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EDITORIAL

Family Resemblance Approach in Science Education

Recent Developments

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1 Introduction

The Family Resemblance Approach (FRA) was developed by Irzik and Nola (2011, 2014) to provide a unifying and holistic account of the nature of science (NOS). Building on existing consensus (e.g., Abd-El-Khalick & Lederman, 2000; Eflin et al., 1999; Lederman, 2007; McDonald, 2017) and grounded in the scholarship of the philosophers, historians, and sociologists of science, the FRA provides a structural account of the main characteristics of "science," depicting it as a family of disciplines that share similar features, but also positions each discipline (e.g., chemistry, physics, and biology) as different in nuanced ways. According to the FRA, NOS can be systematically and comprehensively characterized in terms of a number of science categories which exhibit strong similarities and overlaps among diverse scientific disciplines.

While editing this special issue, we received the sad news of the passing of Professor Robert Nola. Dr. Robert Nola (1940–2022) was Professor Emeritus of Philosophy at the University of Auckland, New Zealand. He was an eminent philosopher of science with wide ranging interest in, and contribution to, metaphysics, epistemology, and science education. His take on what makes science "science" spread worldwide and his academic work is highly cited to this day. In his work, Nola provided a comprehensive discussion of scientific methodology and meta-methodology, presenting a pragmatist account of scientific knowledge. Among of his prominent works is the development of the FRA to NOS, in collaboration with Gurol Irzik, which was first published in 2011 in *Science & Education*. The authors' FRA framework was further developed and adapted by Erduran and Dagher (2014) in a book, highlighting the cognitive-epistemic and social-institutional dimensions of NOS. We are honored and grateful that one of Nola's last papers on the FRA is presented in this special issue as an opening article.

Since its introduction, the FRA to NOS has been receiving attention from science educators and the research community (e.gAkbayrak & Kaya, 2020; Barak et al., 2022; Erduran et al., 2019; Kaya & Erduran, 2016; Kaya et al., 2019; Park et al., 2020). Given that there are other accounts of NOS in science education, questions arise, such as: *How is the FRA*

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distinctive from other approaches? What are its main features and attributes? How can the FRA conceptualize science as both a cognitive-epistemic and a social-institutional enterprise? How can this idea be implemented in teachers' professional development programs, science textbooks, and classroom activities?

These questions formed the motivation and rationale for this special issue. The purpose of the special issue is to address these timely questions and discuss different views and takes on the FRA in science education by different research groups from around the world. The special issue opens with Irzik and Nola's paper that revisits the foundations of the FRA to NOS. Next, Dagher and Erduran address questions related to the FRA, deliberating on its significance in science education. Several papers discuss the use of the FRA to examine and promote a deeper understanding of NOS among teachers and students. Other papers present studies from Turkey, South Africa, and Norway, focusing on the applications of the FRA for in-depth analyses of science curricula and school textbooks. Finally, the special issue concludes with an overview of FRA studies and recommendations for further research. The content of the special issue will be further detailed in the following paragraphs.

2 Reexamining and Expanding the Notion of FRA

Irzik and Nola's opening paper revisits the foundations of the FRA to NOS, with some new ideas. The paper provides clarifications regarding the FRA, revealing that it can be used as a domain-specific as well as a domain-general conceptualization of NOS. The paper expands on the structure of science as a social institution by adding a new category—the "reward system," and justifying it. The authors explore how "observation" and "experimentation" display the character of family resemblance, while discussing the possibility of a rapprochement between the FRA and the consensus view. Next, Dagher and Erduran's paper situates the utility of the FRA in contemporary science education. In this reflective paper, the authors aim at accomplishing three goals. First, they address questions related to the FRA to ensure that its applications in science education are based on robust understanding of the framework. Second, they discuss the significance of the FRA by highlighting its capacity to support science educators with the exploration of a wide range of contemporary issues. Third, they offer recommendations for future directions in FRA research in the areas of science identity development and multicultural education, as well as curriculum, instruction, and assessment in science education. Park and Brock build on the concept of the FRA to reflect on how it can explain the diversity and unity of science and help students to differentiate between science and pseudoscience. Based on the FRA framework, they put forward three principles that can guide teaching and learning about pseudoscience. On the other hand, Satanassi and colleagues explore the potential of the FRA to elaborate on disciplinary identities in an interdisciplinary context, in the particular case of the interplay between physics and mathematics. Collectively, the first set of papers illustrate the diversity of conceptual underpinnings and contributions of FRA in science education.

3 Teachers' and Students' Understanding of NOS

From a global perspective, NOS can be viewed as the infrastructure of science and, therefore, the foundation for teaching and learning science. While much research has been conducted about teacher learning of NOS concepts, less is known about how science

teachers and students develop a coherent understanding about various aspects of NOS. Takriti and colleagues discuss issues related to preservice teachers' views of NOS through the macro-lens of the Reconceptualized Family Resemblance Approach to Nature of Science (RFN) which provides a holistic account of teachers' views. Some researchers have coined the term "RFN" to characterize the applications of FRA in science education (e.g., Kaya & Erduran, 2016). However, it is the same framework that was originally proposed by Erduran and Dagher (2014). The study, which was conducted at the College of Education in a United Arab Emirates University, indicated the existence of mixed views, as well as misconceptions on particular aspects of NOS (i.e., the role of bias, gender, and politics on scientific knowledge, the existence of a universal scientific method, and the distinction between laws and theories). In the USA, Voss and colleagues investigated preservice science teachers' instructional views related to the NOS via different aspects of the FRA. In terms of the explicit and reflective components of NOS instruction, participants generally progressed from utilizing inaccurate representations of NOS to inclusion of accurate implicit messages, and finally to explicit reflective instruction often mimicking course activities. The study indicated that preservice teachers tend to use more abstract and contextualized activities for social institutional aspects of NOS as opposed to concrete and moderately contextualized activities for cognitive-epistemic NOS. A similar study by Demirel, Sungur, and Çakiroglu was conducted among in-service science teachers in Turkey. The study investigated science teachers' views about the NOS and its integration into instruction. The RFN approach was used as a theoretical and analytical framework, and the data were collected through semi-structured interviews. The study indicated that teachers use scientific practices and scientific methods interchangeably. The participants provided detailed explanations regarding the social-institutional system of science, and their views were compatible with the RFN framework. Findings revealed that teachers who had spent more time deliberating on NOS tended to include or thought it is important to include NOS into science lessons.

Shifting the focus from science teachers to students, Çilekrenkli and Kaya's paper presents a study on the development of an instructional sequence based on RFN, investigating its effectiveness on fifth-grade students' understanding of NOS and their ability to attain NOS-related learning goals. Situated in elementary schools in Turkey, the study's results showed that the development of experimental students' understanding of NOS was significantly better than their peers in terms of total and category-based scores, except for the aims and values of science and scientific practices categories. The study presents practical implications for integrating a holistic account of NOS in secondary science education. Another empirical study, by Gören and Kaya, applied the RFN as a holistic framework that covers science as epistemic-cognitive and social-institutional systems. Analysis of data collected from more than seven-hundred students, grades 5 to 8, indicated a significant positive relationship between middle school students' RFN understanding and their metacognitive awareness. Furthermore, the results showed that the students with high metacognitive awareness had higher RFN understanding and vice versa. The study proposes the use of metacognitive strategies in RFN-enriched lessons for experimental and causal-comparative designs. Applying a case study, Berntsen, Vik, and Lykknes use an example from the work of the philosopher Henri Victor Regnault (1810–1878) to explore how the history of the thermometry can provide a context for teaching upper-secondary chemistry students about the NOS. The study, conducted among Norwegian students, maintains that the use of historical episodes framed within FRA, invited students to identify with the researcher, providing context to support students' own construction of their understanding of NOS.

4 Analysis of Science Curricula and Textbooks

Textbooks can be useful teaching materials when the content presented aligns with curriculum guidelines, but they may not completely satisfy students' learning needs. The FRA offers a framework for teachers and students seeking to unpack and construct a comprehensive understanding of NOS. Correspondingly, the study of Okan and Kaya explores the inclusion of NOS in Turkish middle school science textbooks. The content, activity, and assessment sections of science textbooks were analyzed based on the FRA categories, resulting in the identification of references to NOS predominantly under the "activity" sections of the textbooks. The study points to a lack in consistent progression concerning the frequency of NOS-related keywords throughout the grade levels. The study raises the need to integrate NOS into science textbooks holistically and in a balanced way to provide a vertical articulation throughout the grade levels.

In a study conducted in South Africa, Yeh, Dhurumraj, and Ramnarain analyzed the way NOS was represented in three high school textbooks. Using the FRA categories and four levels of information explicitness criteria as analytical tools, they found that scientific practices, scientific knowledge, and social values were the three most frequently used NOS representations. Chronological diagrams were employed to denote how NOS representations interacted with one another, as well as reveal the level of information explicitness. The study typified the way NOS-related content align with the learning goals from the FRA perspective. In Norway, Kostøl, Bøe, and Skår's analyzed the coverage of various NOS aspects in the new national curriculum for biology, chemistry, and physics. The new curricula were analyzed deductively, using the FRA to identify and categorize different NOS aspects. Findings show that NOS aspects from the cognitive-epistemic system of the FRA framework—aims and values, methods, practices, and knowledge—are predominant in all three curricula, whereas aspects concerning how science interacts with society are scarce. Furthermore, different NOS aspects were found typical to specific parts of the curriculum; e.g., practices are found in the "basic skills" sections more than in the "competence aims" sections. The paper discusses how the new curriculum reform can promote students' learning of NOS. Based on the FRA category system, Fricke and Reinisch analyzed seven biology textbooks studied in secondary schools in Germany. Cognitive-epistemic NOS representations in four chapters of each of the textbooks were evaluated regarding manner (implicit, explicit) and adequacy. Results indicated that explicit representations of the cognitive-epistemic system of science were mainly placed in the introduction chapters, whereas subject-related chapters include mostly implicit representations. The study presents the evaluation of the quality of cognitive-epistemic NOS representations in school biology textbooks and discusses implications for science education.

5 Summary of FRA Studies

The papers in the current issue point at the importance of the FRA as a promising and fruitful approach to characterizing the NOS in science education. Deep discussions and diverse solutions are offered to some challenges such as capturing both the domain-general and domain-specific features of science with a single framework. For example, Shi's study analyzes the overlap between the conceptualization of the NOS and the philosophy of science. The paper reports on a study that used explicit pedagogical methods to teach topics related to the philosophy of science to Chinese senior high school students. The results show that students who

participated in the philosophy of science course significantly improved their understanding of scientific literacy and the relationships between science, technology, and society. The concluding paper in this issue, by Cheung and Erduran, presents a systematic review of research on FRA to NOS in science education. A journal content analysis was conducted in order to investigate which FRA categories are covered in journal articles and to identify the characteristics of the studies that have used the FRA. The paper illustrates an increasing number of empirical studies using FRA in recent years and a broad coverage in science education. The systematic review identified intra-connections between the social-institutional categories, though they were not as strong as the intra-connections among categories within the cognitive-epistemic system. The paper thus provides an overview and a summary of FRA studies in science education in recent years with implications for K-12 science education.

Declarations

Conflict of Interest The author declares no conflict of interest.

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