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Magnifying the Scope of Nature of Science (NOS) Toward the Whole: An Investigation of NOS Representation in Early Childhood Science Education Standards

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Abstract Effective teaching and learning of Nature of Science (NOS) has been a curriculum goal for decades and its inclusion into the science education from K-12 is becoming commonplace worldwide, regardless of the differences in the adapted science curricula. However, less attention, if any, has been paid to the holistic representation of NOS at kindergarten schooling level. This study utilizes the Family Resemblance Approach (FRA) on NOS to investigate how NOS is represented in the United Arab Emirates (UAE) science curriculum documents for the kindergarten school years, and the extent of its alignment with the international benchmarks and educational research evidence. Findings from the FRA-based curriculum analysis have demonstrated that the standards include "the nature of science" as one of the key domains of science education in the kindergarten stage. However, the cognitive-epistemic dimensions of NOS appeared to be more dominant than the social-institutional system dimensions. Specifically, the majority of the standards and learning outcomes emphasize learning of scientific methods, scientific practices, and scientific knowledge, alongside very few NOS aspects related to

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scientific ethos, social values, professional practices, and social organization. Pedagogical and practical implications of these results for science education are presented, along with recommendations to help structure NOS account into the UAE science standards that is more progressive, holistic, and interactive, all which can be of interest to a broader audience for purposes of curriculum policy reform both locally and internationally.

Résumé Depuis des décennies, l'un des objectifs du programme scolaire est l'enseignement et l'apprentissage efficaces de la nature de la science (NDLS) et son inclusion dans l'enseignement des sciences de la maternelle à la 12e année devient monnaie courante dans le monde entier, quelles que soient les différences entre les programmes scientifiques adaptés. Toutefois, on accorde moins d'attention ou si peu à la représentation holistique de la NDLS à l'école maternelle. Dans cette étude, nous appliquons l'approche de la ressemblance familiale (ARF) sur la NDLS afin d'étudier la façon dont celle-ci est représentée dans la documentation du programme scientifique des Émirats arabes unis (EAU) de la maternelle, et de constater jusqu'à quel point cette représentation s'aligne avec les points de référence internationaux et les produits de la recherche dans le domaine de l'éducation. Les résultats de l'analyse du programme fondée sur l'ARF indiquent que les normes considèrent « la nature de la science» comme l'un des domaines clés de l'enseignement des sciences à l'école maternelle. Cependant, les dimensions cognitives et épistémiques de la NDLS semblent plus dominantes que celles liées au système socio-institutionnel. Plus précisément, la majorité des normes et des résultats d'apprentissage attendus mettent l'accent sur l'apprentissage des méthodes, des pratiques et des connaissances scientifiques, de concert avec très peu d'aspects relatifs à la NDLS liés à l'éthique scientifique, aux valeurs sociales, aux pratiques professionnelles et à l'organisation sociale. Nous abordons les implications pédagogiques et pratiques de ces résultats en ce qui a trait à l'enseignement des sciences et nous formulons des recommandations pour aider à structurer une prise en compte de la NDLS au sein des normes scientifiques des Émirats arabes unis qui est plus progressive, holistique et interactive. Tant du point de vue local qu'international, ceci pourrait séduire un plus large auditoire, intéressé à la question entourant la réforme des programmes d'enseignement.

Keywords Nature of science (NOS) · Science curriculum · Science education · Early years education · Family resemblance approach

Introduction

Assuring the quality of science education has become a priority in educational planning in order to build a generation who possess the required knowledge and skills for future career demands (Dogan, 2017), to enable international competitiveness and to contribute to sustainable economic prosperity and social advancement.

Effective teaching and learning of Nature of Science (NOS) has been a curriculum goal for decades and its inclusion in science education from K-12 is evident worldwide regardless of the differences in science curricula. However, less attention, if any, has been paid to the holistic representation of NOS at kindergarten schooling level. It is accepted that successful science education to facilitate scientific literacy is heavily reliant not only on the effective teaching and learning of content of science, but, most importantly, on the authentic understanding of NOS (Wilcox & Lake, 2018).

Achieving scientific literacy should not be expected without having an adequate understanding of the NOS (Çil & Çepni, 2016). A recent approach to characterize NOS, the Family Resemblance Approach (FRA), has provided a new perspective to conceptualize NOS. FRA includes elements from earlier perspectives while adding new and nontraditional views that link science to other domains (Dagher & Erduran, 2016). Figure 1 represents the relations between FRA and other perspectives of NOS.

During the past 50 years, NOS has been the focus of much research and this has been reflected in scientific educational reform (Wilcox & Lake, 2018). It is crucial that science teachers possess a sound understanding of the underlying ideas about science in order to be able to teach NOS, particularly via a holistic approach. For this to happen, considerations must be given to the curriculum and the extent at which the NOS-related concepts, strategies, and activities are integrated in the curriculum content. Unfortunately, evidence has shown that NOS content is not successfully imparted in the curricula (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick, 2012). Such a lack of knowledge and instruction for teaching NOS in the K-12 levels is believed to be a key factor influencing student understanding of NOS, and hence contributes to any misconceptions (Forawi, 2014). It can be suggested that consideration must be given to the curriculum and the extent to which the NOS-related concepts, strategies, and activities are integrated in the curriculum content as being one of the vital factors influencing students' conceptions and understandings of the NOS (Forawi, 2014).

In order to support science teachers in integrating content and learning activities, a thoughtful and coherent planning for NOS must exist in science curricula (Yeh et al., 2019). Otherwise, assisting students to gain a sound understanding of concepts underlying NOS would be rather a difficult undertaking (Abell & Smith, 1994; Sahin & Deniz, 2016). This situation has directed research efforts toward designing, implementing, and testing appropriate curricula to facilitate an effective inclusion of NOS in science teaching and learning. Such endeavors, however, need to be complemented with effective instructional strategies and a variety of activities with specific guidelines of how to conduct them interactively (Wong et al., 2016). One important task for science education is to examine, challenge, and broaden teacher's and students' current conceptions of NOS. This concern was targeted extensively among science education research community.

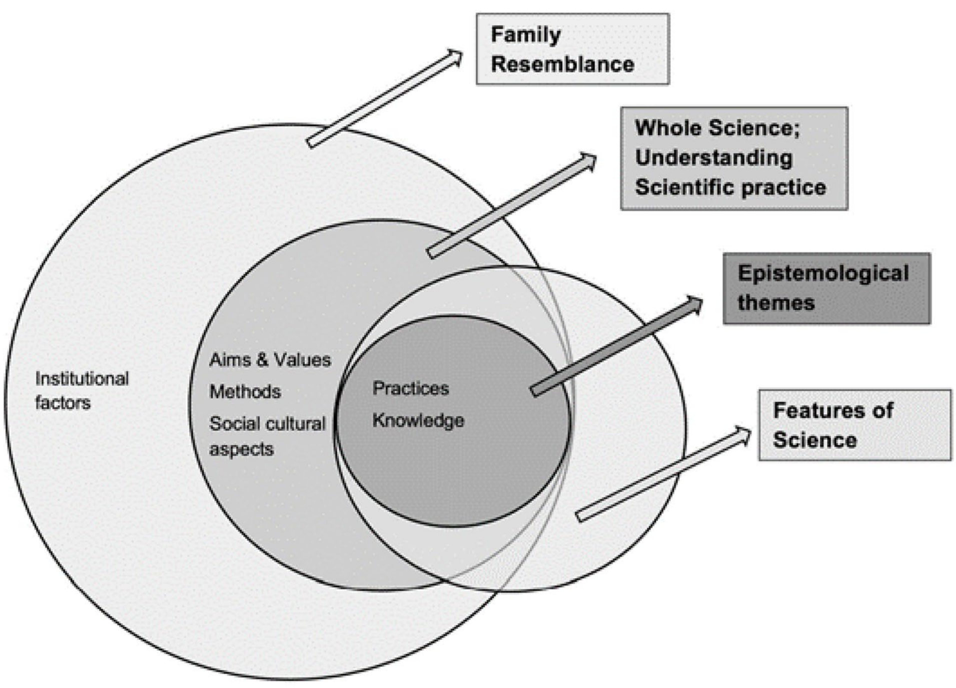

Fig. 1 Representation of the relations between FRA and other perspectives of NOS (adapted from Dagher & Erduran, 2016. p49).

Despite this, less attention is given to the application of NOS as a content and practice, in a holistic manner (Kaya et al., 2019), and thus, the interactive dynamics of its interrelated dimensions has not been an area of focus. Furthermore, previous science curriculum analysis studies have been concerned mostly with the secondary age group (e.g.Yeh et al., 2019), with less attention, if any, being paid to the representation of NOS in early years' education. Science education in the early years can be considered to be important as education with young children tends to be delivered in a less structured way and integration of NOS could be more challenging for teachers as a result (Wilcox & Lake, 2018).

To date, there is a paucity of literature on the status on NOS teaching and learning in the UAE (Al-Naqbi, 2010). In fact, no study has reported how the guidelines for teaching and learning NOS are represented in the UAE science curriculum documents relating to early years of learning, and the extent of its alignment with the international benchmarks and educational research evidence. Internationally, due to the lack of similar analytical studies that handle science curriculum examination especially in the context of the kindergarten science education with a specific focus on NOS, this paper extends prior work by its consideration of the appropriateness of the NOS elements in the UAE science curricula and its scope within the kindergarten science education, a focus that is usually an unrepresented in research.

This study therefore aimed at (a) using the Family Resemblance Approach (FRA) as a framework to analyze UAE science education curriculum documents for early years and to examine how NOS key elements are addressed in these documents and (b) identifying the extent to which NOS elements accurately define the expected learning outcomes. To achieve the purposes, the following questions were asked:

1. How are elements of NOS represented in the UAE science education standard documents for the kindergarten stage?
2. To what extent are the different elements of NOS interconnected in these curriculum documents produced by different educational jurisdictions?

Theoretical Framework

The Interrelated Dynamics of NOS as a Construct

Science is not merely about facts, laws, and theories, but is more about understanding of what science is and how science works, as well as the dynamics and mechanism of science, both as a practice and a discipline (Kaya et al., 2019). This view suggests that the focus of science education should not be limited to the learning of science, but should also include learning about science. Viewing science from such a holistic perspective is commonly referred as "Nature of Science (NOS)" and has been an area of interest in the literature for several years (Erduran & Dagher, 2014; Dagher & Erduran, 2016; Irzik & Nola, 2014).

Researchers such as Irzik and Nola (2014) and Erduran and Dagher (2014) drew on the work of Wittgenstein, which relies on similarities and differences shared among sciences. From this perspective, science operates within two interconnected level-systems, the cognitive-epistemic system and the social-institutional system (Erduran & Dagher, 2014). While the cognitive-epistemic system represents the typical view of science as a system that includes certain beliefs and forms of conduct, the social-institutional system encompasses the dimensions of science that relate to society, politics, and economy. Elements like the standards of behavioral conduct, nature of relations, and impact of institutions are considered significant in conducting scientific research. The first entity relates to the aims and values, practices, methods and methodological rules, and scientific knowledge, whereas the second demonstrates the social ethos, social values, professional activities, social certification and dissemination, and the three categories that were missing in earlier perspectives of science: financial systems, social organizations and interactions, and political power structures.

Irzik and Nola (2014) adapted the Family Resemblance Approach (FRA) while focusing on the interconnections of various aspects of NOS that characterize the scientific enterprise in order to reflect comprehensive representation of these aspects. Erduran and Dagher (2014) have driven a further development of Irzik and Nola's FRA version by extending the theoretical perspective of NOS to include educational applications, resulting in the Reconceptualized Family Resemblance Approach to Nature of Science (RFN). It provides a more holistic account of NOS by considering the scientific enterprise as well as pedagogical, instructional, curricular, and assessment issues in science education (Kaya & Erduran, 2018). FRA is a powerful approach for teaching and learning NOS both holistically and contextually (Kaya et al., 2019). It presents how scientist and scientific events operate in the real world, facilitating students to think and act like scientists in a realistic practical sense. Through this, student cognition and analysis of NOS conceptions can become more evidence-based, case-dependent, and transformational (Yeh et al., 2019).

NOS in the Practice of Science Teaching and Learning

The ultimate goal of science education should not be merely the acquisition of scientific knowledge but the authentic understanding of how this knowledge is constructed to assist understanding of the complexity in the way how science functions within the larger context, both as an enterprise and as a practice (Abell & Smith, 1994). This perspective, indeed, is in line with the benchmarks for science literacy set by the American Association for the Advancement of Science (AAAS, 1993) and the national science education standards (NRC, 1996), as well as in the Specifications for Junior Cycle Science in Ireland (NCCA, 2015). All these initiatives stress NOS understanding through active engagement in inquiry practices such as designing experiments; collecting, analyzing, and interpreting data; and drawing valid conclusions (McDonald & Dominguez, 2005). Accordingly, it is necessary that students possess a solid understanding about the multiple overlapping facets of NOS and their implications in real world so they become able to solve contemporary and future global stressing issues (Forawi & Abdullah, 2019). They need to be able to critically evaluate the current surrounding events in order to make informed personal and social decisions that relate to science. Furthermore, fundamental and explicit changes to the way of how NOS elements are represented in the teaching and learning processes are critical to achieving the overall goal of scientific literacy.

A constructive acquisition of NOS understanding is believed to maximize student awareness in terms of realizing the vital role science plays in societies and cultures as summed up by Driver et al. (1996) who outline the potential benefits of teaching students NOS and indicated that it does not lead only to an increased appreciation of science and more in-depth learning of science content, but also contribute to better understanding of science processes and the norms of the scientific community including the consideration of socio-scientific issues. As such, much effort has focused on restructuring science curricula to consider holistic and coherent integration of NOS in a way that considers its complex and dynamic nature so that it can be explicitly addressed (Wilcox & Lake, 2018; McComas & Nouri, 2016). There have been many efforts to document the representation of NOS in curricula (see, for example, Kaya & Erduran, 2018; Yeh et al., 2019). The findings of these studies in general showed mixed results between presenting NOS as body of knowledge and insufficient representation of scientific thinking and methods of representation of elements of scientific inquiry. However, much is needed to confirm these findings due to contextual and structural differences.

Toward a Holistic and Coherent Integration of NOS into Science Curriculum

The necessity for the integration of NOS instruction into the science education at all levels of schooling from K-12 has been widely advocated for several decades and was highly emphasized in national curricula and standards (Kaya & Erduran, 2018; Lederman, 2007). In essence, the presence of NOS content in the science curriculum and textbooks not only determines the extent at which these will be taught, but more importantly, they greatly influence the way how students will acquire and advance their understanding of NOS (Yager, 1996). Many science teachers rely on the assigned curriculum and textbooks as their content outline and blueprint for their science teaching (Chiappetta et al., 1993). With that in mind, it is logical to assume that the lack of this inclusion of the NOS aspects may likely negatively influence the quality of NOS within science teaching (Sahin & Deniz, 2016).

Science textbooks have been largely dominated by the positivism paradigm which is characterized as being content based where the transmission of heavy content knowledge that embraces an uninformed view about science is the tradition with minor emphasis given for the practical processes and NOS, as well as very little opportunities for real-life connections (Haidar & Balfakih, 1999). This orientation to curriculum resulted in neglecting issues related to NOS, and therefore, NOS was not adequately addressed in the science textbooks with evidence showing that the learning activities also suffered from such a defect of NOS integration (Abd-El-Khalick, 2012).

In recent years, however, science educators started to shift form the traditional and impersonal view of science toward the contemporary view that is underpinned by the history/philosophy approach (Ryan & Aikenhead, 1992). Developing a fundamental knowledge base of NOS that can be embedded into science content, explicitly and implicitly, has become a common worldwide practice in the majority of science education curricula (Al-Bouti, 2018). This goal, though, should go through careful planning in a way that expose students to levels of NOS understanding that can be accumulatively broadened and deepened throughout the school years. For that to happen, NOS cannot anymore be introduced as a separate chapter at the beginning of the textbook, nor as a side note beside the main narrative to reflect on, but rather should be within a relevant context and throughout the entire learning material (Chiappetta et al., 1993). Seminal contributions have been made with this regard; for example, an explicit progression for NOS teaching at different school years was outlined in many policy frameworks such as Benchmarks for Science Literacy (AAAS, 1993) and Next Generation Science Standards (NRC, 2013; Leden et al., 2015). A similar attempt was also pursued by Abd-El-Khalick (2012) who proposed a structure for NOS progression based on NOS tenets that highlight four major aspects of NOS (i.e., tentative, theory-laden, empirical, and social aspects of NOS). This approach was developmentally structured from elementary school to university level, where the NOS content advances in terms of specificity, depth, and complexity across these years. Recently, another NOS progression was developed by Erduran (2014) drawing on FRA framework in which NOS aspects are connected horizontally to science content and vertically to grade level.

Literature Review

Kaya and Erduran (2018) adapted the RFN framework to facilitate analysis across science curriculum guidelines in Turkey, Ireland, and the USA in order to identify trends in the coverage of RFN categories, as well as to mark the gaps related to NOS in these curricula. Findings from this study found that Turkish curricula addressed NOS aspects that identify science as a cognitive-epistemic system but underemphasize science as a social-institutional system. Aspects of NOS were more stressed in some curricula than others, such as the “scientific ethos” in the Irish curriculum and “social organizations and interactions” category in the Turkish curriculum. The study concluded there was no overall coherence in NOS that is inclusive of the various RFN aspects across all the examined documents. Likewise, recent work by Yeh er al. (2019) also adapted FRA as an analytical tool to analyze two sets of Taiwanese curriculum guidelines to see how they address NOS and found that the focus in these documents shifted away from the centralization of the cognitive-epistemic system more toward the social-institutional system.

Two common approaches of teaching NOS have been identified through curriculum analysis. The first is the implicit approach which is underpinned by the belief that NOS understanding is a by-product learning outcome that occurs as a result of engaging in pedagogical learning activities. In this sense, student's understanding of NOS concepts is developed through the processes of questioning, discussion, and investigation. One common orientation of this approach is teaching NOS thought inquiry-based activities (Abd-El-Khalick, 2013; Schwarz, 2009). The second strategy is the explicit approach which regards NOS as curriculum content and uses elements of history and philosophy of science that aim at constructing knowledge of NOS. As such, the focus will be in using historical case studies to engage students in all kinds of reasoning (Lederman et al., 2019; Abell & Lederman, 2007). Curricula with an explicit direct didactic instruction are claimed to be the most effective approach for achieving deep and more sophisticated conceptions of NOS concepts (Abd-El-Khalick, 2013; Forawi, 2014).

Research Context

The current paper reports research conducted in the United Arab Emirates (UAE). In 1979, after the creation of UAE, the Ministry of Education (MOE) developed its National Emirati Curriculum Project, which was implemented in 1985 (Farah & Ridge, 2009). Concurrently, the UAE Government began to place more emphasis on the role of education in building a knowledge-driven economy. The UAE education system, which was established in the early 1970s as per the post-oil era, has encountered multiple stages of developmental transformations since the beginning of the twenty-first century, and thus continued to progress in both the public and private sector schools (Azninda & Sunarti, 2021). These endeavors are directed by the MOE which supervises and regulates the development initiatives within all stages of education in the UAE including schools, colleges, universities, higher education, technical and vocational education, and adult education, as well as they set the overall guidelines they must adhere to (UAE Government Portal, 2021a).

Recently, a great deal of attention has been given to the integration of NOS into the UAE science education. In this respect, the goals for UAE science education highlight the themes of the NOS; processes of science; scientific inquiry; scientific knowledge; scientific literacy; scientific values, attitudes, habits of mind, and dispositions; and the interactions of science, technology, and society (Al-Naqbi, 2010). Additionally, many of the schools across the UAE adapt the Next Generation Science Standards (NGSS) as being the latest science education reform in the UAE (Shakera & Salehb, 2021), as well as the end outcome of the latest science education reform in the USA (Saleh, 2018). They set performance expectations (PEs) indicating what students should be able to demonstrate by the end of each grade level band making up a three-dimensional model of science learning that incorporates Disciplinary Core Ideas (DCIs), Crosscutting Concepts (CCCs), and the Science and Engineering Practices (SEPs). Thus, they provide K-12 science education learning experiences in which knowledge and practice are intertwined, acknowledge the importance and value of NOS, and focus on developing skills and habits that engineers and scientists use in daily life practice (Hoeg & Bencze, 2017). In 2016, the MOE in the UAE signed a 7-year agreement with McGraw-Hill Education to design customized science education program that is aligned with the NGSS curriculum standards (Sahoo, 2016).

In the UAE, efforts were recently undertaken to re-imagine and reform the national school curriculum with specific focus on science, technology, twenty-first century skills, moral values, national identity, innovation, creativity, and critical thinking (Shakera & Salehb, 2021). Consequently, a curricular framework and guidelines were developed for the curricula and teaching materials. Considerations were also given to international standards such as standardized tests such as TIMSS (Trends in International Mathematics and Science Study), PISA (Program for International Student Assessment), and PIRLS (Progress in International Reading Literacy Study) (UAE Government Portal, 2021b).

Based on the previous research focusing on the importance of providing NOS instruction in an age-appropriate manner, building according to grade level, this paper reports a curriculum analysis of NOS content in the kindergarten science education curriculum in the UAE. It is considered that the inclusion of NOS in early years curricula would effectively set the scene for children to understand NOS as an integrated component of science throughout their educational career. Although the study was conducted within the UAE science curricula, it will be of interest to a broader audience beyond the current context, basically science teachers, curriculum developers, and other stakeholders, as findings have practical implications for curriculum policy reform worldwide. Foremost, current insights could yield useful information about what is being emphasized with respect to NOS teaching and learning at the kindergarten learning stage, and to what extent. This may serve as a reference guide in future study to permit for more detailed and broader document analysis or cross-document comparisons, which can be potentially beneficial for orienting own NOS benchmarks based on comparative studies that may examine curricula across different educational systems or countries. This, in turn, illuminates better understanding about what is still lacking and what improvements can be made to the existing guidelines, resulting with having more space to enrich the curriculum content about NOS for upgrading new and more effective pedagogical horizons for science education.

Methodology

The representation of NOS elements in the kindergarten curriculum was investigated by analyzing the standard document in light of the RFN framework. Data collection and analysis followed a qualitative method to achieve categorization and make meaning of statements that guide early years' science teaching and learning in the UAE. The following sections explain the methods this study has followed to attempt to achieve valid and reliable processes for data collection and analysis as well as to yield rich results.

Research Design

Using content analysis design, the data was collected from the Emirati government kindergartens standard document issued by the UAE Ministry of Education in 2019. The standards are divided into four main domains for both levels: KG1 and KG2. The domains are as follows: Earth and space science, Life sciences, Physical science, and the Nature of science and technology. While the domains are provided for the two levels of kindergarten stage, there are some variations in the coverage of these domains between KG1 and KG2.

Instrument and Data Collection

The Family Resemblance Approach (FRA) on NOS (Erduran & Dagher, 2014) was adapted as a framework to examine the NOS aspects reported in the standard documents of the KG curriculum (MOE, 2019). The NOS aspects include Aims and Values, Methods, Scientific Practices, Scientific Knowledge, Scientific Ethos, Social Values, Professional Practices, and Social Organization. The FRA framework was chosen exclusively among other frameworks because it covers a broader scope that comprises the older structures of NOS. This framework has been used for analyzing science curricula from different countries such as Italy (Caramaschi et al., 2022) and Norway (Mork et al., 2022). In an analytical view, adapting such a comprehensive framework to examine and discuss the content of science curriculum was chosen as the most adequate method of conducting this study. To examine the extent of coverage of these aspects in the curriculum, the standard document statements were checked and grouped against these aspects. The documents of kindergarten stage curriculum were analyzed by reading the standards and learning outcomes and then classifying the statements according to the aspects they best represent. The NOS aspects were used as codes to which the standards and learning outcomes were color-coded under. To ensure consistency and reliability of the classification process, two researchers independently examined the curriculum documents, and their coding agreement was determined using Cohen's kappa coefficient, resulting in a coefficient of 0.461, which was regarded as an acceptable index.

Results and Findings

The results of the analysis using the FRA as a framework for analysis suggested in general 100% of the standards and 96.92% of the learning outcomes are categorized under the cognitive-epistemic system dimensions, whereas only 8.25% of standards and 9.54% of outcomes were found to reflect components related to the social-institutional system dimensions. The coding process of the results led to the following themes:

The Representation of NOS Aspects in Kindergarten Curriculum Document

For KG1, all of the embedded 10 standards (100%) and 28 out of the 29 learning outcomes (96.55%) comprise cognitive-epistemic system dimensions. On the other hand, one standard (10%) and 4 of the 29 of learning outcomes (13.79%) fall under the social-institutional system dimensions. Nine standards out of the total of 10 (90%) and 13 outcomes out of the total of 29 (44.82%) fall under the scientific knowledge domain. The categories with the highest number of constituent standards are the scientific knowledge and the methods and methodological rules with 13 and 12 standards, respectively. An example of the standards that represent scientific knowledge is 1.1.1.K1 (Demonstrates an understanding of human's reliance on earth's resources), whereas the 1.1.4.K1 standard statement (Identifies the processes of science and implements them in building his knowledge and understanding in all scientific content domains) was categorized under the methods and methodological rules.

In the social-institutional dimensions, the categorization consisted of one standard (10%) in the social organization dimension. There were one learning outcome in each of the ethos (3.1.1.1.K1: Applies daily life practices from the desert environment that demonstrates the importance of the vital resources in preserving the lives of the living creatures: water, animals) and in the professional activities dimension (2.2.1.4.K1: Shares the observations using pictures, models, or words, and communicates with peers to explain the results of investigations) (3.44% for each category) and two learning outcomes (6.89%) in the social values dimension. Tables 1 and 2 show the results of KG1 curriculum document analysis.✓✓

On the other hand, all of the 11 standards and 36 out of the 37 learning outcomes (97.29%) comprise cognitive-epistemic system dimensions for the KG2 stage. The social-institutional system dimensions included only one standard (9.09%) and one learning outcome (2.70%) was found to constitute social-institutional dimensions under the dimensions of social organization and professional activities (2.2.1.1.K2: Shares the observations using pictures, models, or words, and communicates with peers to explain the results of investigations). At the top of categories, 8 standards out of the total of 11 (72.72%) fall under the scientific knowledge dimension and 15 learning outcomes out of the total of 37 (40.54%) fall under the scientific practices domain. While the categorization (see Tables 3 and 4) appeared to be dominated by the cognitive-epistemic dimensions, none of the standards or outcomes was found to be categorized under the aims and values dimension in both KG1 and KG2 stages. The categorization was found to include four of the social-institutional dimensions as none of the standards and learning outcomes comprises the dimensions of social certification and dissemination, financial systems, and political power structures. Such a result was similarly found in previous studies of curriculum analysis based on the FRA framework (Dagher & Erduran, 2016; Yeh et al., 2019).

Table 1 Coding results of MOE curriculum document—KG1 learning standards

	Cognitive-epistemic system				Social and institutional contexts			
Learning outcome code	Aims and values	Methods	Scientific practices	Scientific knowledge	Scientific ethos	Social values	Professional practices	Social organization
1.1.1.K1				✓				
2.1.1.K1				✓				
3.1.1.K1				✓				
1.1.2.K1				✓				
1.1.3.K1				✓				
1.2.3.K1				✓				
1.1.4.K1		✓		✓				
2.1.4.K1				✓				
1.2.4.K1				✓				✓
2.2.4.K1		✓						

While the standards and learning outcomes under study have covered numerous categories of NOS, it was found that some of the statements fall under two categories. In the KG1 stage, one standard was categorized under the scientific knowledge and methods dimensions and the other dimension fell under the scientific knowledge and the social organization dimensions. These standards are 1.1.4.K1 (Identifies the processes of science and implements them in building his knowledge and understanding in all scientific content domains.) and 1.2.4.K1 (Demonstrates an understanding of the relation between science, technology, and society). Three outcomes fell under two main category combinations: the methods and the social values dimensions and the methods and the scientific knowledge dimensions. An example of that is 3.1.1.2.K1 (Tests to elicit evidence that helps him decide whether a thing is a living creature or a non-living thing). In the KG2 stage, one learning outcome, 1.2.1.K2 (Demonstrates an understanding of the relation between science, technology, and society), implies the inclusion of the scientific knowledge and the social organization dimensions.

Discussion

The Kindergarten Standard Document comprises standards and outcomes that represent a spectrum of NOS aspects, such as the practices of observation, classification, and communication. The curriculum documents include "the nature of science" phrase as one of the key domains of science education in the kindergarten stage. Explicit inclusion of the NOS as a key domain in the kindergarten stage curricula reflected the attention given by the curriculum developers to the importance of science process skills and their development in such an early stage. The findings also shed light on the focus given by the curriculum on the cognitive-epistemic dimensions of FRA in the early years of education.

The analysis of the UAE curriculum documents for higher grades showed that aspects such as scientific values, attitudes, and dispositions are included as key components (Al-Naqbi, 2010). It is notable that the categorization has a similar pattern in both stages of kindergarten, that is, the dominance of the cognitive-epistemic dimensions over the social-institutional dimensions. Akerson et al. (2019) have reported that children do not acquire the predictable understanding of NOS aspects due to the differences in their approach to investigations and their assimilation of newly introduced conceptions when compared to older learners. They disagreed with the assumption stating that young children lack

Table 2 Coding results of MOE curriculum document—KG1 learning outcomes

	Cognitive-epistemic system				Social and institutional contexts			
Learning outcome code	Aims and values	Methods	Scientific practices	Scientific knowledge	Scientific ethos	Social values	Professional practices	Social organization
1.1.1.1.K1				✓				
2.1.1.1.K1				✓				
3.1.1.1.K1					✓			
4.2.1.1.K1			✓					
5.2.1.1.K1			✓					
2.3.1.1.K1						✓		
3.3.1.1.K1		✓				✓		
4.3.1.1.K1			✓					
1.1.1.2.K1				✓				
2.1.1.2.K1			✓					
5.1.1.2.K1			✓					
2.1.1.3.K1			✓					
3.1.1.3.K1				✓				
1.2.1.1.K1				✓				
1.3.1.1.K1				✓				
2.2.1.1.K1			✓					
3.2.1.1.K1				✓				
5.2.1.1.K1			✓					
4.3.1.1.K1		✓		✓				
3.1.1.2.K1		✓		✓				
4.1.1.2.K1				✓				
5.1.1.2.K1			✓					
1.1.1.3.K1			✓					
1.1.2.3.K1				✓				
2.1.2.3.K1				✓				
2.1.1.4.K1			✓					
1.2.1.4.K1			✓					
2.2.1.4.K1							✓	
1.1.2.4.K1				✓				
2.1.2.4.K1			✓					
1.2.2.4.K1			✓					

the cognitive readiness to obtain NOS concepts that are less concrete. Unlike students in their later primary school years, children have a limited repertoire in terms of scientific experiences and a rather little accumulative knowledge. Nevertheless, the characteristics of young children at that early stage of learning can be a limitation to the possibilities to introduce the social and institutional dimensions of science as their abstract nature is not always acquirable due to the uniqueness of their characteristics and the lack of awareness by educators when presenting the science activities (Akerson et al., 2019). The conceptualization of NOS is achievable with explicit instruction that encourages teachers and learners to practice reflection of what NOS entails and how its implications can be noticed in different contexts (Akerson et al., 2014). Abd-El-Khalick (2013) states that NOS is conceptualized best when early learners

Table 3 Coding results of MOE curriculum document—KG2 learning standards

	Cognitive-epistemic system				Social and institutional contexts			
Learning outcome code	Aims and values	Methods	Scientific practices	Scientific knowledge	Scientific ethos	Social values	Professional activities	Social organization
1.1.1.K2			✓					
2.1.1.K2				✓				
1.2.1.K2				✓				✓
2.2.1.K2		✓						
1.2.2.K2				✓				
1.3.2.K2				✓				
2.3.2.K2				✓				
1.1.3.K2				✓				
1.1.4.K2				✓				
1.2.4.K2				✓				
1.3.4.K2			✓					

engage in conversations about scientific concepts and conduct simple investigations of different types and levels. Children books of different types with customization to target concepts of NOS can also be an effective material for teaching and learning science in early years (Akerson et al., 2019). These findings, however, are not in line with the Yeh et al. (2019) study that indicated the change in the newly issued Taiwanese curriculum from emphasis on the cognitive-epistemic dimensions to more inclusion of social-institutional dimensions, while the Turkish curriculum and the Irish curriculum in Dagher and Erduran's (2016) study were found to emphasize the dimensions of scientific ethos and social organization respectively. The lack of representation of such aspects in UAE early learning curriculum might be interpreted within the context of developmentally appropriate curriculum.

In the social-institutional type of dimensions, the scientific ethos dimension includes practices that demonstrate principles such as respect of the environment. Therefore, the learning outcome 3.1.1.1.K1 (Applies daily life practices from the desert environment that demonstrates the importance of the vital resources in preserving the lives of the living creatures: water, animals) was categorized as the only content under the scientific ethos dimension. Similarly, the social values of science dimension included two learning outcomes in the KG1 level: 2.3.1.1.K1 (Practices healthy behaviors inside the kindergarten, such as disposing trash in specified places) and 3.3.1.1.K1 (Conducts scientific agricultural and industrial projects to preserve the environment, such as recycling).

Professional practices represent a key social dimension in how scientists actively belong to a community where scientific matters are discussed and evaluated. In a professional level of practicing science, participating in forums and publishing research papers in scientific journals are as significant as the research methods and investigation activities. However, there is a less representation of professional practices due to the restrictions that govern the developmentally appropriate experiences. As a result of the analysis, the document was found to include one outcome in KG1 level and one outcome in KG2 level under the professional practices dimension. The statement "Shares the observations using pictures, models, or words, and communicates with peers to explain the results of investigations" was used for describing the two outcomes: 2.2.1.4.K1 and 2.2.1.1.K2. The simple practice of sharing findings can be considered an age-appropriate activity of scientists and an effective way to help learners acquire accurate principles and methods of science. Duschl and Osborne (2002) state that schooling often misses on incorporating activities that represent such community element in learners' science classes. When

Table 4 Coding results of MOE curriculum document—KG2 learning outcomes

	Cognitive-epistemic system				Social and institutional contexts			
Learning outcome code	Aims and values	Methods	Scientific practices	Scientific knowledge	Scientific ethos	Social values	Professional activities	Social organization
1.1.1.1.K2				✓				
1.2.1.1.K2			✓					
2.2.1.1.K2							✓	
1.1.2.1.K2				✓				
2.1.2.1.K2			✓					
1.2.2.1.K2			✓					
1.1.2.2.K2				✓				
2.1.2.2.K2				✓				
3.1.2.2.K2				✓				
4.1.2.2.K2				✓				
5.1.2.2.K2				✓				
1.1.3.2.K2			✓					
2.1.3.2.K2				✓				
1.2.3.2.K2			✓					
2.2.3.2.K2			✓					
1.1.1.3.K2			✓					
2.1.1.3.K2			✓					
3.1.1.3.K2			✓					
4.1.1.3.K2			✓					
5.1.1.3.K2		✓						
1.1.1.4.K2				✓				
2.1.1.4.K2			✓					
3.1.1.4.K2				✓				
4.1.1.4.K2				✓				
1.1.2.4.K2				✓				
2.1.2.4.K2		✓						
3.1.2.4.K2		✓						
4.1.2.4.K2		✓						

Table 4 (continued)

	Cognitive-epistemic system				Social and institutional contexts			
Learning outcome code	Aims and values	Methods	Scientific practices	Scientific knowledge	Scientific ethos	Social values	Professional activities	Social organization
1.1.3.4.K2				✓				
2.1.3.4.K2			✓					
3.1.3.4.K2				✓				
4.1.3.4.K2		✓						
5.1.3.4.K2		✓						
6.1.3.4.K2			✓					
7.1.3.4.K2		✓						

students of different grade levels are encouraged to share their claims and findings that are related to scientific practices, they understand that science is not an individual activity, but rather a set of practices that are best done and validated with peers.

The interconnectedness of the elements of NOS in some of the standards and learning outcomes is a positive sign of presence of integrative science education in the Emirati kindergarten stage. When children engage in activities that are planned to equip them with concepts and skills in a meaningful manner, it is close to how science is practiced in the real world (Hoeg & Bencze, 2017). As the scientific knowledge and methods dimensions were the combinations in which some standards and learning outcomes fell under, it can be concluded that building strong foundations of intertwined fundamental concepts and skills of science is one of the goals of Emirati kindergarten curriculum. Such findings imply awareness of the importance of teaching science using factual and well-defined procedural thinking to reflect the dynamicity of science.

Conclusion

The analysis of UAE government kindergartens standards document issued by the MOE (2019) has demonstrated that the standards include "the nature of science" as one of the key domains of science education in the kindergarten stage. However, and understandably, these appeared to be more dominated by the cognitive-epistemic dimensions of NOS rather than the social-institutional system dimensions. Specifically, the majority of the standards and learning outcomes emphasize learning of scientific methods, scientific practices, and scientific knowledge, whereas very little of these concerned NOS aspects related to scientific ethos, social values, professional practices, and social organization. Nevertheless, standards and learning outcomes were inclusive of several core concepts of NOS, demonstrating the interconnectedness of the elements of NOS for some degree. This provided a positive sign of presence of integrative science education in the Emirati kindergarten stage. Together, these imply that in order for the young learners to constructively engage in planned activities that equip them with NOS-related concepts and skills, the standards need to place higher emphasis on how science is practiced in the real world within the larger social and institutional context.

Limitation and Future Research

The current study has to be seen in light of some limitations. The findings were drawn building on the analysis of Science MOE standards in the UAE science education context, with the specific focus on the kindergarten stages (KG 1 and 2). Therefore, and in order to drive further revisions of the NOS content in the UAE science standards, a natural progression of this work is to comprehensively examine Science MOE standards per each grade level or cycle across K-12. In addition to that, comparative studies could be done by comparing the representation of NOS elements in the MOE standards and other standards adapted in the UAE private schools (e.g., schools adapting American/UK curriculum). Second, the extent at which the examined standards are presented in the used science curriculum, as well as the extent at which they are effectively delivered and attained in science classrooms, was not investigated as being beyond the scope of the current study. A normal extension of the work therefore would be to further investigate how these benchmarks are transformed in actual practices and curriculum to see what needs to be further supported. This would enable assessing whether the NOS content in the examined curriculum is well suited to the intended grade level, as well as help identify the challenges faced during implementation and what supporting structures might be needed to enhance the science classroom instructions for teaching and learning of this content. Last, future research should be also devoted on understanding how the science teachers view and comprehend these NOS content–based standards in order to supply adequate pedagogical resources and professional development support.

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Declarations

Conflict of Interest The authors declare no competing interests.

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