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## Early years education teachers' perceptions of nature of science

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### ABSTRACT

Research indicates that teachers lack a sophisticated understanding of Nature of Science (NOS), which in turn, can impact their instructional decisions and students' understanding of NOS. The aim of the study was to investigate United Arab Emirates (UAE) early years' science teacher's ( $N = 433$ ) perceptions about the NOS. Results obtained from a 70-item questionnaire revealed that teachers have an adequate understanding on many aspects related to science and NOS, especially those pertaining to the 'Social-Institutional', 'Scientific Practices' and 'Educational Applications' categories. However, varied perceptions were found on some key concepts such as the role of bias and prejudices on scientific facts, the employment of same scientific practices across different branches of science, and the influence of politics in science. Misconceptions on particular aspects of NOS were also recognised (e.g. the distinction between laws and theories and the fixed nature of procedures followed in experiments). The findings suggest practical and pedagogical implications for teaching and outline an agenda for further research.

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## Introduction

Under the umbrella of science education, students are expected to possess a solid understanding of key conceptual scientific ideas manifested in the traditional body of scientific knowledge, such as concepts, laws, and theories (Lederman et al., 2019). Students also need to internalise the science values and practices that are incorporated in the construction, development, and assessment of scientific knowledge and understand how science is situated within wider contexts (philosophical, historical, socio-cultural, economical, and political) (Lederman et al., 2019). The latter focus is commonly known as 'Nature of Science' (NOS), or what is interchangeably referred to as 'How Science Works', which is seen as a critical component in science education as well as a fundamental element to achieve in the benchmarks of scientific literacy (AAAS, 1990).

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Lederman (1992) regarded NOS as a way of knowing the epistemology of science along with the values and beliefs associated with scientific knowledge and its development. Clough and Olson (2008) conceptualised the dynamicity of NOS as a construct while highlighting issues relating to what science is, how it works, its epistemological and ontological foundations, and the way it operates within the social context. Such a constructive acquisition of NOS understanding is believed to encourage students to critically think about the multiple interrelated facets of NOS and their implications in the real world from a holistic perspective while considering current and future global issues (Al-Bouti, 2018; Forawi & Abdallah, 2019).

In line with the increased attention in Early Childhood Science Education (ECE) (Anastasiou et al., 2015), great emphasis is given for introducing NOS in early childhood science classroom as being the first building blocks for progression of scientific understanding and practices throughout school learning stages (Hansson et al., 2021). Therein comes the need for upgrading more effective pedagogical horizons for the delivery of NOS content at all levels including early years' education worldwide (Abd-El-Khalick & Lederman, 2000). The literature, however, shows that research about NOS and effective NOS-based instructional activities for the youngest children are extremely less than required (Hansson et al., 2021; Piasta et al., 2014). Moreover, research into perceptions of NOS indicates that K-12 science teachers lack a sophisticated understanding or have misconceptions about NOS (Lederman et al., 2019). This, in turn, can potentially impact teachers' instructional decisions and their students' understanding of NOS.

Given the context of the United Arab Emirates (UAE), and in line with the recent educational reforms taking place as part of the country's National Agenda and the Ministry of Education (MOE) Strategic Plan 2017–2021, significant emphasis is placed upon fostering scientific literacy, STEM education and NOS (Al Murshidi, 2019). Specifically, the UAE science curricula starting from the early years stage to grade 12 supports the authentic understanding of NOS content, or what interchangeably referred as 'How Science Works', as an essential component in science education (Al-Naqbi, 2010). This is evident in the new customised national science curricula that is designed by McGraw-Hill Education in line with the Next Generation Science Standards (NGSS) as part of the latest science education reform in the UAE (Saleh, 2018; Shakera & Saleh, 2021). The NGSS sets the stage for teaching and learning about the NOS while focusing on teaching of processes of science, scientific knowledge and practices, scientific values and attitudes, and habits of mind and dispositions; along with the interactions between science, technology, and society (Al-Naqbi, 2010).

Particularly, the UAE science standards document for Kindergarten (KG) issued by the MOE in 2019 are structured in four main domains which include NOS and addresses issues related to scientific investigation and application, and the interaction of science, engineering, and technology. As such, the KG curricula is directed towards students' acquisition of the processes and skills of science and doing simple investigation such as describing, comparing, and classifying objects; raising questions; making and recording observations using words, drawings, or charts; developing hypothesis and explanations, and working collaboratively with others to present results and share ideas.

In light of the above, and given the attention paid by the MOE on early years' science standards for NOS teaching, this paper focuses on the NOS understanding of early years' teachers in the UAE, which is indeed, a fruitful area to explore as locally, to date, only a

few studies have been undertaken with this focus within the UAE early childhood and elementary science classroom settings.

## Literature review

### *Teachers' perceptions of NOS*

Research into perceptions and beliefs of NOS has contributed to the body of knowledge around how teachers understand NOS, as well as their pedagogical approaches to teach NOS (Abd-El-Khalick & Lederman, 2000). Some comparative studies have compared perceptions of NOS between teachers and their students (e.g. Dogan & Abd-El-Khalick, 2008), between pre-service and practising teachers (e.g. Hoh, 2013; Tairab, 2001), or across teachers with different cultural backgrounds such as the United States & Nigeria (e.g. Akerson et al., 2000; BouJaoude et al., 2011). Furthermore, attempts have also been made towards changing and improving those views (Akerson et al., 2000; Hansson & Leden, 2016). Overall, the consensus of the work on teachers' perceptions of NOS is that teachers, generally, lack an adequate understanding about the NOS (BouJaoude et al., 2017; Tairab, 2001; Tsai, 2002; Yacoubian & Khishfe, 2018). Furthermore, there is evidence of somewhat naive views and misconceptions about the NOS (Irez, 2006; Lederman et al., 2019).

For instance, Tsai (2002) carried out a study to explore middle and high school science teacher's ( $n = 37$ ) perceptions of science learning, teaching, and NOS. Findings from individual interviews revealed that more than half the participants held traditional beliefs that are not in line with NOS. In a similar vein, Al-Omary (2006) investigated science teachers' ( $n = 17$ ) beliefs on the NOS, the learning and teaching of science, and how these might be related to their teaching practices. Data collected through individual interviews alongside the video-recording of classes found that 35% of the teachers held traditional beliefs about NOS, 24% held informed beliefs, and 41% held a mixture of both.

Likewise, Saleh and Khine (2014) conducted a study to assess UAE pre-service teacher education students ( $n = 24$ ) views of NOS using an open-ended instrument, namely the Views on Nature of Science Questionnaire Form C (VNOS-C) adapted from Lederman et al. (2002). This instrument particularly focused on the following aspects of the NOS: the empirical nature of science; the relationship between observation, inference, and theoretical entities; the way how theories and laws are different; creativity and imagination of scientific knowledge; the theory-laden aspect of scientific knowledge; the cultural and social nature of scientific knowledge; the myth of the scientific method; and the tentative aspect of scientific knowledge. Findings from this study indicated that many of the NOS reported views were either ill-informed or ambiguous, such as, the definition of science as a study, the experimental nature of scientific knowledge, and the distinction between a scientific theory and a scientific law, amongst others. In addition, Tairab (2001) investigated how aspiring teachers and in-service teachers perceive NOS using a developed questionnaire that addresses NOS elements such as scientific knowledge and the relation between science and society. The findings reflected having an understanding of science and research that is mainly oriented either by content or process, as well as reported having adequate views about scientific knowledge in terms of tentativeness and the description of theories, laws, and facts.

Furthermore, many correlational studies attempted to relate teacher's understanding and successful teaching of NOS to certain potentially determining factors, such as grade point average, experience, academic major, courses, training, and subject matter knowledge (Azninda & Sunarti, 2021; Bell et al., 1998; Gheith & Aljaberi, 2017; Hoh, 2013). Other studies suggest that NOS views may be attributed to varying demographic variables such as intellectual level (Akerson & Buzzelli, 2007), background culture, and religious beliefs (Dogan & Abd-El-Khalick, 2008). There is, however, a need for more research that investigates in what way the difference in attainment of NOS perceptions may be correlated with such variables.

### ***Teaching and learning of NOS in early childhood science education***

NOS is a central element in science education in early childhood which is a critical stage of development because it sets up the foundation for conceptual understandings of science concepts and skills, as well as develops positive attitudes towards science (Akerson et al., 2011), therefore, impacts young children's scientific understanding and scientific literacy in the later years of schooling (McComas, 2017). Specifically, attaining an appropriate understanding of NOS at the early childhood level has many advantages, both in the short and long run, such as inspiring children's curiosity (Hansson et al., 2021) and allowing children to explore processes and skills of science either explicitly or implicitly (e.g. look for patterns, classify and compare objects, raise questions, make careful observations and prediction, and come up with tentative explanations). It also engages children in simple investigations (Hansson et al., 2021) and enables them to learn how to apply science processes and skills to the world in which they live (Worth, 2010). Importantly, it is in the early childhood science classroom where teachers can challenge stereotypical images about science and scientists which are commonly communicated through teaching or media (Akerson, Carter, et al., 2019). Moreover, NOS fosters the collaborative work and encourages children to share and discuss ideas with others early on (Worth, 2010). Together, engaging in such experiences is particularly vital to children's science learning so they can have meaningful and relevant science experiences (Brunton & Thornton, 2010).

Practically speaking, relevant research shows that rich and well-designed opportunities to emphasise aspects and themes of NOS that are appropriate for ECE can potentially promote more informed views of NOS and enable young children to conceptualise the NOS content (Akerson et al., 2000; Akerson & Buzzelli, 2007). According to the recommendations in the National Science Teachers Association (NSTA) NOS Position Statement (2000), NOS issues appropriate for ECE children may include empirical NOS, the distinction between observation and inference, the creative NOS, the subjective NOS, and the tentative NOS. Similarly, McComas's framework (2017) recommends addressing issues highlighting characteristics and limits of scientific knowledge, scientific processes and tools, and human elements of science (Hansson et al., 2021). For example, the diversity of tools and methods that are used in science need to be visible for children in the early years. Teachers also can direct attention towards the question: 'How do we know this?' so children get to understand that scientists try to find out 'scientific facts' and that they may 'think differently' because they have 'different brains' (Hansson et al., 2021). May teaching strategies and instructions are proposed in literature to

introduce such topics specifically for K-2 grade level such as scaffolding to help young children's in inquiry-based science teaching and using children's literature (see; Akerson et al., 2011; Akerson, Carter, et al., 2019; Clough, 2006; Hanuscin et al., 2011; Lederman et al., 2019; Metz, 1997; Smith et al., 2000).

Considerations, however, need to be given to the need of making NOS content developmentally appropriate while using a language that is more 'kid friendly' (Akerson & Volrich, 2006), so to be accessible to pre and primary school children due to the limitations of their cognitive abilities (Anastasiou et al., 2015). Crafting and embedding such content at the right level to appeal to children's characteristics depend heavily on the teachers' content knowledge of NOS, their pedagogical knowledge for teaching NOS, as well as their knowledge of learners of young ages (Akerson et al., 2019). There is therefore a need for offering NOS-based instruction that supports such developmental characteristics of young children and assists the construction of solid foundation of scientific knowledge and related skills for ECE stage, besides the preparation of knowledgeable educators who are well informed about NOS pedagogy and the effective delivery of its components (Akerson et al., 2011).

### ***The reconceptualised family resemblance approach to NOS (RFN)***

Different approaches to NOS are proposed in the literature by many scholars building on distinct theoretical perspectives, such as the consensus view (Lederman et al., 2002; McComas, 1998), NOS tenets (Lederman, 2007), whole science (Allchin, 2011), and features of science (Matthews, 2012). Along with these, one recent framework for conceptualising NOS in the educational context is known as the Reconceptualised Family Resemblance Approach to Nature of Science (RFN) developed by Erduran and Dagher (2014a). It is rooted in the family resemblance approach (FRA) first proposed by Wittgenstein aiming at illustrating similarities and differences shared among sciences and was further built on Irzik and Nola's (2014) model of Family Resemblance.

The RFN framework provides a more coherent and holistic account of NOS while addressing the interplay between various aspects of NOS. These are embedded within two major dimensions, first is the 'cognitive-epistemic' consisting of scientific aims and values, scientific practices, methods, and scientific knowledge categories. The second is the 'social-institutional' dimension relating to social-institutional aspects of science (e.g. the social ethos, professional activities, certification, financial systems, and political power structures). In addition, the RFN framework also incorporates educational applications of NOS building on science education research (Erduran & Dagher, 2014a).

Together, these aspects of NOS are crucially important because they enable a sophisticated understanding of how scientists and science, both as an enterprise and a practice, operate in the real world. The RFN is a reliable and valid framework that was widely considered and applied for assessing NOS pre/in-service science teacher's perceptions (Kaya & Erduran, 2016), curriculum and textbooks (e.g. BouJaoude et al., 2017; Erduran & Dagher, 2014b), and science teacher education (e.g. Erduran & Dagher, 2014a, 2014b, 2017). It is unique in terms of its comprehensiveness, meaning that besides epistemological aspects of NOS, it considers the social, cultural, financial, political, and institutional

aspects of science, which are usually overlooked (Leung et al., 2015). Therefore, addressing these aspects through the macro-lens of the RFN framework adds precision and richness to the analysis of the teachers' views of NOS, making it suitable for the purpose of this study.

Drawing on this framework, the current study invited UAE in-service science teachers in early years education, which include grade levels from KG1 to grade 2, to determine the current state of their understanding of the NOS and NOS instruction through the RFN framework. A second aim was to assess differences in teachers' perceptions of NOS with respect to their demographics, namely, years of teaching experience, the academic major, and having training in NOS. The following two questions were addressed in the study:

1. What are the perceptions of UAE in-service teachers towards NOS?
2. Do in-service teachers' perceptions of NOS differ in relation to how many years they have been teaching, the focus of their academic degree, or whether they have had any formal training in Nature of Science?

## Methods and methodology

The current study is part of a funded large-scale research project examining the provisions of NOS as part of Science Education at the Early Years' school level in the UAE, with the aim of designing, implementing, and evaluating the impact of RFN strategies. Research ethics approval was granted by the Social Science & Humanities Ethics Committee at the institution of the first and corresponding authors. Moreover, research approval was obtained from the MOE who facilitated the circulation of the online questionnaires across the participating schools.

## Participants

The sample consisted of 433 in-service teachers from various public (17.8%) and private (82.2%) schools in the UAE who teach science at the school levels of Kindergarten (KG) to Grade 2 (start at age 4 and end at age 7). All participants voluntarily participated in the study during the 2020/21 academic school year. The basic demographic characteristics of the sample are presented in Table 1.

## Instruments

In order to assess in-service teachers' perceptions of NOS, the study used the Reconceptualised Family Resemblance Approach to NOS Questionnaire (RFNQ) which was originally developed by Kaya et al. (2019). The RFNQ consists of two main sections, the first is specified for the demographic information of the participants including years of teaching experience, the academic major of study, and whether or not they have received NOS training. The second section contained a total of 70 items assessed using a five-point Likert scale running from strongly agree to strongly disagree to indicate the level of agreement with each statement (see Appendix A). These items are grouped into two dimensions (cognitive-epistemic system encompassing, social-institutional system) and 6 categories (Aims and Values, Scientific Practices, Scientific Methods, Scientific



**Table 1.** Demographic characteristics of the study participants.

Sample demographics (N = 433)		
	Frequency (n)	Percent (%)
<b>Age</b>		
20–29	47	11%
30–39	185	43%
40–49	168	39%
>50	33	8%
<b>Grade level</b>		
Pre-KG	11	2.5%
KG1	90	20.8%
KG2	134	30.9%
KG1 & KG2	35	8.1%
Grade1	46	10.6%
Grade2	117	27.0%
<b>Years of teaching experience</b>		
<5	91	21.5%
5–10	157	36.3%
>10	185	42.7%
<b>Academic qualification</b>		
Diploma	23	5.3%
Bachelors	269	62.1%
Masters	106	24.5%
Ph.D.	2	0.5%
Others	33	7.6%
<b>Major</b>		
Sciences	97	22.4%
Mathematics	19	4.4%
Languages	58	13.4%
Early childhood education	118	8.3%
Social sciences	36	8.3%
Computer sciences/technology	16	3.7%
Others	89	20.6%

Knowledge, Social-institutional Aspects, and Educational Application); reflecting all aspects of RFN as shown in Table 2. The negative items were reverse-coded. The reliability of the RFNQ items yielded a Cronbach's  $\alpha$  reliability coefficient of 0.82 (0.82) indicating the RFNQ was a reliable tool for the current population.

## Results

Results generated from Pearson's  $r$  product-moment correlations, as shown in Table 3, revealed significant correlations among all RFNQ dimensions. The highest significant

**Table 2.** Dimensions, categories and item distribution of RFN questionnaire.

Major Dimensions	Categories	N Items	Positive Items	Negative Items
Cognitive-epistemic system encompassing	<i>Aims and Values</i>	7	2, 20, 40, 51, 69	46, 56
	<i>Scientific Practices</i>	13	4, 5, 15, 19, 23, 33, 38, 57, 61, 63	26, 52, 64
	<i>Scientific Methods</i>	9	11, 22, 24, 28	8, 25, 37, 49, 60
	<i>Scientific Knowledge</i>	9	10, 30, 44, 50, 54	3, 16, 43, 66
Social-institutional system	<i>Social-institutional Aspects</i>	16	7, 9, 14, 32, 34, 41, 45, 48, 53, 58, 67, 70	13, 18, 36, 39
	<i>Educational Applications</i>	16	1, 6, 12, 17, 21, 27, 29, 31, 42, 55, 59, 62, 65	35, 47, 68



**Table 3.** Results of Pearson's  $r$  correlations between RFNQ dimensions.

	Cognitive-epistemic system	Social-institutional aspects	Educational applications
Cognitive-epistemic system	X	.631**	.668**
Social-institutional aspects	.631**	X	.655**
Educational applications	.668**	.655**	X

\*\*Correlation is significant at the 0.01 level (2-tailed).

correlation was between the 'Cognitive-Epistemic System' and 'Educational Applications' ( $r(431) = .67, p < .01$ ), whereas the lowest correlation existed between the 'Cognitive-Epistemic System' and 'Social-Institutional Aspects' ( $r(431) = .63, p < .01$ ).

Table 4 presents mean scores and standard deviations for the RFNQ dimensions and sub-categories. The mean score for the 'Social-Institutional' dimension ( $M = 3.71$ ) was somewhat higher than that for the 'Cognitive-Epistemic' dimension ( $M = 3.49$ ). At the sub-categorical level, the highest mean scores occurred for 'Scientific Practices' ( $M = 3.76$ ) and 'Educational Applications' ( $M = 3.76$ ), with the 'Scientific Methods' sub-category having the lowest mean score ( $M = 3.10$ ).

At the item level, Table 5 shows the scores on each item for the detailed descriptive analysis of individual statements belonging to the 'Aims and Values of Science' sub-category. Results showed the highest mean scores occurred for 'teaching scientific values as part of the science curriculum' ( $M = 3.88$ ), followed by 'aims and values affect the choice of methods' ( $M = 3.72$ ). Furthermore, participants seemed to be uncertain about whether 'scientific facts are not affected by bias and prejudices as indicated by the varied responses (22.8% agreed, 36% were not sure, and 41.4% disagreed), yielding the lowest mean score across items for this category ( $M = 2.80$ ). 70.4% of the teachers acknowledged the need for 'diversity of scientists while solving problems to decrease biased results', as well as believed it is necessary for scientists 'to question their ideas if not empirically supported'.

The responses for 'Scientific Practices' are shown in Table 6. The vast majority of participants saw the need for 'multiple testing of scientific hypothesis', yielding the highest mean score across all the items for this category ( $M = 4.1$ ). Similarly, participants agreed, to a large extent, with the ideas that 'scientific work must be evaluated against standards', 'data analysis and interpretation are scientific practices', 'scientists evaluate each other's work', and that 'observations are used across all fields of science'. Furthermore, the need for 'validating scientific knowledge' was confirmed by 77.1% of the participants. Although 77.4% of the teachers believed that 'experiments follow fixed procedures' (item 38), they appeared somehow sceptical on whether 'different branches of science employ the same scientific practices' as indicated by variation in their responses

**Table 4.** Mean and SD for RFNQ Dimensions and Sub-categories.

Dimensions/Sub-categories	M	SD	N of Items
Whole questionnaire	3.60	.23	70
Cognitive-epistemic system	3.49	.21	38
Aims & Values	3.47	.37	7
Scientific Practices	3.76	.34	13
Scientific Methods	3.10	.30	9
Scientific Knowledge	3.47	.32	9
Social-Institutional System			
Social-Institutional Aspects	3.71	.33	16
Educational Applications	3.76	.33	16

**Table 5.** Descriptive statistics for 'Aims & Values' category.

Item	Mean	SD	Responses distribution of the items <i>N</i> (%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
2. Epistemic/cultural values of science cannot be ...	3.29	0.93	11(2.5)	87(20.1)	123(28.4)	191(44.1)	21(4.8)
20. The diversity of scientists solving a problem together ...	3.70	0.92	11(2.5)	43(9.9)	74(17.1)	243(56.1)	62(14.3)
40. Scientists should change their minds when their ideas ...	3.56	0.96	18(4.2)	51(11.8)	75(17.3)	247(57)	42(9.7)
51. Teaching scientific values should be the core components ...	3.88	0.71	0(0)	16(3.7)	90(20.8)	256(59.1)	71(16.4)
69. Scientific aims and values affect scientists' choice ..	3.72	0.73	2(5)	36(8.3)	72(16.6)	295(68.1)	28(6.5)
46(R)*. Scientific facts are not affected by bias ...	2.80	0.94	24(5.5)	154(35.6)	156(36)	82(18.9)	17(3.9)
56(R). There is no relationship between scientific facts ...	3.34	1.12	31(7.2)	87(20.1)	59(13.6)	216(49.9)	40(9.2)

(42.3% agreed, 20.2 were not sure, and 37.7% disagreed). The least agreed responses (26.6%) were obtained for the statement 'scientific practices are not influenced by cultural factors' with a mean score of (2.68).

Results for items belonging to the third category concerning teachers' perceptions about 'Scientific Methods' are shown in Table 7 and indicate the highest agreement (93.5%) obtained for 'the use of multiple methods to produce enough evidence', yielding the highest mean score across items for this sub-category ( $M = 4.21$ ). However, varied results were obtained for the existence of a 'standard scientific method' that has to be followed worldwide, evident in variations among agreeing responses (43% and 25.1%, respectively) and disagreeing responses (38.8% and 49.9%, respectively). Furthermore, the overwhelming majority of the participating teachers acknowledged the 'diverse nature of different branches of science' and the 'contribution of diversity in scientific methods' (89.4% and 88%, respectively). Lastly, no clear position was reported on whether 'all hypothesis testing is manipulative' as responses were relatively close for agreeing, not sure, and disagreeing responses.

Table 8 shows responses for 'Scientific Knowledge' with results reflecting a great deal of agreement across teacher's perceptions for 'scientific ideas need to be evaluated and revised' with the highest mean score and an overall of 91.7% of agreement percentage. The point that 'scientific knowledge does not change' (item 3R) was confirmed by 62.3% of the total responses. Whereas the least agreement (8.8%) was obtained for 'laws are theories that are confirmed' and for 'laws are more verifiable than theories' (7.9%).

Table 9 presents results of teacher's perceptions relating to the fifth category 'Social-Institutional Aspects of Science', the highest mean score ( $M = 4.42$ ) was obtained for 'scientists should respect the environment' with 95.4 percent of agreement. High agreement was also seen for 'sharing research with others' (85.7%), 'the need of money for research doing' (84%), and for 'the production of values that contribute to society' (86.2%). Furthermore, the majority of the participants acknowledged that 'science as a social system' where 'social interactions exist among scientists', whereas they believed less on the 'existence of social hierarchies among scientists' and that science takes place in institutions (around 57% agreed). However, varied perceptions seen for 'politics

**Table 6.** Descriptive statistics for ‘Scientific Practices’ category.

Item	Mean	SD	Responses distribution of the items <i>f</i> (%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
4. Scientists review and assess each other's work.	4.07	0.70	4(9)	9(2.1)	40(9.2)	279(64.4)	101(23.3)
5. The power of experimentation comes from testing ...	4.11	0.83	15(15)	6(1.4)	20(4.6)	269(62.1)	123(28.4)
15. Analysis and interpretation of data are components ...	4.07	0.73	16(1.4)	11(2.5)	30(6.9)	284(65.6)	102(23.6)
19. Scientists build and use models to understand ...	4.05	0.60	4(0.9)	3(0.7)	32(7.4)	322(74.4)	72(16.6)
23. All branches of science use observations.	4.07	0.80	7(1.6)	17(3.9)	30(6.9)	263(60.7)	116(26.8)
33. Classification helps scientists explain and predict phenomena.	4.0	0.67	4(9)	10(2.3)	45(10.4)	306(70.7)	68(15.7)
38. Scientific experiments follow a certain set of procedures.	3.83	0.88	10(2.3)	31(7.2)	57(13.2)	258(59.6)	77(17.8)
57. Scientists from all branches of science validate scientific. ...	3.82	0.77	4(0.9)	28(6.5)	67(15.5)	279(64.4)	55(12.7)
61. There are standards for evaluating the quality of scientific ...	4.10	0.61	2(0.5)	3(0.7)	40(9.2)	291(67.2)	97(22.4)
63. Models can help scientists to explain and predict phenomena.	4.04	0.61	1(0.2)	8(1.8)	42(9.7)	304(70.2)	78(18)
26(R). Some branches of science do not use representations.	2.99	0.92	9(2.1)	140(32.3)	150(34.6)	116(26.8)	18(4.2)
52(R). Different branches of science have the same practices.	3.03	1.00	19(4.4)	144(33.3)	87(20.1)	173(40)	10(2.3)
64(R). Scientific practices produce knowledge and are ...	2.68	1.00	36(8.3)	191(44.1)	91(21)	106(24.5)	9(2.1)

**Table 7.** Descriptive statistics for 'Scientific Methods' category.

Item	Mean	SD	Responses distribution of the items <i>f</i> (%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
11. Each branch of science has a different nature.	4.07	0.81	10(2.3)	15(3.5)	21(4.8)	275(63.5)	112(25.9)
22. There is no step by step order to doing science.	2.67	1.11	51(11.8)	191(44.1)	54(12.5)	122(28.2)	15(3.5)
24. Diversity of methods contributes to scientific ...	4.02	0.69	5(1.2)	11(2.5)	36(8.3)	301(69.5)	80(18.5)
28. Scientists have to use different methods to produce ...	4.21	0.63	4(9)	1(0.2)	23(5.3)	278(64.2)	127(29.3)
8(R). All scientific disciplines use the same scientific ...	3.01	1.08	32(7.4)	136(31.4)	79(18.2)	168(38.8)	18(4.2)
25(R). All hypothesis testing is manipulative.	2.93	0.94	18(4.2)	133(30.7)	164(37.9)	98(22.6)	20(4.6)
37(R). There is a universal scientific method that all ...	2.72	1.07	42(9.7)	174(40.2)	108(24.9)	82(18.9)	27(6.2)
49(R). Changing variables is a fundamental requirement ...	2.16	0.66	52(12)	271(62.6)	97(22.4)	13(3)	0(0)
60(R). All scientific disciplines require constructing ...	2.08	0.60	57(13.2)	292(67.4)	78(18)	6(1.4)	0(0)

**Table 8.** Descriptive statistics for 'Scientific Knowledge' category.

Item	Mean	SD	Responses distribution of the items <i>f</i> (%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
10. Scientific progress occurs when ideas are evaluated ...	4.14	0.69	5(1.2)	8(1.8)	23(5.3)	284(65.6)	113(26.1)
30. Scientific knowledge consists of a coherent set of ideas.	4.04	0.68	2(0.5)	7(1.6)	43(9.9)	301(69.5)	80(18.5)
44. Scientific models are tools to represent the real world.	3.97	0.68	3(0.7)	17(3.9)	39(9)	307(70.9)	67(15.5)
50. Theories, laws and models work together ...	4.10	0.65	4(9)	3(0.7)	39(9)	288(66.5)	99(22.9)
54. There are different kinds of theories ...	3.99	0.65	5(1.2)	6(1.4)	46(10.6)	306(70)	70(16.2)
3(R). Scientific knowledge does not change.	3.44	1.14	22(5.1)	98(22.6)	43(9.9)	208(48)	62(14.3)
16(R). Theories and laws are forms of scientific knowledge ...	3.10	1.07	27(6.2)	118(27.3)	96(22.2)	165(38.1)	27(6.2)
43(R). Laws are theories that are confirmed.	2.12	0.84	79(18.2)	265(61.2)	51(11.8)	32(7.4)	6(1.4)
66(R). Laws are more verifiable scientific knowledge ...	2.36	0.79	45(10.4)	223(51.5)	131(30.3)	31(7.2)	3(0.7)

does not influence science' (37.6% disagreed, 25.6% were not sure, and 36.7% agreed), yielding the least mean score across items for this category ( $M = 2.94$ ).

Additionally, 70.2% of the participants acknowledged that 'scientists need to write papers in academic journals', yet around an equal portion (74.8%) didn't think it is necessary for scientists to 'share their research', and only 56.3% believed the 'intellectual honesty should be taught as part of the science lessons'. Last, the point that 'money is earned by some scientists more than others' and that 'science takes place in institutions', both received low agreement percentages (37.9% and 57.7% respectively).

**Table 9.** Descriptive statistics for ‘Social-Institutional Aspects of Science’ category.

Item	Mean	SD	Responses distribution of the items <i>f</i> (%)				
			Totally disagree	Disagree	Not sure	Agree	
7. Science takes place in institutions such as universities ...	3.27	1.21	33(7.6)	123(28.4)	27(6.2)	195(45)	55(12.7)
9. Science is a social system.	3.82	0.82	3(0.7)	39(9)	58(13.4)	268(61.9)	65(15)
14. Scientists should respect the environment.	4.42	0.70	6(1.4)	1(0.2)	13(3)	197(45.5)	216(49.9)
32. Scientists need money to do research.	4.05	0.83	6(1.4)	19(4.4)	44(10.2)	243(56.1)	121(27.9)
34. All scientific disciplines produce values that can ...	4.03	0.77	61(1.4)	15(3.5)	39(9)	271(62.6)	102(23.6)
41. Policies of governments affect the growth of scientific ...	3.73	0.84	11(2.5)	24(5.5)	87(20.1)	260(60)	51(11.8)
45. Some scientists earn more money than others, ...	3.18	0.88	17(3.9)	69(15.9)	183(42.3)	149(34.4)	15(3.5)
48. Race and ethnicity of scientists have nothing to do ...	3.77	1.00	10(2.3)	48(11.1)	75(17.3)	200(46.2)	100(23.1)
53. Scientists write papers in academic journals.	3.74	0.76	2(0.5)	28(6.5)	99(22.9)	254(58.7)	50(11.5)
58. Scientists participate in conferences to share ...	4.06	0.78	10(2.3)	4(0.9)	48(11.1)	259(59.8)	112(25.9)
67. There are social hierarchies among science ...	3.57	0.69	2(0.5)	22(5.1)	160(37)	226(52.2)	23(5.3)
70. Scientists socially interact with other scientists ...	3.90	0.72	2(0.5)	16(3.7)	77(17.8)	271(62.6)	67(15.5)
13(R). Politics does not influence science.	2.94	1.10	46(10.6)	117(27)	111(25.6)	137(31.6)	22(5.1)
18(R). Scientists don't have to share their research ...	3.81	1.08	18(4.2)	51(11.8)	40(9.2)	210(48.5)	114(26.3)
36(R). The gender of scientists influences ...	3.61	1.20	15(3.5)	91(21)	62(14.3)	143(33)	122(28.2)
39(R). Intellectual honesty in science does not have to ...	3.42	1.17	22(5.1)	95(21.9)	72(16.6)	165(38.1)	79(18.2)

The last category is devoted to teachers' perceptions regarding 'Educational Applications of NOS' (Table 10). Overall, results show that the need for 'fostering collaboration amongst students in science classrooms' received the highest mean score and agreement percentage across all items belonging to this scale (92.1%). In addition, items stressing the 'science values as part of science education' were considered highly important by the participant teachers as seen for items 65 17, 27, and 62 emphasising 'educating students about the scientific aims/values' (91.9%, 92.6%, 84.5%, and 90.5%, respectively). Comparatively, although the majority of the participants confirmed the need of incorporating 'social/cultural aspects of science', the inclusion of the 'financial aspects of science' was somehow undervalued (only 57.8% agreed). Moreover, giving students the opportunity to 'choose the methodological design' and to 'determine the methods of their science investigations themselves' were confirmed by the majority of the participants (92.6% and 77.2%, respectively).

Research question 2 was devoted to investigate whether there were any differences in in-service teacher's perceptions towards NOS across the RFN dimensions and sub-categories based on years of teaching experience, what grade level they are currently teaching, what academic degree the teachers hold and whether they had previously received any training in NOS. Results obtained from one-way analysis of variance test showed no main or interaction effects for Aims and Values; Scientific Practices; Scientific

**Table 10.** Descriptive statistics for 'Educational Applications of NOS' category.

Item	Mean	SD	Responses distribution of the items <i>f</i> (%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
1. Science lessons should include financial ...	3.41	0.93	17(3.9)	62(14.3)	104(24)	228(52.7)	22(5.1)
6. Concept maps can be an effective way of teaching ...	3.98	0.79	14(3.2)	6(1.4)	37(8.5)	294(67.9)	82(18.9)
12. Students should determine the methods of their ...	3.78	0.88	5(1.2)	50(11.5)	44(10.2)	270(62.4)	64(14.8)
17. Teaching scientific aims/values is likely to improve ...	4.13	0.07	5(1.2)	10(2.3)	20(4.6)	285(65.8)	113(26.1)
21. Students should understand that theories are ...	3.76	0.79	6(1.4)	37(8.5)	52(12)	300(69.3)	38(8.8)
27. Educating students about scientific aims and values ...	4.19	0.65	3(0.7)	6(1.4)	23(5.3)	275(63.5)	126(29.1)
29. Students should be encouraged to collaborate with ...	4.23	0.71	4(0.9)	9(2.1)	21(4.8)	250(57.7)	149(34.4)
31. The curriculum should stress that theories in chemistry ...	2.90	0.97	16(3.7)	159(36.7)	128(29.6)	111(25.6)	19(0.4)
42. Students should sometimes have the choice to design..	4.05	0.58	5(1.2)	2(0.5)	25(5.8)	334(77.1)	67(15.5)
55. Science curriculum should also cover the social ...	4.03	0.74	6(1.4)	13(3.0)	36(8.3)	285(65.8)	93(21.5)
59. Scientific methodology can help students distinguish..	4.00	0.64	4(0.9)	9(2.1)	48(11.1)	313(72.3)	59(13.6)
62. Internalising scientific aims/values enables students ...	3.95	0.62	2(0.5)	8(1.8)	57(13.2)	307(70.9)	59(13.6)
65. Students should understand that scientists need to have ...	4.21	0.67	2(0.5)	5(1.2)	34(7.9)	252(58.2)	140(32.3)
35(R). It does not make a difference when students ...	3.31	1.18	26(6)	115(26.6)	52(12)	178(41.1)	62(14.3)
47(R). Science teaching should specify that laws ...	2.76	1.08	36(8.3)	187(43.2)	79(18.2)	109(25.2)	22(5.1)
68(R). It's not necessary for students to understand ...	3.58	1.12	16(3.7)	88(20.3)	39(9)	209(48.3)	81(18.7)

**Table 11.** Means and standard deviations on scientific knowledge and cognitive-epistemic systems split by grade level and whether or not the teacher had received NOS training.

Grade level	Scientific knowledge		Cognitive-epistemic systems	
	Training	No training	Training	No training
KG1	3.31 (0.28)	3.42 (0.30)	3.45 (0.19)	3.45 (0.18)
KG2	3.46 (0.25)	3.45 (0.28)	3.44 (0.18)	3.46 (0.22)
KG1&2	3.71 (0.43)	3.45 (0.35)	3.65 (0.24)	3.47 (0.31)
Grade 1	3.49 (0.31)	3.53 (0.32)	3.51 (0.19)	3.53 (0.22)
Grade 2	3.53 (0.33)	3.51 (0.35)	3.56 (0.20)	3.51 (0.21)

Methods; Educational Applications, and Social-Institutional aspects. However, one interaction effect existed between grade level taught and whether the teacher had received training in NOS for the Scientific Knowledge ( $F(1,91) = 1.34, p = 0.033$ ) and Cognitive-Epistemic System ( $F(1,91) = 1.54, p = 0.006$ ). Furthermore, for both the scientific knowledge category and the cognitive-epistemic dimension, Post-hoc Scheffé tests revealed a significant difference between teachers in KG1 and those who taught both KG1 and KG2 who had received training. Those who taught both KG1 and KG2 scored significantly higher (see Table 11).

## Discussion and practical implication

Overall, key findings from the current study concerning the understanding of NOS demonstrate that generally, UAE in-service science teachers appeared to have more informed conceptions of the social-institutional dimension of NOS, as well as on the scientific practices and educational applications of NOS compared to their perceptions of the scientific methods. These results seem to be consistent with other research which found that teachers have had well-informed perceptions of societal and cultural issues relating to NOS (Kaya et al., 2019; Parker et al., 2008). Saleh and Khine's (2014) study also reported that the majority of the UAE preservice teacher education students found to be aware about science the social aspects reflected by science, mainly due to the integrated curriculum used in some schools in the UAE (e.g. integrating social science courses with the hard sciences like biology). The results also accord with Azninda and Sunarti (2021) findings in which the scientific method category also received the lowest perception score in the RFN.

Given that the academic discipline may play an important role in shaping perceptions of NOS (Akgun & Kaya, 2020; Leung et al., 2015), a possible reason for these results could be that the majority of the Early years' teachers participating in this study are not majoring in science, but come from different non-science majors such as Languages, Early Childhood Education, and Social Sciences, which typically cover variety of multidisciplinary topics that are subsumed in social science domains (e.g. humanities, culture, and philosophy). Comparatively, science courses undertaken in educational-oriented disciplines usually draw less deep on the epistemological and methodological approaches in science (e.g. observational methods and hypothesis testing), compared to specialised science courses (Akgun & Kaya, 2020). Therefore, teachers enrolled in non-science majors may possibly develop better understanding of societal and cultural rather than methodological-based knowledge of science. There is evidence showing that the non-science teachers had a better understanding than the science group, especially in the social aspects of NOS (Azninda & Sunarti, 2021; Irzik & Nola, 2011).

Specifically, and speaking of the cognitive-epistemic aspects of NOS (see Table 5), results showed that Early years' teachers greatly considered the effect of scientific aims and values (e.g. epistemic, cognitive, social, cultural, political, and ethical) on the choice of methods and the need to educate students about these as part of the science curriculum. The methodological pluralism in science was also highly supported by the majority of the participants (see Tables 7 and 8) in terms of the need for 'multiple testing of scientific hypothesis', 'the use of multiple methods to produce enough evidence', and giving students the opportunity to 'choose the methodological design' of their science investigations themselves. Together, are considered part of the normal and healthy scientific practices because they give room for comparing and discussing multiple data that are generated from several experiments, resulting in more valid and reliable evidence to support or refute the hypothesis (Windschitl et al., 2008). The current findings also exhibited informed conceptions regarding 'the need to evaluate and revise the scientific ideas', 'seeing scientific knowledge as a coherent set of ideas' and 'acknowledging the collective contribution of theories, laws and models in the production of scientific knowledge' (see Table 9).



Teachers however, seemed uncertain about mainly the impact of bias and prejudices on the construction and development of scientific knowledge, and how scientific practices might be utilised differently across different disciplines. These results might be indicative of lacking important understanding about these central ideas related to NOS, hence, need to be stressed in Early years' teachers' professional development training so teachers can recognise the different types of bias that scientists might be experiencing or exposed to, their sources, and their implications in shaping the science methodological rules, decisions, orientations, and interpretations (Erduran & Dagher, 2014a).

Moreover, two ill-informed perceptions were shown in the current data that experiments follow fixed procedures and the existence of a standard scientific method that has to be followed worldwide. In the real world, however, it is expected that scientists may decide to adopt new procedures or alter the approach of their investigations, all of which result from the emergent nature of the science work that is highly contextualised, and thus, cannot be fully controllable or predictable. Such common misunderstanding of the universal scientific method and step-by-step investigations was repeatedly reported in previous studies (e.g. Akgun & Kaya, 2020; Kartal et al., 2018; Woodcock, 2014; Zion et al., 2020). This is because the linear-model depiction of the scientific method steps is still dominated in many science textbooks and classrooms; resulting in students following recipes of systematic steps when doing experiments (Gheith & Aljaberi, 2017). This area may also constitute an important issue for early years teachers' professional development in the NOS to emphasise.

Findings in Table 9 also attracted attention to the need to increase awareness of how laws are distinguished from theories which is important especially for early years teachers, which reinforce findings from previous research indicating that there is often a common misunderstanding between hypothesis, theories, and laws (Akerson et al., 2006; Kaya, 2012; Lederman et al., 2002; Miller et al., 2010). They are also consistent with the findings of Akgun and Kaya (2020) which reported that teachers had uninformed perceptions about the differences between scientific theories and laws, as well as with Saleh and Khine (2014) study which found that pre-service teacher education students in the UAE had ambiguous perceptions in this regard. Indeed, the articulation of the differences between a scientific theory and a scientific law is usually overlooked in science education (Author, 2014a), thus, needs to be a key focus in NOS (McComas, 1998),

Discussing the teachers' perceptions on the Social-Institutional dimension of NOS in the RFN which emphasises the social, political, and financial context that interplay with the activities of scientists (see Table 9), findings show that the overwhelming majority of the teachers strongly assert the concept of 'respect for the environment' as part of the scientific enterprise, however, however, 'intellectual honesty' was much less acknowledged. These demonstrate two professional ethos manifested in the ethical conduct of science, besides many others (e.g. respect for research subjects, social responsibility, non-discrimination, human subject's protection, and animal care). In real practice, scientists, to the best of their ability, are expected to respect such principles of scientific work and not violate them (Irzik & Nola, 2014). It is important that Early years' science teachers enable children to demonstrate such ethos and attitudes which scientists are expected to exemplify and adhere to while pursuing scientific activities.

Another important finding relating to the socio-scientific issues of NOS showed that most of the teachers did not think it is necessary for scientists to ‘share their research’. Importantly, without the act of public sharing and dissemination of results through different means such as research, knowledge will not go under revision, validation, and duplication. Having such understanding about the social and professional connections in scientists’ lives is important so that science teachers can promote such socialisation activities as part of science teaching and learning in classrooms. Such concept is stressed in contemporary social constructivist science education approaches (Erduran & Dagher, 2014b). Accordingly, science teachers need to discuss with learners at the Early years level that besides producing and testing knowledge, scientists also have professional commitment towards engaging in a series of activities such as sharing, presenting, and publishing findings, attending conferences, and writing research, all which are embedded in community practices across various professional organisations and peer-reviewed journals (Irzik & Nola, 2014).

The influence of policies of governments on the scientific knowledge was also somehow underestimated by the teachers. Consistent with this result, Azninda and Sunarti (2021) reported that teachers had no idea about the influence of political power on science although they explained the impact of social aspects well. This suggests that the recognition of the influence of politics in science is not necessarily self-evident for all teachers (Author, 2014a). This focus should not be overlooked in the early years of NOS teaching because science is at its heart a social system, meaning that the scientific work is situated in specific social, historical, political, and cultural settings, all which govern the multiple interactions in science (McComas, 1998)

Lastly, the current findings revealed statistically significant differences in NOS mean scores between teachers who had taken training on NOS and those who did not for the Cognitive-Epistemic System and Scientific Knowledge, with teachers who taught both KG1 and KG2 scored significantly higher at both. However, other variables (years of teaching experience and academic degree) found to have no significant impact on teachers’ understanding of NOS, which supports previous findings reporting that such variables do not necessarily contribute to an increased understanding of NOS (Celik & Bayrakceken, 2012; Gheith & Aljaberi, 2017; Yilmaz-Tuzun, 2008). This also suggests that although prior training may have enabled trainee teachers to adopt more informed notions on the epistemological knowledge about NOS, issues addressing social-institutional and instructional approaches of NOS might be underrepresented in this training, depending on the focus of the delivered content and the designed learning experiences (Abd-El-Khalick & Lederman, 2000).

## Conclusion

This study was conceptually grounded in the Reconceptualised Family Resemblance Approach to NOS (RFN) (Erduran & Dagher, 2014a) as a holistic framework to investigate the conceptions UAE in-service teachers hold about the NOS. Based on the current findings, it is clear that generally, early years teachers have an adequate understanding of many aspects related to science and the NOS, especially those pertaining to the social-institutional, scientific practices, and educational applications of NOS. However, they seemed to hold varied perceptions on other aspects of NOS (e.g. the distinction

between laws and theories, the fixed nature of procedures followed in experiments, the existence of a standard scientific method worldwide, the role of bias and prejudices on scientific facts, and the influence of politics in science). These findings lead to a similar conclusion as that highlighted in previous studies, that teachers may hold some erroneous perceptions and misconceptions regarding NOS (e.g. Abd-El-Khalick & Lederman, 2000; Bilican et al., 2015; Karaman, 2018; Nur & Fitnat, 2015; Sahin & Deniz, 2016).

Critically, early years teachers having incomplete or erroneous ideas about NOS, such as the ones addressed in this study, could potentially pass those on to young children. Speaking of the current context, targeted professional development on NOS is advantageous in resolving such misconceptions. Equal attention needs to be given in professional training for epistemological, social-institutional, and instructional approaches of NOS so early years teachers can capitalise on NOS teaching opportunities to stress these ideas of NOS in their science pedagogical practice.

## Limitations and future research

The current study was bound to the context of in-service teachers from sampled public and private schools in the UAE who teach science at the school levels from KG to grade 2, thus, the results are not generalisable to account for other contexts beyond the one mentioned. Further attempts could replicate the study and continue to explore perceptions on NOS with larger samples of teachers across multiple schools in the UAE. Additionally, the reported findings were drawn from self-report questionnaire. The numerical data generated by means of scale items in the questionnaires provides only a snapshot of information. Therefore, generating qualitative data would lead to more meaningful additions by elucidating the qualitative nature of the participants' perceptions and the beliefs underlying them (Cresswell & Plano Clark, 2011), instead of merely judging those perceptions as adequate or inadequate (Lederman et al., 2002).

## Ethics

Ethical approval was granted by the Social Sciences Ethics Committee at the United Arab Emirates University (ERS-2021-7271).

## Disclosure statement

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## References

- (AAAS) American Association for the Advancement of Science (1990) *Science for all Americans*. Oxford University Press.
- Abd-El-Khalick, F. & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International journal of science education*, 22(7), 665-701. <https://doi.org/10.1080/09500690050044044>
- Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 37(4), 295-317. [https://doi.org/10.1002/\(SICI\)1098-2736\(200004\)37:4](https://doi.org/10.1002/(SICI)1098-2736(200004)37:4)
- Akerson, V. L., Avsar Erumit, B., & Elcan Kaynak, N. (2019). Teaching nature of science through children's literature: An early childhood preservice teacher study. *International Journal of Science Education*, 41(18), 2765-2787. <https://doi.org/10.1080/09500693.2019.1698785>
- Akerson, V. L., Buck, G. A., Donnelly, L. A., Nargund-Joshi, V., & Weiland, I. S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology*, 20(5), 537-549. <https://doi.org/10.1007/s10956-011-9312-5>
- Akerson, V. L., & Buzzelli, C. A. (2007). Relationships of preservice early childhood teachers' cultural values, ethical and cognitive developmental levels, and views of nature of science. *Journal of Elementary Science Education*, 19(1), 15-24. <https://doi.org/10.1007/BF03173651>
- Akerson, V. L., Carter, I., Pongsanon, K., & Nargund-Joshi, V. (2019). Teaching and learning nature of science in elementary classrooms: Research-based strategies for practical implementation. *Science & Education: Contributions from History, Philosophy and Sociology of Science and Mathematics*, 28(3-5), 391-411. <https://doi.org/10.1007/s11191-019-00045-1>
- Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching*, 43(2), 194-213. <https://doi.org/10.1002/tea.20099>
- Akerson, V. L., & Volrich, M. L. (2006). Teaching nature of science explicitly in a first-grade internship setting. *Journal of Research in Science Teaching*, 43(4), 377-394. <https://doi.org/10.1002/tea.20132>
- Akgun, S., & Kaya, E. (2020). How do university students perceive the nature of science? *Science & Education*, 29(2), 299-330. <https://doi.org/10.1007/s11191-020-00105-x>
- Al-Bouti, E. (2018). The UAE high school students' conceptions of the Nature of Science (NOS). *Journal for Researching Education Practice and Theory*, 1(2), 55-76. <https://bspace.buid.ac.ae/handle/1234/1353>
- Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education*, 95(3), 518-542. <https://doi.org/10.1002/sce.20432>
- Al Murshidi, G. (2019). Stem education in the United Arab Emirates: Challenges and possibilities. *International Journal of Learning, Teaching and Educational Research*, 18(12), 316-332. <https://doi.org/10.26803/ijlter.18.12.18>
- Al-Naqbi, A. (2010). The degree to which UAE primary science workbooks promote scientific inquiry. *Research in Science & Technological Education*, 28(3), 227-247. <https://doi.org/10.1080/02635143.2010.506316>

- Al-Omary, A. (2006). Science teacher beliefs about the nature of science, teaching and learning and their relationship to classroom practice [Doctoral Dissertation]. Amman Arab University.
- Anastasiou, L., Kostaras, N., Kyritsis, E., & Kostaras, A. (2015). The construction of scientific knowledge at an early age: Two crucial factors. *Creative Education*, 6(2), 262. <http://doi.org/10.4236/ce.2015.6202>
- Azninda, H., & Sunarti, T. (2021). Teachers' views about Nature of Science (NOS) using Reconceptualised Family Resemblance Approach to Nature of Science (RFN) Questionnaire. In *Journal of Physics: Conference Series*, 1747(1), 012019. <https://doi.org/10.1088/1742-6596/1747/1/012019>
- Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (1998). Implicit versus explicit nature of science instruction: An explicit response to Palmquist and Finley. *Journal of Research in Science Teaching*, 35(9), 1057–61. <https://doi.org/10.1002/tea.10034>
- Bilican, K., Cakiroglu, J. and Oztekin, C. (2015). How contextualized learning settings enhance meaningful nature of science understanding. *Science Education International*. 26(4), 463-487.
- BouJaoude, S., Asghar, A., Wiles, J. R., Jaber, L., Saredidine, D., & Alters, B. (2011). Biology professors and teachers' positions regarding biological evolution and evolution education in a middle eastern society. *International Journal of Science Education*, 33(7), 979-1000. <https://doi.org/10.1080/09500693.2010.489124>
- BouJaoude, S., Dagher, Z. R., & Refai, S. (2017). The Portrayal of Nature of Science in Lebanese 9th Grade Science Textbooks. In C. V. McDonald, & F. Abd-El-Khalick (Eds.), *Representations of nature of science in school science textbooks: A global perspective* (pp. 79–97). Routledge.
- Brunton, P., & Thornton, L. (2010). *Science in the early years: Building firm foundations from birth to five*. SAGE.
- Celik, S., & Bayrakceken, S. (2012). The influence of an activity-based explicit approach on the Turkish prospective science teachers' conceptions of the nature of science. *Australian Journal of Teacher Education*, 37(4). <https://doi.org/10.3316/informit.767762763863077>
- Clough, M. P. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science & Education: Contributions from History, Philosophy and Sociology of Science and Mathematics*, 15(5), 463–494. <https://doi.org/10.1007/s11191-005-4846-7>
- Clough, M. P., & Olson, J. K. (2008). Teaching and assessing the nature of science: An introduction. *Science & Education*, 17(2), 143-145. <https://doi.org/10.1007/s11191-007-9083-9>
- Cresswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. SAGE Publications
- Dogan, N. & Abd-El-Khalick, F. (2008), 'Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching*, 45 (10), 1083-1112. <https://doi.org/10.1002/tea.20243>
- Erduran, S., & Dagher, Z. (2014a). *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories*. Springer.
- Erduran, S., & Dagher, Z. (2014b). Reconceptualizing the nature of science for science education. *Contemporary Trends and Issues in Science Education*, 43, <https://doi.org/10.1007/978-94-017-9057-4>
- Forawi, S., & Abdallah, L. (2019). UAE elementary students' conceptions of nature of science. *International Journal of Latest Research in Humanities and Social Science*, 2(1), 25-32.
- Gheith, E., & Aljaberi, N. M. (2017). The conceptions of pre-service kindergarten and elementary school teachers on teaching science and the nature of science. *Advances in Social Sciences Research Journal*, 4(2). <https://doi.org/10.14738/assrj.42.2532>
- Hansson, L., & Leden, L. (2016). Working with the nature of science in physics class: Turning 'ordinary' classroom situations into nature of science learning situations. *Physics Education*, 51(5), 055001. <https://doi.org/10.1080/1350293X.2021.1968463>
- Hansson, L., Leden, L., & Thulin, S. (2021). Nature of science in early years science teaching. *European Early Childhood Education Research Journal*, 29(5), 795–807. <https://doi.org/10.1080/1350293X.2021.1968463>

- Hanuscin, D. L., Lee, M. H., & Akerson, V. L. (2011). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Education*, 95(1), 145–167. <https://doi.org/10.1002/sce.20404>
- Hoh, Y. K. (2013). Pre-service versus in-service science teachers' views of NOS. *Teaching Science*, 59(2), 31–36.
- Irez, S. (2006). Are we prepared? An assessment of preservice science teacher educators' beliefs about the nature of science. *Science Education*, 90(6), 1113–1143. <https://doi.org/10.1002/sce.20156>
- Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science. *Science & Education*, 20(7), 591–607. <https://doi.org/10.1007/s11191-010-9293-4>
- Irzik G., & Nola R. (2014) New directions for nature of science research. In: Matthews M. (Ed.), *International handbook of research in history, philosophy and science teaching* (pp. 999–1021). Springer.
- Karaman, A. (2018). Eliciting the views of prospective elementary and preschool teachers about the nature of science. *European Journal of Educational Research*. 7(1), 45–61. <https://doi.org/10.12973/eu-jer.7.1.45>
- Kartal, E. E., Cobern, W. W., Dogan, N., Irez, S., Cakmakci, G., & Yalaki, Y. (2018). Improving science teachers' nature of science views through an innovative continuing professional development program. *International Journal of STEM Education*, 5(1), 30. <https://doi.org/10.1186/s40594-018-0125-4>
- Kaya, Ebru, & Erduran, Sibel. (2016). From FRA to RFN, or How the Family Resemblance Approach Can Be Transformed for Science Curriculum Analysis on Nature of Science. *Science & Education*, 25(9-10), 1115–1133. <https://doi.org/10.1007/s11191-016-9861-3>
- Kaya, S. (2012). An examination of elementary and early childhood pre-service teachers' nature of science views. *Procedia-Social and Behavioral Sciences*, 46, 581–585. <https://doi.org/10.1016/j.sbspro.2012.05.165>
- Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: Review of the research. *Journal of research in science teaching*, 29(4), 331–359. <https://doi.org/10.1002/tea.3660290404>
- Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831–879). Lawrence Erlbaum Associates, Publishers.
- Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of research in science teaching*, 39(6), 497–521. <https://doi.org/10.1002/tea.10034>
- Lederman, N. G., Abd-El-Khalick, F., & Smith, M. U. (2019). Teaching nature of scientific knowledge to kindergarten through university students. *Science & Education*, 28(3), 197–203. <https://doi.org/10.1007/s11191-019-00057-x>
- Leung, J., Wong, A. & Yung, B. (2015). Understandings of nature of science and multiple perspective evaluation of science news by non-science majors. *Science & Education*, 24(7/8), 887–912. <https://doi.org/10.1007/s11191-014-9736-4>
- Matthews, M. R. (2012). Changing the focus: From Nature of Science (NOS) to Features of Science (FOS). In M.S. Khine (Ed.), *Advances in nature of science research* (pp. 3–26). Springer.
- McComas, W. F. (1998). The principal elements of the nature of science: Dispelling the myths. In W.F. McComas (Ed.), *The nature of science in science education* (pp. 53–70). Springer.
- McComas, W. F. (2017). Understanding how science works: The nature of science as the foundation for science teaching and learning. *School Science Review*, 98(365), 71–76.
- Metz, K. E. (1997). On the complex relation between cognitive developmental research and children's science curricula. *Review of Educational Research*, 67(1), 151–163.
- Miller, M. C., Montplaisir, L. M., Offerdahl, E. G., Cheng, F.-C., & Ketterling, G. L. (2010). Comparison of views of the nature of science between natural science and non science majors. *CBE Life Sciences Education*, 9(1), 45–54. <https://doi.org/10.1187/cbe.09-05-0029>



- National Science Teachers Association. (2000). NSTA position statement: The nature of science. Retrieved April 15, 2022, from <http://www.nsta.org/159&psid=22>
- Nur, E. M. & Fitnat, K. (2015). Explicit-reflective teaching nature of science as embedded within the science topic: Interactive historical vignettes technique. *Journal of Education and Training Studies*, 3(6), 40–49. <https://doi.org/10.11114/jets.v3i6.965>
- Parker, L. C., Krockover, G. H., Lasher-Trapp, S., & Eichinger, D. C. (2008). Ideas about the nature of science held by undergraduate atmospheric science students. *Bulletin of the American Meteorological Society*, 89(11), 1681–1688. <https://doi.org/10.1175/2008BAMS2349.1>
- Piasta, H., Pelatti, C., & Miller, H. (2014). Mathematics and science learning opportunities in pre-school classrooms, *Early Education and Development*, 25(4), 445–468, <https://doi.org/10.1080/10409289.2013.817753>
- Sahin, E. A., & Deniz, H. (2016). Exploring elementary teachers' perceptions about the developmental appropriateness and importance of nature of science aspects. *International Journal of Environmental and Science Education*, 11(9), 2673–2698. <https://doi.org/10.12973/ijese.2016.715a>
- Saleh, H. A. (2018). A study of the effectiveness of the next generation science standards implementation at a private US curriculum school in Dubai, UAE [Unpublished doctoral dissertation]. The British University in Dubai (BUiD).
- Saleh, I., & Khine, M. (2014). Examining the views about the nature of science among elementary pre-service teachers. *International Review of Contemporary Learning Research*, 3(2), 63–70. <https://doi.org/10.12785/IRCLR/030202>
- Shakera, E., & Saleh, H. (2021). Teachers' perceptions of science curriculum reform in UAE: A study in an American private school in Dubai. *Millennium Journal of Humanities and Social Sciences*, 2(1), 117–137. <https://doi.org/10.47340/mjhss.v2i1.8.2021>
- Smith, C. L., Maclin, D., Houghton, C., & Hennessey, M. G. (2000). Sixth-grade students' epistemologies of science: The impact of school science experiences on epistemological development. *Cognition and Instruction*, 18(3), 349–422. [https://doi.org/10.1207/S1532690XCI1803\\_3](https://doi.org/10.1207/S1532690XCI1803_3)
- Tairab, H. H. (2001). How do pre-service and in-service science teachers view the nature of science and technology? *Research in Science & Technological Education*, 19(2), 235–250. <https://doi.org/10.1080/02635140120087759>
- Tsai, C. C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International journal of science education*, 24(8), 771–783. <https://doi.org/10.1080/09500690110049132>
- Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, 92(5), 941–967. <https://doi.org/10.1002/sce.20259>
- Woodcock, B. A. (2014). “The scientific method” as myth and ideal. *Science & Education*, 23(10), 2069–2093. <https://doi.org/10.1007/s11191-014-9704-z>
- Worth, K. (2010). Science in early childhood classrooms: Content and process. *Early Childhood Research & Practice (ECRP)*, 12(2), 1–17. <https://doi.org/10.12691/education-5-5-10>
- Yacoubian, H. A., & Khishfe, R. (2018). Argumentation, critical thinking, nature of science and socioscientific issues: A dialogue between two researchers. *International Journal of Science Education*, 40(7), 796–807. <https://doi.org/10.1080/09500693.2018.1449986>
- Yilmaz-Tuzun, O. (2008). Preservice elementary teachers' beliefs about science teaching. *Journal of Science Teacher Education*, 19(2), 183–204. <https://doi.org/10.1007/s10972-007-9084-1>
- Zion, M., Schwartz, R. S., Rimerman-Shmueli, E., & Adler, I. (2020). Supporting teachers' understanding of nature of science and inquiry through personal experience and perception of inquiry as a dynamic process. *Research in Science Education*, 50(4), 1281–1304. <https://doi.org/10.1007/s11165-018-9732-9>



## Appendix

### Section 1

Age ☐ 20 – 29 years ☐ 30 – 39 years ☐ 40 – 49 years ☐ Above 50 years

**Which grade level do you teach?**

☐ Pre-KG ☐ KG 1 ☐ KG 2 ☐ Both KG1 & KG 2 ☐ Grade 1 ☐ Grade 2

**How many years have you been teaching?**

☐ Less than 5 years ☐ Between 5 – 10 years ☐ More than 10 years

**Please indicate the highest educational degree you hold**

☐ Diploma

☐ Bachelor Degree

☐ Master Degree

☐ Ph.D.

☐ Other, please specify \_\_\_\_\_

**Please indicate the major of your first educational degree**

☐ Sciences (science, biology chemistry, physics, earth science, astronomy)

☐ Mathematics ☐ Languages

☐ Early Childhood Education

☐ Social Sciences ☐ Computer Sciences/ Technology ☐ Other, please specify \_\_\_\_\_

### Section 2

**The Following statements relates to 'Nature of Science'. Please indicate to what extent do you agree/disagree with each statement using the following choices:**

1 = Strongly disagree

2 = Disagree

3 = Not Sure

4 = Agree

5 = Strongly agree

RFN questionnaire Items.

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1. Science lessons should include financial (economical) aspects of science.
  2. Epistemic, cognitive and cultural values of science cannot be distinctly distinguished from each other.
  3. Scientific knowledge does not change.
  4. Scientists review and assess each other's work.
  5. The power of experimentation comes from testing a scientific hypothesis many times by scientists.
  6. Concept maps can be an effective way of teaching classification as scientific practice.
  7. Science takes place in institutions such as universities and research centres.
  8. All scientific disciplines such as physics, biology and chemistry use the same scientific method.
  9. Science is a social system.
  10. Scientific progress occurs when ideas are evaluated and revised.
  11. Each branch of science has a different nature.
  12. Students should determine the methods of their science investigations themselves.
  13. Politics does not influence science.
  14. Scientists should respect the environment.
  15. Analysis and interpretation of data are components of scientific practices.
  16. Theories and laws are forms of scientific knowledge but models are not.
  17. Teaching scientific aims and values of science is likely to improve students' understanding of science.
  18. Scientists don't have to share their research with society.
  19. Scientists build and use models to understand complex scientific phenomena.
  20. The diversity of scientists solving a problem together means less biased results.
  21. Students should understand that theories are a collection of models.
  22. There is no step by step order to doing science.
  23. All branches of science use observations.
  24. Diversity of methods contributes to scientific understanding.
  25. All hypothesis testing is manipulative.
  26. Some branches of science do not use representations.
  27. Educating students about scientific aims and values improves scientific literacy.

28. Scientists have to use different methods to produce enough evidence so that they can solve problems.
  29. Students should be encouraged to collaborate with their peers in science lessons because scientists collaborate with other scientists when doing research.
  30. Scientific knowledge consists of a coherent set of ideas.
  31. The curriculum should stress that theories in chemistry and physics are the same.
  32. Scientists need money to do research.
  33. Classification helps scientists explain and predict phenomena.
  34. All scientific disciplines such as physics, biology and chemistry produce values that can contribute to society.
  35. It does not make a difference to students' learning of science when they participate in discussions about experimental data.
  36. The gender of scientists influences how they do science.
  37. There is a universal scientific method that all scientists use all over the world.
  38. Scientific experiments follow a certain set of procedures.
  39. Intellectual honesty in science does not have to be taught in science lessons.
  40. Scientists should change their minds when they realise that their ideas are not supported by evidence.
  41. Policies of governments affect the growth of scientific knowledge.
  42. Students should sometimes have the choice to design methods for their investigations.
  43. Laws are theories that are confirmed.
  44. Scientific models are tools to represent the real world.
  45. Some scientists earn more money than others, causing tension between scientists.
  46. Scientific facts are not affected by bias and individual subjective prejudices of scientists.
  47. Science teaching should specify that laws are certain and unchangeable.
  48. Race and ethnicity of scientists have nothing to do with science.
  49. Changing variables is a fundamental requirement for a scientific study.
  50. Theories, laws and models work together to produce scientific knowledge.
  51. Teaching epistemic, cognitive, social and cultural values should be the core components of the science curriculum.
  52. Different branches of science like physics, biology and chemistry have the same practices.
  53. Scientists write papers in academic journals.
  54. There are different kinds of theories. Some are accepted, others are still debated.
  55. Science curriculum should not only cover scientific knowledge, but also the social and cultural aspects of science.
  56. There is no relationship between scientific facts and values.
  57. Scientists from all branches of science validate scientific knowledge by evaluating each other's ideas.
  58. Scientists participate in conferences to share their research with other scientists.
  59. Understanding scientific methodology can help students distinguish between science and non-science.
  60. All scientific disciplines such as physics, biology and chemistry require constructing hypotheses.
  61. There are standards for evaluating the quality of scientific work.
  62. Internalising scientific aims and values enables students to understand scientific knowledge.
  63. Models can help scientists to explain and predict phenomena.
  64. Scientific practices produce knowledge and are not influenced by cultural factors.
  65. Students should understand that scientists need to have social values such as honesty.
  66. Laws are more verifiable scientific knowledge than theories.
  67. There are social hierarchies among science teams and these can change.
  68. It's not necessary for students to understand how knowledge develops in science.
  69. Scientific aims and values affect scientists' choice of methods in their investigations.
  70. Scientists socially interact with other scientists while doing research.
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