documents, there seems to be a trend in presenting these categories in a rather fragmented set of statements that do not add to a coherent overall vision for that category. For example, regarding scientific knowledge, models as a type of scientific knowledge are mentioned in the curriculum but the relationship and coherence among theories, laws, and models as types of scientific knowledge were not addressed. The other important point is that there are some implicit statements referring to the RFN categories, although they are not illustrated with concrete examples. For instance, the category of "social organizations and interactions" is not explicitly included in the 2013 curriculum. There is some reference to scientific institutions in the document, but the issue of the institutional dimensions of science is not articulated in the sense that the defined RFN category characterizes this concept, for instance as labor division in a laboratory work space.

While there are some keywords related to the RFN categories, they do not actually refer to the inclusion of those categories as defined by Erduran and Dagher (2014a). For example, the statements including "economics" or "politics" are not the indication of "financial system" or "political power structure" categories, respectively, since they are not in accordance with the definitions of these categories. In other words, they do not capture the nuance present in these authors' characterization. With respect to the comparative analysis of international curriculum documents from the USA, Ireland, and Turkey, there was limited coverage of the categories of professional activities, financial systems, and political power structures in all documents. The category of "social organizations and interactions" was present only in the Turkish curriculum, and the "scientific ethos" category was only present in the Irish curriculum. In all documents, there was no indication of NOS as a holistic narrative. Thus, the RFN framework indicates where more attention can be placed in order to make science curriculum more comprehensive and holistic in relation to NOS. The analysis of Turkish curricula has illustrated how the RFN can be used to not only indicate the presence (i.e., scientific aims and values) or absence (i.e., political power structures) of particular aspects of science in the curriculum but also how the RFN provides a nuanced approach to aspects of science that are not traditionally captured in the curriculum. For example, the exclusion of the economic dimensions of science in the "financial system" category showed how the curriculum reinforces economical factors as extrinsic to science and not an intrinsic aspect of NOS.

The present article contributes to the body of work on NOS in science education that has focused on curriculum analysis (e.g., McComas 2014). As stated earlier, while the consensus view of NOS (e.g., McComas 2014; Lederman et al. 2002) refers to statements about NOS in terms of particular tenets (e.g., tentativeness of scientific knowledge, difference between observations and inferences), the FRA-to-NOS consists of classes or categories about NOS (e.g., scientific knowledge, aims and values of science). In this sense, the FRA-to-NOS is a broader and more inclusive framework to capture various aspects of NOS rather than discrete ideas about NOS tenets. Our analysis has thus captured several variations and kinds of statements in each category than might be expected to be captured from a consensus view analysis. For example, one of the consensus view ideas is "Scientific Theories and Laws: Both scientific laws and theories are subject to change. Scientific laws describe generalized relationships, observed or perceived, of natural phenomena under certain conditions" (Lederman et al. 2002). This tenet can be construed as one idea among others in the FRA-to-NOS category of "scientific knowledge". In line with Erduran and Dagher (2014a, b), our depiction of scientific knowledge as a broader category is inclusive of not only theories and laws but also models. This approach to scientific knowledge enabled us to capture statements such as the following: "Know the importance of using models to generate scientific knowledge and to present them to other people with the aim of explaining this scientific knowledge" (MEB 2006, from Table 2). A broader framework may not only capture missing ideas not accounted for by a consensus view analysis but may also set the precedence for curriculum revision if significant aspects of NOS are not addressed in the science curriculum.

In conclusion, the present article clarifies the various depictions of the family resemblance idea which gets transformed for different purposes, from depiction of the nature of science to the educational contexts of nature of science. We highlight how the particular RFN categories can be used as an analytical tool for curriculum analysis. Our analysis further illustrates how curriculum revisions can be studied across time and how comparative curriculum analysis can be facilitated by application of the RFN to curriculum statements. Although our analysis seems to point to some of the missing and incoherent components of the science curriculum about NOS, our intention is to be constructive in using a FRA framework to understand where revisions in the curriculum could be made in order to make it more comprehensive, nuanced, and holistic in its coverage of NOS aspects. Overall, the contribution of our analysis is that the derivatives of the family resemblance idea such as the RFN may not only serve as analytical research tools but also they can serve as conceptual tools for curriculum development. Of course, while some curricula might show evidence of coverage of more RFN categories, inferences cannot be drawn about the quality of science teaching (in terms of breadth of NOS) in the national curricular context as the implementation of the curriculum is a separate issue.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicting interests

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