Science & Education
https://doi.org/10.1007/s11191-022-00399-z

SI: FAMILY RESEMBLANCE APPROACH

Nature of Science in Norway's Recent Curricula Reform

Analysis of the Biology, Chemistry, and Physics Curricula

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Accepted: 5 October 2022

Abstract

Developing students' understanding of the nature of science (NOS) is seen as critical for educating scientifically literate citizens, and has emerged as an important curricular goal internationally. In Norway, a new curriculum reform has recently been implemented, intended to improve the Norwegian education in several ways. The reform aims to promote deep learning, and there has been an increased focus on twenty-first-century skills, including critical thinking, problem solving, and collaboration. The purpose of this study is to analyse the coverage of various NOS aspects in the new national curriculum for biology, chemistry, and physics, year 12 and 13. The curricula were analysed deductively, using the *Family Resemblance Approach* (FRA) to identify and categorise different NOS aspects, providing insight into how NOS is addressed. Findings include that NOS aspects from the cognitive-epistemic system of the FRA framework—*aims and values*, *methods*, *practices*, and *knowledge*—are predominant in all three curricula, whereas aspects concerning how science interacts with society are scarce. The exception is several occurrences of the aspect *social values*, i.e. the need for responsible interaction between science, society, and nature, especially in the biology curriculum. Furthermore, different NOS aspects are found in different parts of the curriculum, e.g. *practices* are found in the basic skills sections more than in the competence aims sections. Findings are discussed in terms of how the new curriculum reform can promote Norwegian students' learning of NOS.

1 Introduction

The value of nature of science (NOS) in science education is well established, and promoting and improving NOS teaching and learning has been, and continues to be, an important field within science education research (Erduran & Dagher, 2014a; Lederman & Lederman, 2014; McComas & Clough, 2020). Consequently, improving students' understanding of NOS is an important objective in many curricular frameworks, as illustrated by e.g. the big ideas *about* science presented by Harlen et al., (2010), *science and engineering practices* as one of three main dimensions in the Next Generations Science Standards (NGSS) in the US

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Published online: 07 November 2022

(National Research Council, 2012), and *procedural* and *epistemic knowledge* as two of three competences in scientific literacy in the 2018 PISA framework (OECD, 2019). Nevertheless, empirical research over the last decades concludes that teachers' and students' understanding of NOS is typically not adequate, and teachers do not seem to consider learning outcomes related to NOS equally important as more traditional subject-related outcomes (Lederman & Lederman, 2014). Lederman and Lederman (2014) further ascertains that NOS is best learned through explicit instructions that includes reflection, and that implicit learning by simply "doing" science or engaging in scientific inquiry is not sufficient for promoting students' understanding of NOS.

In Norway, a new curriculum reform was recently implemented (2020 and 2021), aiming to promote deep learning rather than fragmented and surface level learning (Ministry of Education and Research, 2016), and with an increased focus on twenty-first-century skills, such as critical thinking, problem solving, and collaboration. The platform document of the reform states that the goal of education as a whole is for students to develop knowledge, skills, and attitudes to be able to master their lives and participate in both work and community in the society (p. 21). These formulations align with arguments for science education put forward by Norwegian science educator Sjøberg (2004), which include science for making sense of the natural world and its impact on our history and culture, science as a tool for education and work, and science as essential for informed citizenship. Based on the assessment of the subjects in primary and secondary education in terms of requirements for competences in future working life and society, an appointed committee presented several research-based recommendations for the curriculum reform (NOU, 2014:7; NOU, 2015:8). Specifically, they advocated for supporting deep learning through prioritising the central building blocks of the subjects: their methods and ways of thinking, their concepts, and their important relations. This corresponds well with both the NGSS, which was an effort to move away from surface learning to a curriculum facilitating deep learning (National Research Council, 2012), and with Harlen et al.'s (2010) argument that science education should support students to develop specific big ideas *of* science and *about* science, which would 'enable them to understand the scientific aspects of the world around and make informed decisions about the applications of science' (p. III).

In the resulting Norwegian curriculum reform, the relevance of NOS seems to be emphasised by the introduction of two aspects in particular: The interdisciplinary topics *health and life skills*, *democracy and citizenship*, and *sustainability*, and core elements for each subjects which for all of the sciences include one NOS-related core element called e.g. *practices and ways of thinking in physics*. In the present study, we analyse how different aspects of NOS are present in the new national curriculum for biology, chemistry, and physics, and in which parts of the curriculum NOS aspects appear. Before presenting further details about methodology and findings, the context and the theoretical perspectives informing the study are explained.

1.1 Conceptualisations of the Nature of Science for Science Education

NOS has been an important objective for science education for a long time. In 1992, Lederman (1992) reviewed 40 years of research in conceptions on NOS among teachers and students, demonstrating the long-standing nature of the issue. Moreover, students' understanding of NOS is seen as an important part of the broader goal of scientific literacy

(Lederman & Lederman, 2010; McComas & Clough, 2020), and for being able to engage with socio-scientific issues (Sadler & Zeidler, 2009).

A range of more or less different conceptualisations of NOS has been presented over the years. McComas (2017) and Lederman and Lederman (2014) are among the promoters of the *consensus view* of NOS, which comprises a set of key aspects seen as the most important for science education in primary and secondary school. Matthews (2012) proposed the *features of science* approach, which focuses more on the history and philosophy of science. Allchin (2011) argued that the list of key NOS elements presented in the consensus view entailed a fragmented view on NOS that lacked certain important aspects, and proposed the *whole science* framework for assessment of students understanding of NOS. In 2020, McComas (2020) presented the consensus view of NOS not as a list but as three connected domains with nine sub-elements: the *tools and products of science* (evidence is vital in science, laws and theories are related but distinct, shared methods but no stepwise method); the *human elements of science* (in science, creativity is everywhere, subjectivity and bias are present, and society and culture interact with science); and *science knowledge and its limits* (science is distinct from engineering and technology, science is tentative, durable and self-correcting, science has limits).

1.2 Theoretical Framework

In this paper, we employ the *family resemblance approach* (FRA) to NOS, as proposed by Erduran and Dagher (2014a). They stated that 'nature of science in its broader sense encapsulates a range of practices, methodologies, aims and values, and social norms that have to be acknowledged when teaching science' (p. 19), and argues that the FRA works as such a broader encapsulation of NOS. To our knowledge, the new Norwegian biology, chemistry, and physics curriculum have not previously been analysed for NOS. Hence, we wanted to use a holistic approach, trying to capture both the nature of scientific knowledge and of science as a discipline, including its social-institutional dimensions. The FRA was therefore chosen as the basis for our analysis.

Irzik and Nola (2011) were the first ones to propose a family resemblance approach to the nature of science for educational purposes. They based their work on Wittgenstein's idea that family resemblance is a helpful metaphor for describing unity in a diverse field. Family members resemble each other by sharing a range of characteristics that are not necessarily present in every family member, but that are still recognisable as family traits. Employing this idea, Irzik and Nola (2011) argued that the basic components of NOS were *activities* (e.g. data collection practices), *aims and values* (e.g. providing explanations that are as simple as possible), *methods and methodologies* (e.g. experiments should be controlled), and *products* (e.g. laws, theories and models). They later added components of science as a social-institutional system (Irzik & Nola, 2014). Erduran and Dagher (2014a) added further to Irzik and Nola's work, and presented their FRA to NOS as consisting of a *cognitive-epistemic* system and an extended *social-institutional* system, illustrated in Fig. 1. The cognitive-epistemic system is represented by the inner circle in Fig. 1, while the social-institutional system consists of the middle and outer circle. The two systems coexist and interact with each other, and Erduran et al. (2020) argued that FRA in this way is consistent with the consensus view as presented in McComas (2020). The following presentation of the FRA is based on Erduran et al. (2019) and refers to the illustration shown in Fig. 1.

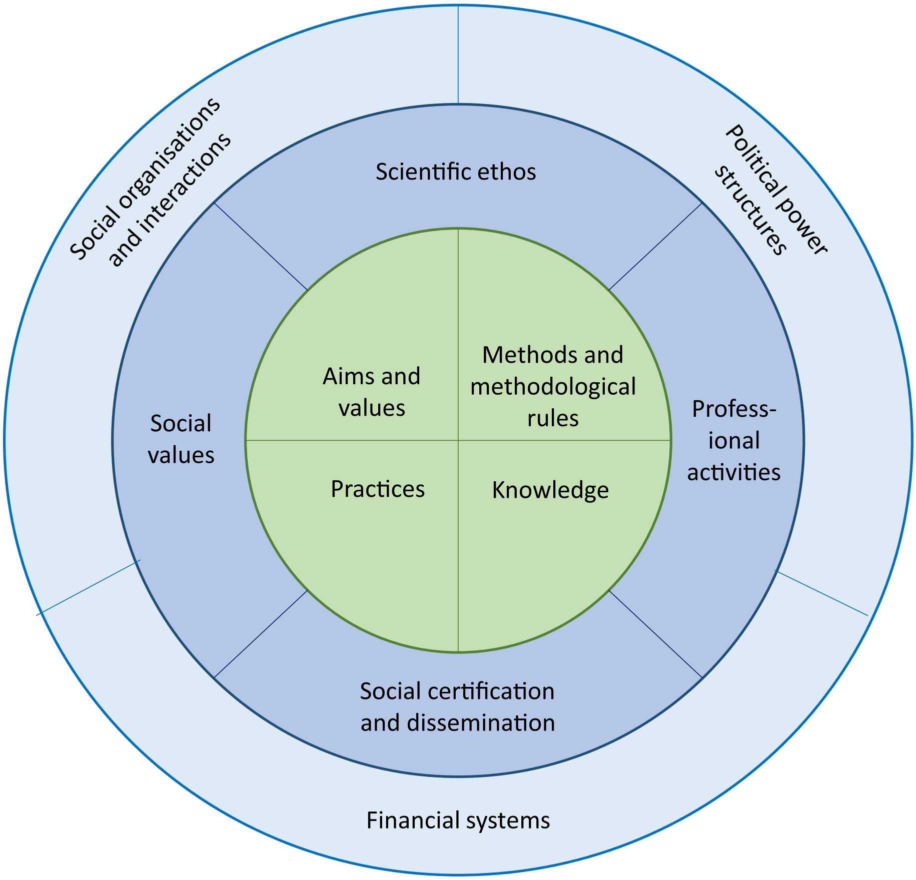

Fig. 1 The Family Resemblance Approach to NOS of Erduran and Dagher (2014a), with its 11 categories divided into a cognitive-epistemic system (inner circle) and a social-institutional system (middle and outer circles) (our illustration)

The cognitive-epistemic system consists of four categories:

- *Aims and values*: The aims and values that guide scientific practices, such as simplicity and objectivity
- *Scientific practices*: The cognitive, epistemic, and discursive practices of the scientific enterprise, such as observation, modelling, and argumentation
- *Methods and methodological rules*: The various methods used to generate evidence and construct theories, and the rules these methods are guided by, such as scientific methods being revisionary in nature
- *Scientific knowledge*: Theories, laws, and models produced through the scientific enterprise, and that are conceptualized as a coherent network

The social-institutional system consists of seven categories:

- *Professional activities*: Activities scientists engage in to communicate their research, such as publishing in journals and presenting at conferences
- *Scientific ethos*: The set of norms that scientists are expected to abide by in their own work and in interaction with colleagues, such as openness and respect for the environment
- *Social certification and dissemination*: The practices in which scientists' work is reviewed and evaluated by their peers, such as the peer-review process
- *Social values of science*: The social values embodied by science, such as social utility and addressing human needs
- *Social organizations and interactions*: The organization of science in institutions such as universities and research centres, with organizational structures that govern social interaction among scientists
- *Political power structures*: The influence of the political environment on the direction and use of science, which is not always beneficial for individuals, groups, or cultures
- *Financial systems*: The economic factors that mediates the scientific enterprise, such as nationally governed funding, which in turn influences the types of scientific research that is conducted

These 11 categories are not seen as mutually exclusive, but as different dimensions of science as an enterprise. In Sect. 2.3, we present our interpretation of the FRA categories for the purposes of our analysis.

1.3 Nature of Science in Science Curricula—Empirical Findings

In the wake of the suggested Family Resemblance Approach to NOS in science education, the FRA has been adapted and used as an analytical tool for analysing curriculum frameworks in several studies (Caramaschi et al., 2022; Cheung, 2020; Erduran & Dagher, 2014b; Kaya & Erduran, 2016; Park et al., 2020; Yeh et al., 2019). A recurring finding is that the social-institutional aspects of science—i.e. aspects concerning how science interacts with society—are more scarcely represented in the curricula compared to the cognitive-epistemic aspects, as seen for example in the analysis of Turkish middle school science curricula (Kaya & Erduran, 2016), curriculum documents from the USA (NGSS) and Ireland (Kaya & Erduran, 2016), and science curriculum documents from Taiwan (Yeh et al., 2019). Similar results have been found for the physics curriculum in Italy (Caramaschi et al., 2022) and the biology curriculum in Hong Kong (Cheung, 2020). The latter found that 84% of the biology curriculum that was identified as NOS, was given FRA categories within the cognitive-epistemic system, with *aims and values* and *practices* being most prominent (Cheung, 2020). Caramaschi et al. (2022) reported similar results from their analysis of the Italian physics curriculum, with 88% of the identified NOS aspects falling within the cognitive-epistemic system. Here, *knowledge* and *practices* were the most prominent categories. However, in a recent study of the new Norwegian science curriculum (years 1–10), Mork et al. (2022) found *social values* to be the second most dominating aspect of NOS after *practices*, forming a contrast to the other comparable curriculum analysis. Their result could be related to the new Norwegian curriculum's emphasis on sustainability, health, and democracy and citizenship, all areas where science and society interact in important ways. It is interesting to investigate to what extent the social-institutional aspects of science are represented in the new curriculum for biology, chemistry, and physics, as they are underemphasised internationally, but somewhat better represented in the Norwegian integrated science curriculum.

Other frameworks have also been used to analyse NOS content in curricula (e.g. McComas & Nouri, 2016; Olson, 2018; Summers et al., 2019). For example, Olson (2018) examined science education standards documents from nine different countries, applying McComas et al.'s (1998) view on NOS. Findings indicated that NOS aspects rarely are present as expected learning outcomes for students, but instead are more commonly found in other parts of the curriculum material, like introductions or appendices (Olson, 2018). It should be noted that statements requiring students to engage in specific process skills, like e.g. observing or interpreting data, were not included as NOS in the analysis unless there was a clear connection between these process skills and the work of scientists. Also drawing from the consensus perspective on NOS, Summers et al. (2019) evaluated several US science standards and the NGSS with regards to representation of different NOS aspects and whether the presentation of NOS was explicit or implicit. They concluded that the majority of modern K-12 science education standards documents lacked several key NOS aspects and that the amount of explicit, informed representations of NOS—which was low in many states—had not improved over the last 30 years. However, in the NGSS, NOS was represented in a more informed and explicit manner.

1.4 Science Education in Norway and the New National Curriculum

In the present study, we analyse the new Norwegian curriculum for biology, chemistry, and physics. In Norway, science is a compulsory subject from year 1 through year 11 for all students. Through these years, the scientific disciplines biology, chemistry, geology, and physics are not treated as separate subjects, but are taught as integrated science. However, in years 12 and 13, the last two years of upper secondary school, science is voluntary, and students who proceed with science can choose which of the scientific disciplines they want to continue with.

In August 2020, a new national curriculum, LK20, was introduced for integrated science (years 1–11), consisting of new subject-specific curricula and a revision of the core curriculum, which describes and elaborates the overriding values and principles for education and training in Norway (Ministry of Education and Research, 2016). In August 2021, equivalent new curricula were introduced for the discipline specific subjects (years 12–13). As the previous national curriculum, LK20 is a goal-oriented and competence-focused curriculum, as opposed to a content-focused curriculum. Accordingly, the curriculum determines a set of clear competence aims for the students, but trusts the schools to decide how to reach them (Ministry of Education and Research, 2004), giving the teachers considerable latitude.

The structure of the curricula are the same for all subjects, consisting of six main parts (illustrated in Table 1): *Relevance and central values*, *Core ideas*, *Interdisciplinary topics*, *Basic skills*, *Competence aims*, and *Assessment* (Norwegian Directorate for Education & Training, 2021). The set of determined competence aims that the students are to reach is found in the part *Competence aims*. In the previous national curriculum, assessment of students were to be directly based on these competence aims,

Table 1 The structure of the new curriculum, LK20

The new national curriculum in Norway—LK20
1. Core curriculum The overriding values and principles for education and training in Norway
2. Subject specific curriculum *About the subject* • Relevance and central values • Core ideas • Interdisciplinary topics • Basic skills *Competence aims and assessment* • Competence aims divided by year • Formative and summative assessment

which were more elaborate and numerous than in the new curriculum reform. However, in LK20, a new element is added stating that the competence aims, "should be understood in light of the text about the subject in the curricula" (Norwegian Directorate for Education and Training, 2020, p. 6), that is, in light of the other sections such as *Core ideas* and *Basic skills*. As this is a new approach, one could expect that Norwegian teachers will still place great emphasis on the competence aims themselves, at least at first. It is therefore interesting to look at where in the curriculum NOS is identified, in addition to how much NOS there is and which aspects are represented. The importance of this is further supported by Olson's (2018) findings that NOS aspects are commonly found in curriculum introduction or appendixes and more rarely as expected learning outcomes for students.

2 Methodology

2.1 Research Questions

In light of the newly implemented curriculum reform in Norway, the importance of NOS in science education, and the empirical findings described above, the present study asks the following research questions:

1. How is NOS, as conceptualised by the FRA, represented in the new Norwegian curriculum for physics, chemistry, and biology?
2. In which parts of the three curricula do the different NOS aspects appear?

2.2 Data Sources

In the present study, the data comprise the subject-specific curriculum for biology, chemistry, and physics. The three curricula were downloaded in its entirety from the Norwegian Directorate for Education and Training, who are responsible for the national curriculum in Norway. All text in the six main parts of the curricula were included as data. Table 2 gives a general description of the different parts.

Table 2 Description of the six main parts of the new subject specific curriculum in Norway

Main parts of the curriculum	Description
Relevance and central values	Describes how the specific subject is relevant for the students' understanding of their everyday world, and in what way the subject will prepare the students for participating in society and working life. It further describes how the specific subject contributes to realising the overriding values of the education, given by the core curriculum
Core ideas	Each curriculum has listed a set of core ideas, with the purpose of describing the subject's most central concepts, methods, ways of thinking, fields of knowledge, and expressions. Together, the core ideas are supposed to embrace what the students need to learn to be able to master and apply the subject. The biology, chemistry, and physics curriculum all include core ideas related to NOS
Interdisciplinary topics	The core curriculum instructs all schools to facilitate learning in the following interdisciplinary topics: • *Public health and life skills*, which is about giving students competence that promote good physical and mental health and provide opportunities to make responsible life choices • *Democracy and citizenship*, which should prepare students for participation in democratic processes, give knowledge about the democracy's rules and values, and improve students' ability in critical thinking and dealing with conflicts of opinion • *Sustainable development*, which is about helping students realise that our lifestyle and consumption of resources have local, regional, and global consequences, and helping them understand how dilemmas and development in society can be dealt with in a sustainable way The subject specific curriculum describes and exemplifies the interdisciplinary topics in the context of the subject. However, not all three topics are considered relevant in all subjects. Whereas all three are described for chemistry, only *Public health and life skills* and *Sustainable development* are described for biology, and only *Democracy and citizenship* and *Sustainable development* for physics
Basic skills	Describes what the five basic skills—reading, writing, numeracy, oral skills, and digital skills—imply in each specific subject. The basic skills are part of the competence in the subjects, are considered necessary for learning and understanding, and are recognised as important for the students' ability to participate in education, work, and society
Competence aims	Each curriculum specifies a list of competence aims for the students, indicating what competence students should hold after completing the subject. It is intended that work with relevance and central values, core ideas, interdisciplinary topics, and basic skills should be integrated with work towards the competence aims
Assessment	Describes the formative and summative assessment in the subjects and outlines how students develop and show competence in the subjects

2.3 Data Analysis Approaches

The research team consisted of three researchers with background from either physics, chemistry, or biology. The three curricula were first read by the researchers to gain an overview of the data. Each researcher then analysed the curriculum within their field of expertise in NVivo12, using the 11 categories from the FRA framework as codes (Fig. 1). The unit of analysis was defined to be one full sentence or a competence aim. Consequently, all text in the three curricula was analysed sentence by sentence to identify possible presence of NOS and which FRA categories to apply. For accuracy, several codes could be applied to one sentence.

To ensure consistency in the coding, the research team met frequently in the preliminary phase of the analysis to discuss examples of each other's coding and collaboratively code small extracts from the curricula. Disagreements and uncertainties were solved through discussions among the researchers and by consulting an expert, in particular one of the developers of the FRA framework. Table 3 gives a definition of the different FRA categories together with an illustrative example of this category found in the curriculum.

When the research team had a common understanding of the FRA categories, each researcher completed the coding of their curriculum. The researchers were then randomly allocated one of the other curricula and analysed this curriculum in its entirety. The results of the two analyses, performed by two different researchers, were compared, and inter-rater reliability, i.e. the percentage of sentences coded the same way by both researchers, was calculated. Sentences that were not coded identically were noted as disagreements. This included sentences where the two researchers agreed on one code, but where one of the researches had given the sentence an additional code. The results of the comparisons are summarised in Table 4. As can be seen from Table 4, disagreements on whether or not to apply a code were most common, whereas disagreements regarding which code to use were rare. All differences were subsequently resolved through discussions.

3 Findings

Table 5, 6, and 7 report the frequencies of each FRA category found in the different parts of the curriculum for biology, chemistry, and physics, respectively. As can be seen from the tables, approximately half of the units of analysis in each curriculum were given one or more codes, meaning that about half of the curricula is interpreted as NOS related. In all three subjects, codes from the cognitive-epistemic part of the FRA framework were the most prominent, with *practices* being the most commonly used code by far. For example, in the chemistry curriculum, 40 occurrences in total were found to belong to the cognitive-epistemic system, of which 29 sentences were coded as *practices*, five were coded as *methods*, three as *knowledge*, and three as *aims and values*. The way we have interpreted the FRA categories, sentences coded as *practices* typically describe students doing science, i.e. training their procedural knowledge where NOS is not necessarily explicit. More explicit formulations about epistemic knowledge, e.g. *why* these practices are used in science and what characterises knowledge developed in such ways, were typically coded as *methods* or *knowledge*. The following extracts are examples of sentences that were coded as *practices*:

> Biology: [The students should be able to] plan and investigate, collect, process and interpret data, and present results and findings.
> Chemistry: To be able to do calculations in chemistry involve to obtain, process, interpret, and present different types of data.
> Physics: [The students should be able to] plan and conduct experiments, analyse data, and draw conclusions.

Table 3 Definitions of the FRA categories including illustrating examples from the curriculum

FRA category	Definition adapted from Erduran and Dagher (2014a)	Example
Aims and values	Descriptions of key objectives and values of science, and explicit descriptions of that students should develop such values	'The subject [chemistry] should also contribute to that the students develop a scientific and critical way of thinking and a professional ethical awareness'
Methods and methodological rules [Methods]	Descriptions of how methods are developed and of students choosing methods or reflecting on methodology, not for simply using scientific methods (coded as practices)	'Moreover, the students demonstrate and develop competence when they argue for choice of methods, reflect on findings, and critically evaluate sources and information'
Practices	Descriptions of scientific activities such as planning and conducting investigations, using and creating models, communicating and discussing results, and taking part in scientific argumentation and critical thinking	'[The students should be able to] plan and conduct experiments, estimate uncertainty and consider sources of error, present results and argue for the validity of results and conclusions'
Knowledge	Descriptions of how scientific knowledge is developed	'The core element practices and ways of thinking in physics concerns how science methods, experiments, theories, and models are developed and used'
Scientific ethos	Descriptions of norms that scientists use in their work, such as ethical considerations or the sharing of ideas	'[The students should be able to] consider commercial use of gene technology in medicine and food production, and discuss ethical challenges with the use of such technology'
Social values	Descriptions of how science contributes to society, and of the need for responsible interactions between science, society, and nature	'Competence in biology and ethical and environmental awareness form the basis for sustainable management of biodiversity and for securing our own livelihood for the future'
Social certification and dissemination	Descriptions of social mechanisms for evaluation and validations of science, such as the peer-review process	No such descriptions were identified
Professional activities	Descriptions of professional settings that scientists engage in, such as conferences	No such descriptions were identified
Social organisations and interactions	Descriptions of how science as an enterprise is organised in institutions and collaborations between such institutions	'[The students should be able to] present central elements of new knowledge in physics that is a result of international research collaboration, and evaluate how such collaboration contributes to the knowledge development'
Financial systems	Descriptions of the financial and economic aspects of science, such as funding for research	No such descriptions were identified
Political power structures	Descriptions of power dynamics within science	No such descriptions were identified

Table 4 Disagreements in the analysis and inter-rater reliability

	Disagreements on whether or not to apply code	Use of different codes	Inter-rater reliability (%)
Biology	12	1	83
Chemistry	15	1	80
Physics	16	3	76

The categories *methods* and *knowledge* can be illustrated by the following examples, where the first example is coded as both *methods* and *knowledge*, and the second is coded as *knowledge*:

> Chemistry: The core idea practices and ways of thinking in chemistry is about how scientific hypothesis, theories, methods, and models within the field are developed and applied, and how these are connected to experiments and testing.
> Physics: [The students should be able to] describe the central principles in the special and general theories of relativity and account for how these have changed our understanding of time, space, and fields.

The outer rings of the FRA framework—the social-institutional system—were more scarcely represented. Two sentences in each of the curricula were coded with *scientific ethos* and only one sentence in total (a competence aim from the physics curriculum) was given a code from the outer-most ring, namely *social organisation and interaction*:

> Physics: [The students should be able to] present central elements of new knowledge in physics that is a result of international research collaboration, and evaluate how such collaboration contributes to the knowledge development.

The aspects *professional activities*, *social certification and dissemination*, *financial* systems, and *political power structures* were not identified at all. However, the aspect *social values* from the social-institutional system occurred more frequently. This category was by far most prominent in the biology curriculum compared to chemistry and physics, with 18 occurrences in total, i.e. almost equally frequently identified as *practices* (20 occurrences). The following example illustrates a unit of analysis coded as *social values*:

> Biology: [The students should be able to] explore what consequences climate change and land use can have on biodiversity, and discuss measures for a more sustainable management.

Social values was also the second most frequent code used in the analysis of the chemistry curriculum, identified 10 times. However, with only four occurrences in total, this aspect was not particularly prominent in the physics curriculum. Here, instead *knowledge* was the second most used code, identified nine times, as compared to two and three times in the biology and chemistry curriculum, respectively.

Regarding the distribution of NOS aspects across different parts of the curriculum, the analysis revealed some results that are worth noticing. First, the parts *Relevance and*

Table 5 Frequencies of the FRA codes found in the biology curriculum

FRA categories	Main parts of the biology curriculum						
	Relevance and central values	Core ideas	Inter-discipli-nary topics	Basic skills	Competence aims Biology 1	Competence aims Biology 2	Assessment	Total
Aims and values	0	0	0	1	0	0	0	1
Knowledge	0	1	0	0	1	0	0	2
Methods	0	1	0	1	0	1	0	3
Practices	1	2	0	11	1	2	3	20
Professional activities	0	0	0	0	0	0	0	0
Scientific ethos	0	1	0	0	0	1	0	2
Social cert. and dissem	0	0	0	0	0	0	0	0
Social values	5	2	5	0	2	3	1	18
Financial systems	0	0	0	0	0	0	0	0
Political power structures	0	0	0	0	0	0	0	0
Social org. and interaction	0	0	0	0	0	0	0	0
Total units of analysis	10	15	6	14	11	11	11	78
Coded units of analysis (each unit can have more than one code)	6 (60%)	6 (40%)	5 (83%)	13 (93%)	4 (36%)	5 (45%)	4 (36%)	43 (55%)

The unit of analysis is defined to be one full sentence or a competence aim. 'Total units of analysis' is thus the number of sentences or competence aims in the different parts of the curriculum.

Table 6 Frequencies of the FRA codes found in the chemistry curriculum

FRA categories	Main parts of the chemistry curriculum							
	Relevance and central values	Core ideas	Inter-discipli-nary topics	Basic skills	Competence aims Chemistry 1	Competence aims Chemistry 2	Assessment	Total
Aims and values	2	0	1	0	0	0	0	3
Knowledge	0	1	0	0	1	1	0	3
Methods	0	2	0	1	1	1	0	5
Practices	0	4	1	12	6	2	4	29
Professional activities	0	0	0	0	0	0	0	0
Scientific ethos	1	0	0	0	0	1	0	2
Social cert. and dissem	0	0	0	0	0	0	0	0
Social values	2	2	4	0	1	1	0	10
Financial systems	0	0	0	0	0	0	0	0
Political power structures	0	0	0	0	0	0	0	0
Social org. and interaction	0	0	0	0	0	0	0	0
Total units of analysis	7	12	6	14	17	15	11	82
Coded units of analysis (each unit can have more than one code)	5 (71%)	5 (60%)	5 (83%)	12 (86%)	8 (47%)	4 (27%)	4 (36%)	43 (52%)

The unit of analysis is defined to be one full sentence or a competence aim. 'Total units of analysis' is thus the number of sentences or competence aims in the different parts of the curriculum.

Table 7 Frequencies of the FRA codes found in the physics curriculum

FRA categories	Main parts of the physics curriculum							
	Relevance and central values	Core ideas	Inter-discipli-nary topics	Basic skills	Competence aims Physics 1	Competence aims Physics 2	Assessment	Total
Aims and values	4	0	2	0	0	0	0	6
Knowledge	3	2	1	0	1	2	0	9
Methods	0	1	0	0	0	0	1	2
Practices	0	2	0	7	3	2	5	19
Professional activities	0	0	0	0	0	0	0	0
Scientific ethos	1	0	0	0	0	1	0	2
Social cert. and dissem	0	0	0	0	0	0	0	0
Social values	1	0	2	0	0	0	1	4
Financial systems	0	0	0	0	0	0	0	0
Political power structures	0	0	0	0	0	0	0	0
Social org. and interaction	0	0	0	0	0	1	0	1
Total units of analysis	9	11	4	15	14	12	13	78
Coded units of analysis (each unit can have more than one code)	7 (78%)	4 (36%)	3 (75%)	7 (47%)	4 (29%)	5 (42%)	7 (54%)	37 (47%)

The unit of analysis is defined to be one full sentence or a competence aim. 'Total units of analysis' is thus the number of sentences or competence aims in the different parts of the curriculum.

central values and *Interdisciplinary topics* received a significantly higher proportion of coded units of analysis than other parts of the curriculum, for all three subjects. In the biology and chemistry curriculum, this was also the case for *Basic skills*. Second, there were differences between where in the curriculum the different NOS aspects were present. For example, the aspect *aims and values* was commonly identified in *Relevance and central values* and *Interdisciplinary topics* and was not identified at all in *Competence aims* in any of the curricula. *Social values*, *practices*, and *methods* are other aspects that were not particularly prominent in *Competence aims*, compared to the overall occurrence of these aspects in the rest of the curriculum. The extract below is an example from the part *Interdisciplinary topics* coded with *social values*:

> Chemistry: Sustainable development in chemistry is also about finding solutions for managing and recycling the earth's resources in a sustainable way.

Finally, only a few of the NOS aspects were identified in the *Assessment* part of the curriculum. In the biology curriculum, *practices* and *social values* were identified in *Assessment*; only *practices* was identified in the chemistry curriculum; and *methods*, *practices*, and *social values* occurred in this part of the physics curriculum. The following example illustrates the aspect *practices* found in the part *Assessment*:

> Biology: The students demonstrate and develop competence in biology 1 by using professional language, subject theory, and models to explore, discuss, and explain biological systems and processes, and how biological competence can be used.

4 Discussion

The purpose of this study was to identify and categorise the presence of NOS in the new Norwegian curriculum for biology, chemistry, and physics, using the *Family Resemblance Approach* to conceptualise NOS. Overall, approximately half of the curriculum text for each subject was interpreted as NOS related. Below, we discuss the results of the analysis in terms of how the new curriculum reform can promote Norwegian students' learning of NOS.

4.1 Not Necessarily Explicit Engagement with NOS

In both biology, chemistry, and physics, codes from the cognitive-epistemic system were the most prominent, with *practices* being the dominating category. Other studies have also found the cognitive-epistemic system to dominate heavily in science (Kaya & Erduran, 2016; Yeh et al., 2019), biology (Cheung, 2020), and physics (Caramaschi et al., 2022) curricula. For physics, Caramaschi et al. (2022) found that *practices* and *knowledge* featured most often, as did we. The large presence of practices means that Norwegian biology, chemistry, and physics students will be working actively with their subjects through inquiry, potentially benefiting learning as well as motivation (Aditomo & Klieme, 2020; Furtak et al., 2012; Potvin & Hasni, 2014). As described in Sect. 3, sentences we coded as *practices* typically describe students *doing* science, i.e. using scientific practices like making observations, analysing data, or presenting findings. Sentences that included reflections on *why* science is done in those ways tended to be coded as *knowledge* or *methods*. The dominance of the *practices* category suggests, therefore, that the new curriculum largely does not require students to engage with NOS explicitly. This is similar to Summers et al.'s (2019) findings from analysing several US science standards. The formulations we coded as *practices* do not preclude explicit reflections on NOS, but we would argue that it is possible to reach the competence aims without it. Consequently, it is up to the teachers to decide both *whether* and *how* to add a layer of NOS reflection to the students' doing of science. According to Lederman and Lederman (2014), when NOS is implicitly embedded within the focus of scientific practices—i.e. that the metacognitive perspective related to *why* these practices are used and what they lead to are not explicitly expressed—instructions will focus on students *doing* the practices. Accordingly, the high proportion of non-explicit NOS in the biology, chemistry, and physics curriculum places great demands on the Norwegian teachers, as they by themselves need to facilitate the epistemic reflections for students to develop conceptions of NOS related to scientific practices. In a meta-study of learning outcomes in inquiry-based science teaching, Furtak et al. (2012) found that students learned the most in activities that focused on the epistemic domain of inquiry, or on the epistemic, procedural, and social domains combined, and when supported by an active teacher. Whether or not the new Norwegian curriculum will promote students' learning of NOS is, therefore, highly dependent on the teachers, their competence, attitudes, and support. Bearing in mind the empirical research stating that teachers' understanding of NOS typically is not adequate, and that teachers do not consider NOS learning outcomes equally important as subject related outcomes (Lederman & Lederman, 2014), one can question how well students will learn these NOS aspects. Possibly, the metacognitive reflections could be addressed by textbooks or learning resources. However, a recurring finding from several studies analysing science textbooks from different countries is that the representation of NOS, when present, often is naïve and implicit (e.g. Abd-El-Khalick et al., 2017; BouJaoude et al., 2017; McDonald, 2017; Park et al., 2019). This also seems to be the case for Norwegian science textbooks tasks, both before and after the curriculum reform (Andersson-Bakken et al., 2020; Bakken & Andersson-Bakken, 2021).

4.2 Uneven Representation of Science and Society Interactions

In all three curricula, NOS aspects connected to the social-institutional system were more rarely identified. Specifically, the aspects *professional activities*, *social certification and dissemination*, *financial systems*, and *political power structures* were not identified in any of the curricula, and *social organisations and interactions* was only identified once in the physics curriculum. This is consistent with studies analysing science curricula in other parts of the world (Caramaschi et al., 2022; Cheung, 2020; Erduran & Dagher, 2014b; Kaya & Erduran, 2016; Yeh et al., 2019). However, *social values* was identified several times in each curriculum and was the second most used code in both the chemistry and biology analysis, which is strikingly different from results in the international studies mentioned above. However, the results are concurrent with the analysis of the new Norwegian science curriculum (Mork et al., 2022). With 18 occurrences in total, the aspect was by far most prominent in the biology curriculum. Our data do not allow us to answer why the Norwegian biology curriculum is so different in this regard, but it is an interesting finding that the FRA framework enabled us to observe. A possible contributing factor to the overall high occurrence of *social values* is the introduction of the interdisciplinary topics *health and life skills*, *democracy and citizenship*, and *sustainability*, which almost by definition involve interactions between science and society. In this respect, the finding is promising for promoting students' informed citizenship (Evagorou & Dillon, 2020).

Nevertheless, apart from *social values* and a few occurrences of *scientific ethos*, the other aspects related to the social-institutional system were more or less absent. A question to be raised is, therefore, what consequences do the absence of these other aspects have for the students, as citizens and as possible university students in science? As mentioned in Sect. 1, the goal of the Norwegian education as a whole is that students should be able to master their lives and participate in the society (Ministry of Education and Research, 2016). People need to engage with science-related information all the time (Sadler & Zeidler, 2009), also in situations where political power structures or financial elements are important aspects to consider. How does innovations in sustainable energy production depend on state funding? Should pharmaceutical companies waive vaccine patents during a pandemic? Such connections between science and society are not explicitly addressed by the curricula we have analysed, possibly limiting students' acknowledgement of these aspects and how they may influence their lives. We are not arguing that all FRA categories should be given equal weight in curricula or in classrooms. For example, *social values* (descriptions of how science contributes to society and of the need for responsible interactions between science, society, and nature) could be viewed as more important than *professional activities* (knowledge about professional settings that scientists engage in, such as conferences) for democracy and citizenship, while the latter would have particular relevance for aspiring scientists. However, we believe it is important to point out the total absence of some aspects, to inform the discussion about how NOS can be taught in Norwegian biology, chemistry, and physics classrooms based on the new curricula.

4.3 Demands on Teachers to Implement the Whole Curriculum

Another interesting finding is the quite distinct differences between where in the curriculum the various NOS aspects occur. Specifically, for all three subjects, the parts *Relevance and central values* and *Interdisciplinary topics* have a significantly higher proportion of coded units than other parts of the curriculum. In addition, some of the NOS aspects have a relatively low occurrence, or are not present at all, in the part *Competence aims*, which is the part that explicitly states what competence students should hold after completing the subject. For example, the aspect *aims and values* was typically found in the *Relevance and central values* part, while *social values* often was identified in *Interdisciplinary topics*. Furthermore, only a few of the NOS aspects occurred in *Assessment*, another curriculum part that teachers most likely will emphasise. As mentioned in Sect. 1.4, the Norwegian Directorate for Education and Training (2020) emphasises that the new curriculum is supposed to be understood as an integrated whole. This means that the competence aims in the biology, chemistry, and physics curriculum are supposed to be understood and implemented in light of the other main parts of the curriculum. However, if official guidelines for how to use the curriculum are not employed (Rødnes & deLange, 2012) and teachers approach the new curriculum in the same way as the previous one, several of the NOS aspects, although present in the curriculum, may be lost from the classrooms. Therefore, there is a need for further research into how the new curriculum is actually implemented and what the students' learning gains are in terms of NOS.

5 Conclusion and Implications

The present study gives a picture of how different aspects of NOS, as conceptualised by the *Family Resemblance Approach*, appear in the new national curriculum for biology, chemistry, and physics in Norway. From our analysis, it can be concluded that aspects related to the cognitive-epistemic system dominate. Specifically, all three curricula emphasise engaging students in scientific practices, like planning experiments and making observations. However, explicit reflections connected to *why* these practices are used in science and what characterises knowledge developed in such ways are less prominent. This indicates that Norwegian teachers are left with the great responsibility of facilitating epistemic reflections related to NOS, without being obligated to by the curriculum. Future revisions should consider addressing this, for example by including reflective prompts also regarding scientific practices. In the meantime, learning resources and textbooks should support teachers in implementing science practices in ways that make NOS explicit. Moreover, teachers should receive support in using the other parts of the curriculum to interpret and concretise the few and broadly formulated competence aims, to avoid that NOS aspects that are underrepresented in those competence aims are also underrepresented in student learning.

Even though aspects related to the social-institutional system was less prominent in the three curricula analysed, and several of the FRA categories were lacking, *social values* was identified surprisingly often, especially in the biology curriculum. The introduction of the interdisciplinary topics *health and life skills*, *democracy and citizenship*, and *sustainability* in the new curriculum reform is suggested as an explanation. This curricular emphasis of interactions between science and society seems promising for preparing Norwegian students for informed participation in work life and society. However, this requires that the new national curriculum will be implemented as intended—i.e. with all curriculum parts integrated as a whole. Otherwise, the uneven distribution of NOS on parts of the curriculum suggests that several NOS aspects might be lost from the Norwegian classrooms. In the greater landscape of international curriculum studies of NOS, our findings follow the trend of cognitive-epistemic aspects dominating, but they also identified a stronger presence of *social values* than seen before, connected to sustainability and citizenship in ways that are promising for science education. It remains to be seen how this intended curriculum is enacted and attained in Norwegian classrooms. If it succeeds in better enabling students to use their science-and-society competence to address sustainability and other pressing issues, it could be an example to follow for curricula internationally.

Funding Open access funding provided by University of Oslo (incl Oslo University Hospital)

Conflict of Interest The authors declare that they have no conflict of interest.

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