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Humanising the nature of science: an analysis of the science curriculum in Norway

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ABSTRACT

If students are to acquire deep learning in science, they need to know about the nature of science (NOS), particularly not only the cognitive-epistemic but also the social-institutional aspects of NOS. In this paper, we investigate the content of the Norwegian science curriculum in order to establish how NOS is represented, in particular to the social-institutional aspects of NOS, which have been reported to be underemphasised in science curricula from different parts of the world. We use the Family Resemblance Approach (FRA) to NOS as the theoretical and analytical framework to investigate the science curriculum from Norway where there is a history of emphasising the values human dignity, identity and cultural diversity as well as respect for nature and environmental awareness. The findings show that the dominating aspects of NOS in the science curriculum are scientific practices and social values. The observation about the prominence of social values of science is in sharp contrast to comparable analyses, suggesting a particular orientation to NOS that considers the human element in the Norwegian science curriculum. Implications for science curriculum reform and future studies are discussed.

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Nature of science; social values; curriculum analysis

Introduction

Many science curriculum standards around the world advocate the teaching and learning of the nature of science (e.g. Ministry of Education, 2006; National Research Council, 2013). The term ‘Nature of Science’ (NOS) has been defined in numerous ways (e.g. Allchin, 2012; Lederman et al., 1992; Matthews, 2012) over the years and it refers to the epistemological, ontological and sociological aspects of science (Clough & Olson, 2008). Lederman (1992) refers to the NOS as the values and assumptions fundamental to science and its knowledge development, which include the tentativeness of scientific knowledge as well as the cultural and social embeddedness of science. McComas (2004) refers to the definition and scope of NOS as the ‘rules of the game’ (p. 25) which have led to the knowledge production and the evaluation of truth claims in the

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natural world. A vast amount of research on NOS has now focused on various issues including scientists' views (Schwartz & Lederman, 2008), teachers' conceptions (Abd-El-Khalick & Lederman, 2000) and assessment of students' learning (Akerson et al., 2019; Lederman et al., 2002).

A relatively new perspective on NOS is the Family Resemblance Approach (FRA) (Erduran & Dagher, 2014; Irzik & Nola, 2014) and some contributions of the FRA in science education have been reviewed (Erduran et al., 2019). FRA has been applied to teacher education (Kaya et al., 2019), undergraduate education (Akgun & Kaya, 2020; Cilekrenkli & Kaya, 2022; Mohan & Kelly, 2020; Petersen et al., 2020), curriculum analysis (Caramaschi et al., 2022; Cheung, 2020; Kaya & Erduran, 2016; Yeh et al., 2019), textbook analysis (McDonald, 2017; Park et al., 2020; Reinisch & Fricke, 2022), STEM education (Couso & Simmaro, 2020), and analysing student, teacher and scientists view of NOS (Peters-Burton et al., 2022). FRA considers NOS as a cognitive-epistemic and social-institutional system. As such, it is an approach that is inclusive of some broad categories of different aspects of NOS.

In this paper, we investigate how NOS is represented in the context of recent science curriculum reform in Norway where all national curricula for compulsory school (years 1–10) and upper secondary were renewed in 2020–2022. The main aim of this reform is that all subjects should better prepare students for a changing world through increased emphasis on features like deeper learning and critical thinking (Ministry of Education and Research, 2016). These changes are also in line with descriptions of twenty-first century skills in international documents (Kennedy & Sundberg, 2020; National Research Council, 2012; OECD, 2018). A central feature of the renewed curriculum is the implementation of core elements in each subject (Norwegian Directorate for Education and Training, 2020). Although the context of our investigation is Norway, the paper has implications for how NOS can be situated within science curricula more broadly. Furthermore, the study's empirical analysis of the Norwegian curricula will highlight a methodological approach that can be utilised by researchers internationally to specify curriculum content including where further emphases might be needed in order to include any potential under-represented aspects of NOS.

Literature review

Nature of science from FRA perspective

Irzik and Nola (2014) applied 'family resemblance', based on an idea discussed by Wittgenstein, to the characterisation of NOS. The starting point for this perspective on NOS is the need to justify why a domain is considered 'science', and indeed why different fields such as chemistry, biology and physics can all be considered 'science'. The analogy of a family is used to illustrate that like a biological family, some members of the family of sciences will resemble each other (i.e. domain-generality) but also will also differ (i.e. domain-specificity). In Yeah et al's. (2019, p. 293) words: '*although observation is common to all science disciplines, the precise nature of observation and what counts as evidence may be fairly unique in different fields of inquiry*'. Many problems in fields such as astronomy and geology use historical evidence that may not lend themselves to manipulation of variables in the way that evidence can be controlled in some experimental

sciences such as physics and chemistry. Furthermore, philosophers of science Irzik and Nola (2014), as well as science education researchers Erduran and Dagher (2014) consider NOS from FRA perspective to be inclusive of the cognitive-epistemic and social-institutional aspects of science.

FRA provides a holistic view of the scientific enterprise, ranging from its aims and values to practices and knowledge as well as the social context. FRA considers science as a cognitive-epistemic system encompassing processes of inquiry, aims and values, methods and methodological rules, and scientific knowledge, while science as a social-institutional system encompasses professional activities, scientific ethos, social certification and dissemination of scientific knowledge, and social values (Erduran & Dagher, 2014).

Erduran and Dagher (2014) argued that FRA provides a comprehensive representation of different aspects that characterise how science works. Such representation can help teachers and teacher educators becoming aware of missing components of NOS in science education and support decisions on which aspects to prioritise when and for what purpose. Moreover, introducing a set of social-institutional aspects into the cognitive-epistemic aspects of science has the potential to engage a wider range of learners, including those who do not favour the cognitive aspects that dominate school science (Yeh et al., 2019). According to Yeh et al. (2019), the holistic approach is a core value for teaching and learning NOS from an FRA perspective.

The original depictions of FRA in science education literature focused on philosophical considerations (Irizik & Nola, 2014) as well as conceptual implications for science education research, policy and practice (Erduran & Dagher, 2014). More recently, Inêz et al. (2021) proposed a model that can serve as a pedagogical tool for teaching about NOS in the context of biological education. These authors synthesised the FRA framework proposed by Erduran and Dagher (2014) with a conceptual framework of biology proposed by Scheiner and Samuel (2010). Inêz et al. (2021) argued that the FRA account of NOS can provide a useful framework that can be combined with the main theories of a field and how they are interrelated. Mohan and Kelly (2020) argued that NOS education at the post-secondary level should switch in analytic focus from the individual engaging with science to an individual engaging in scientific research within a scientific community. In shifting the focus from the individual to the research community, the authors suggested the consideration of FRA as a model since it acknowledges participation in an epistemic community given the interplay of the cognitive-epistemic and social-institutional dimensions of FRA (Mohan & Kelly, 2020).

Further studies have shifted towards empirical investigations on analysis of assessments (Cheung, 2020) and textbooks (BouJaoude et al., 2017) as well as teachers' engagement with NOS from an FRA perspective (e.g. Erduran et al., 2021). Some research has focused on particular FRA categories such as scientific methods (Wei et al., 2021) and social-institutional aspects (Akbayrak & Kaya, 2020). Some researchers have capitalised on the FRA perspective to investigate the content of curricula, a theme that is relevant to the objectives of this paper and it will thus be reviewed in more detail in the next section.

Curriculum studies on NOS from the FRA perspective

Science curriculum documents from different countries have been analyzed using the FRA framework. Kaya and Erduran (2016) investigated Turkish curricula in comparison to the US and Irish curriculum statements and concluded that there was a strong emphasis on the cognitive-epistemic categories such as aims and values, knowledge, practices, and methods. These researchers also showed that the social-institutional aspects such as professional activities, financial systems and political power structures were under-represented in all of the documents investigated. With respect to the 'social organizations and interactions' category, only the Turkish curriculum included a statement such as '*Students investigate and present the studies conducted by public/private institutions and civil society organizations that contribute to the development of chemical industry in our country*' (Kaya & Erduran, 2016, p. 34). Related to the 'scientific ethos' category, the following statement '*Conduct research relevant to a scientific issue, evaluate different sources of information, understanding that a source may lack detail or show bias*' (p. 17) was an example of 'scientific ethos' and was present only in the Irish curriculum, while the US (NGSS) and Turkish curriculum statements did not include any instances of this category (Kaya & Erduran, 2016).

Yeh et al. (2019) analyzed the recent science curricula in Taiwan using the FRA framework as an analytical lens. The two categories most frequently considered among the benchmarks in the Taiwanese curricula were methods and scientific practices. Such findings were consistent with an emphasis on inquiry skills as a key focus of the Taiwanese science curriculum. When two versions of the recent Taiwanese science curricula were compared, the most frequent combination in the benchmarks (methods and scientific practices) across the two versions reflected an emphasis on inquiry-based science teaching (Yeh et al., 2019).

As for the new benchmarks (National Academy for Educational Research, 2016) in the Taiwanese curriculum, the combination of methods and scientific practices was consistently introduced throughout each grade level in a progressive scheme (Yeh et al., 2019). In Yeh et al.'s (2019) study, a total of 36 of the 37 coded parts of the curriculum documents (97.30%) from the old benchmarks fell within the cognitive-epistemic system category, in contrast to the 22 out of 27 codes (81.48%) from the new benchmarks. Some of the focus on NOS features shifted to aspects about the social-institutional system.

Cheung (2020) investigated science curriculum and assessment content for NOS using the FRA and epistemic network analysis (ENA) as analytical frameworks. When the empirical data were subjected to ENA, the intra-connections among FRA categories in the social-institutional system and the interconnections between categories in the cognitive-epistemic system and the social-institutional system in curriculum and assessments could be visualised using networks. The ENA method enabled for consideration of whether NOS instruction should focus on students' understandings of a list of declarative statements or coherent and reflexive understandings of the cognitive and sociological aspects of science. A key finding of Cheung's (2020) study was that NOS categories in relation to the social-institutional system are downplayed in both the Hong Kong curriculum and assessments. Sjøberg (2021) investigated NOS in the Norwegian science curriculum in light of socio-scientific issues and sustainable development and pointed to the lack of explicit attention to social aspects of NOS like collaboration, peer review and

funding. Although previous studies have revealed a downplaying of the socio-institutional system (i.e. Kaya & Erduran, 2016; Yeh et al., 2019), these studies did not reveal how weakly these categories are connected to each other. Hence, Cheung (2020) argued that the combination of ENA with FRA provided further nuance to curriculum and assessment analysis.

The various studies using the FRA as analytical framework have thus demonstrated the potential of FRA for international comparative curriculum analysis (Kaya & Erduran, 2016), investigating learning progressions across the curriculum in terms of NOS (Yeh et al., 2019) and the interconnections between curriculum statements through visualisation using concurrently epistemic network analysis (Cheung, 2020). A key finding from the set of studies reviewed is that the social-institutional aspects of NOS are under-represented in the science curriculum standards in different parts of the world studied so far. However, it is not entirely clear how the national priorities and curricular ambitions may affect such trends, particularly in countries where values of education is traditionally strong. For example, Norway has a history of emphasising the values of human dignity, identity and cultural diversity as well as respect for nature and environmental awareness, and democracy and participation (Norwegian Directorate for Education and Training, 2017). Hence, it is worthwhile to ask how NOS may be represented in the science curricula in cultures with such traditions of framing the broader science curriculum in the context of a strong set of social values. In the rest of the paper, we thus turn to an empirical study of science curricula in Norway to investigate how NOS is represented using the FRA as an analytical framework so as to be able to contrast the findings to existing literature.

Methodology

Research question

In order to investigate how the Norwegian curriculum is framing the various aspects of NOS, particularly the social-institutional aspects of NOS, we ask the following research questions: (a) *How does the Norwegian science curriculum frame NOS from the perspective of the FRA?* and (b) *What are the patterns about the social-institutional aspects of NOS in the Norwegian science curriculum?*

Curriculum context

The Norwegian curriculum is organised as a core curriculum describing values and principles for primary and secondary education and training (Norwegian Directorate for Education and Training, 2017) and curricula for subject disciplines (Norwegian Directorate for Education and Training, 2020). The core curriculum gives direction for teaching and training in the subjects, and all the subjects contribute to realising the broad purpose of primary and secondary education and training. The core curriculum emphasises the values human dignity, identity and cultural diversity, critical thinking and ethical awareness, the joy of creating, engagement and urge to explore, respect for nature and environmental awareness and democracy and participation.

Table 1. Overview of the Norwegian curriculum LK20. Texts in italics are specifications of the science curriculum.

LK20

(a) Core curriculum

Values and principles for primary and secondary education

(b) Curricula for subject disciplines– **About the subject**– **The relevance and central values**– **Core elements**○ *Scientific practices and ways of thinking*○ *Technology*○ *Energy and matter*○ *The Earth and life on Earth*○ *Body and health*– **Interdisciplinary topics**

○ Public health and mastery of life

○ Democracy and citizenship

○ Sustainable development

– **Basic skills**

○ Oral skills

○ Writing

○ Reading

○ Numeracy

○ Digital skills

Competence aims and assessment (*For science: specified after year 2, 4, 7 and 10*)

The subject curricula include an introductory text about relevance and values and texts describing core elements, interdisciplinary topics, basic skills and a list of competence aims, including short general texts about assessments, see Table 1.

The introductory text in the science curriculum emphasises that science should contribute to the pupils' sense of wonder, curiosity, inventiveness, engagement and innovation by engaging them in practical and exploratory work, and that through science pupils should gain insights into how people's way of life and actions affect life on Earth.

In Norway, science is taught as an integrated subject (Biology, Chemistry, Geology and Physics) throughout year 10. The science curriculum consists of five core elements (see Table 1), where technology (i.e. technology and engineering) is one of these. However, technology is not included in our analyses since we focus on the nature of science in this study. The core elements are supposed to point out the most important content students should learn and consists of central concepts, methods, ways of thinking, knowledge areas and expressions in each subject (Ministry of Education and Research, 2016).

The three interdisciplinary curriculum topics are based on prevailing societal challenges that demand engagement and effort by individuals and local communities, nationally and globally. The basic skills, that is, literacies, are part of the competence in the subjects and necessary tools for learning and understanding subjects.

The subject curricula establish the content and goals of each subject and are based on a definition of competence that must underpin the work with subject curricula and assessment:

Competence is the ability to acquire and apply knowledge and skills to master challenges and solve tasks in familiar and unfamiliar contexts and situations. Competence includes understanding and the ability to reflect and think critically.

The competence aims in the subjects must be considered together, both in and across the subjects and must also be understood in light of the objectives clause and the other sections of the curriculum.

Coding procedure

The texts of the science curriculum were coded by a deductive approach using the FRA-framework (Erduran & Dagher, 2014; Kaya & Erduran, 2016), see the overview of codes in Table 2.

Table 2. FRA categories (adapted from Erduran & Dagher, 2014; Yeh et al., 2019).

Aims and values	The scientific enterprise is underpinned by adherence to a set of values that guide scientific practices. These aims and values are often implicit and they may include accuracy, objectivity, consistency, scepticism, rationality, simplicity, empirical adequacy, prediction, testability, novelty, fruitfulness, commitment to logic, viability and explanatory power
Scientific practices	The scientific enterprise encompasses a wide range of cognitive, epistemic, and discursive practices. Scientific practices such as observation, classification, and experimentation utilise a variety of methods to gather observational, historical, or experimental data. Cognitive practices, such as explaining, modelling and predicting, are closely linked to discursive practices involving argumentation and reasoning
Methods and methodological rules	Scientists engage in disciplined inquiry by utilising a variety of observational, investigative and analytical methods to generate reliable evidence and construct theories, laws, and models in a given science discipline, which are guided by particular methodological rules. Scientific methods are revisionary in nature, with different methods producing different forms of evidence, leading to clearer understandings and more coherent explanations of scientific phenomena.
Scientific knowledge	Theories, laws, and models (TLM) are interrelated products of the scientific enterprise that generate and/or validate scientific knowledge and provide logical and consistent explanations to develop scientific understanding. Scientific knowledge is holistic and relational, and TLM are conceptualised as a coherent network, not as discrete and disconnected fragments of knowledge.
Professional activities	Scientists engage in a number of professional activities to enable them to communicate their research, including conference attendance and presentation, writing manuscripts for peer-reviewed journals, reviewing papers, developing grant proposals and securing funding.
Scientific ethos	Scientists are expected to abide by a set of norms both within their own work and during their interactions with colleagues and scientists from other institutions. These norms may include organised scepticism, universalism, communalism and disinterestedness, freedom and openness, intellectual honesty, respect for research subjects and respect for the environment.
Social certification and dissemination	By presenting their work at conferences and writing manuscripts for peer-reviewed journals, scientists' work is reviewed and critically evaluated by their peers. This form of social quality control aids in the validation of new scientific knowledge by the broader scientific community
Social values of science	The scientific enterprise embodies various social values including social utility, respecting the environment, freedom, decentralising power, honesty, addressing human needs and equality of intellectual authority.
Social organisations and interactions	Science is socially organised in various institutions including universities and research centres. The nature of social interactions among members of a research team working on different projects is governed by an organisational hierarchy. In a wider organisational context, the institute of science has been linked to industry and the defence force.
Political power structures	The scientific enterprise operates within a political environment that imposes its own values and interests. Science is not universal, and the outcomes of science are not always beneficial for individuals, groups, communities or cultures
Financial systems	The scientific enterprise is mediated by economic factors. Scientists require funding in order to carry out their work, and state- and national-level governing bodies provide significant levels of funding to universities and research centres. As such, these organisations have an influence on the types of scientific research funded and ultimately conducted

The four first authors did the coding and the last author, who is an expert on the FRA-framework, validated the coding. As a very first step into the coding process, the three first authors individually coded the competence aims after year 2 (see Table 1). There was full agreement on the coding of 30% of the text, and also for an additionally 40% of the text there was agreement on the coding across the three authors, but in these cases, one or two authors had also coded for one or several additional codes. Accordingly, the four first authors met and discussed their initial coding and came to a common understanding about how to interpret and apply the codes. Important decision that came out of this discussion was an agreement that the unit of analysis should be whole sentences or whole competence aims. We also decided that the coding was not mutually exclusive, so one sentence or one competence aim could be designated several codes. Then the four first authors together coded all the other curriculum texts. The authors also experienced that some content in the curriculum texts, even though not explicitly expressed, could be interpreted as NOS-related and hence they established the sub-code *implicit* for all the original codes in the FRA-framework.

The next step was to meet the last author to discuss and validate the interpretations of the codes in the FRA-framework and the coding. One important change that came out of this meeting was to approach the data semantically; hence, we would strive to focus on what the texts explicitly expressed, without interpreting what they might mean. All the *implicit*-codes were therefore dropped. Additionally, the four first authors had coded a considerable amount of content as *knowledge*. Being an expert on the FRA-framework, the last author helped the other authors refine their understanding of this code by modelling and arguing for how and why this code should only be applied to content explicitly linked to theory, laws and models. Based on these discussions the four first authors went through all the coding once more and made necessary revisions, which for instance resulted in some parts of the curriculum remained un-coded. The revised codes were once again discussed and validated with the last author. Accordingly, just a few minor revisions were necessary to finalise the coding process.

Results and findings

Coverage of NOS in the science curriculum

In this section, we start by presenting an overview of the results on how the Norwegian curriculum is framing various aspects of the NOS, before delving more into details. When we cite texts from the curriculum, we use the official translation. In order to address our research question, we have analyzed the compulsory science curriculum, years 1–10, which consists of the following text: *The relevance and central values, core elements, interdisciplinary topics, basic skills and competence aims*. Figure 1 shows the size of each text based on word count which points to the observation that the competence aims dominate the curriculum.

We have chosen not to analyze the texts of the core curriculum, as the core curriculum is an overarching part for all subjects. However, values and perspectives in the core curriculum that are particularly relevant in science are embedded in the texts of the science curriculum. Also, the texts about assessment from the science curriculum are not included in our analysis, as they are very generic.

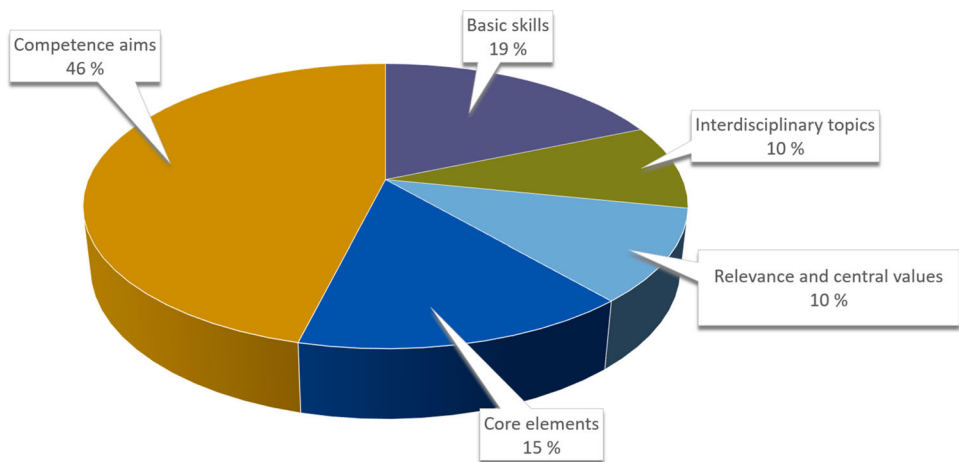


Figure 1. Word count distribution of the science curriculum texts.

Our analysis of NOS in the Norwegian science curriculum resulted in the frequency of codes presented in [Figure 2](#).

As shown in [Figure 2](#), only two FRA categories are not found in the science curriculum; *scientific ethos* and *social organizations and interactions*. As expected, the features of

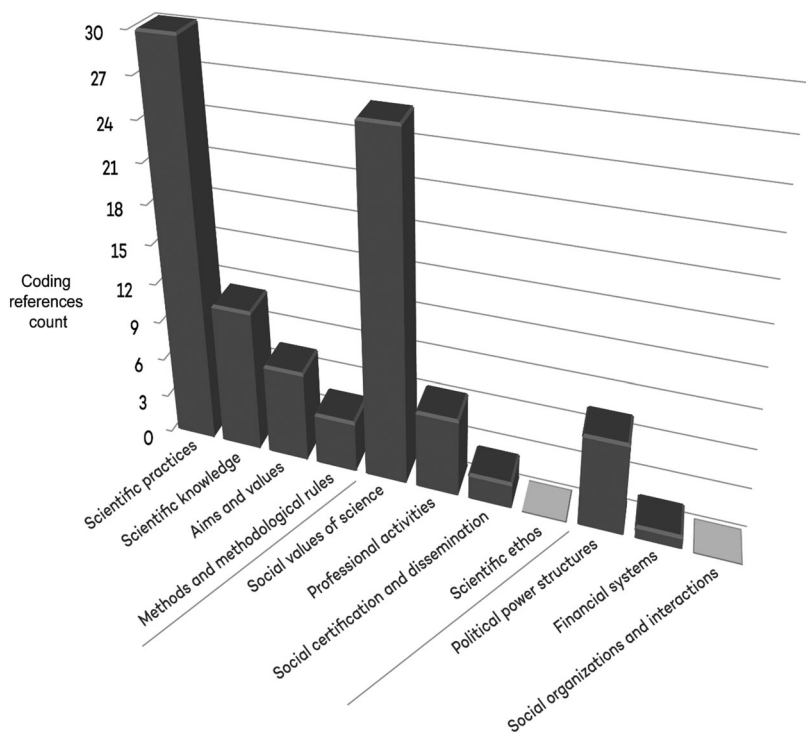


Figure 2. Frequency of all the FRA codes. The four first categories from the left are features of science as a cognitive-epistemic system, whereas the remaining categories relates to science as a social-institutional system.

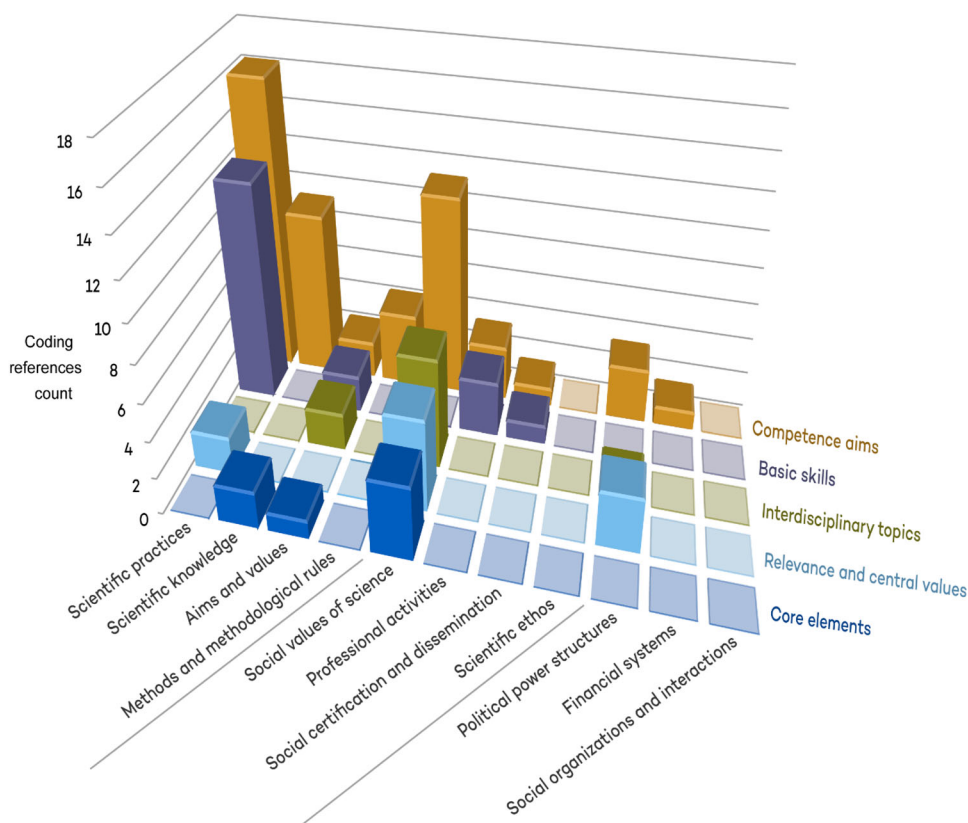


Figure 3. Overview of how aspects of NOS are represented in the various texts of the Norwegian science curriculum.

science as a cognitive-epistemic system are represented, in particular *scientific practices* which is the most frequent feature. We would also like to highlight the high frequency of references to *social values of science*.

Figure 3 shows the frequency of the different features of NOS and how they are distributed across the various texts in the science curriculum. The horizontal axis shows the codes from the FRA-framework, the vertical axis on the left-hand side shows the frequency of the code, whereas the vertical axis on the right shows the five categories of texts in the science curriculum.

FRA categories in the curriculum statements

In this section, we will detail how the various FRA categories are represented in the Norwegian science curriculum in order to provide a qualitative indication of the curriculum statements. The selected examples are illustrative of each category.

Scientific practices

The FRA category *scientific practices* is the dominating feature of NOS in the curriculum documents and most frequently found in the competence aims, but also in the texts about

basic skills, and relevance and central values. However, it is surprising that this feature is not found in the core elements since one of the core elements is actually called ‘scientific practices and ways of thinking’. The naming of this core element can be interpreted as an intention to follow international trends turning the focus from inquiry towards focusing more on scientific practices (e.g. Haug, Sørborg, Mork, & Frøyland, 2021; National Research Council, 2012; Rönnebeck et al., 2016).

In the following sections, we show examples of how *scientific practices* are expressed in the three curriculum texts. The majority of the references to this feature are found in the competence aims. We include examples of aims after years 2, 4, 7 and 10, and that represent the breadth of the FRA definition of *scientific practices*:

Explore and describe observable properties of different objects, materials and substances and sort them according to their properties. (year 2)

Query, ask questions, formulate hypothesis and explore them to find answers. (year 4)

Compare models with observations and talk about why we use models in natural science. (year 4)

Distinguish between observations and conclusions, structure data, use cause and effect arguments, draw conclusions, assess sources of error and present findings. (year 7)

Use and assess models that represent phenomena that cannot be observed directly and explain why models are used in natural science. (year 7)

Analyse and use collected data to make explanations, discuss the explanations in the light of relevant theory and assess the quality of one’s own and other’s explorations. (year 10)

Use and make models to predict or describe natural-science process and systems and explain (gjør rede for) the strengths and limitations of the models. (year 10)

The *scientific practices* that are elaborated in the texts about basic skills can be characterised as cognitive (e.g. explaining, modelling and predicting) and discursive (e.g. argumentation and reasoning) practices, for example:

Oral skills also refers to using natural-science terminology and concepts to describe, demonstrate understanding, present knowledge, develop questions, argue, explain, reflect and give grounds for one’s own attitudes and choices.

Writing in natural science refers to formulating questions and hypothesis and writing natural science explanations based on evidence and sources.

Numeracy in natural science also refers to the ability to compare, assess and argue whether calculations, results and presentations are valid or not.

In the text about relevance and central values, *scientific practices* are expressed in a more overarching and general way:

When the pupils use natural-science terminology and natural-science methods, practices and approaches for working on topics in the subject, they will acquire the foundation for understanding how natural-science knowledge is used and developed.

Natural science shall contribute to the pupils’ sense of wonder, curiosity, inventiveness, engagement and innovation by opening for them to work in the subject in a practical and exploratory manner.

The curriculum texts concerning competence aims, basic skills and relevance and central values serve various purposes and are therefore formulated differently.

Methods and methodological rules

This FRA category has four references, that all are found in the competence aims for example:

Distinguish between observations and conclusions, structure data, use cause and effect arguments, draw conclusions, assess sources of error and present findings (year 7)

Ask questions and formulate hypothesis about natural-science phenomena, identify dependent and independent variables and collect data to find answers (year 10)

Erduran and Dagher (2014) drew attention to the need for broadening student understanding of the diversity of scientific methods and expose them to the range of methodological diversity involved in the science domain. The four references neither contradict such a view, nor explicitly support it, however, this feature of NOS is scarce and not anchored in different parts of the curriculum. Especially we had expected to find references to *methods and methodological rules* in the core elements and in the basic skills.

Scientific knowledge

Even though *scientific knowledge* is the third most frequent code (11 ref.), the number of references emerges as low. This category primarily emphasises theories, laws and models that work together in generating scientific explanations that lead to knowledge growth. Thus, concept knowledge is not included within this code but grouped in a category named non-code. We elaborate on this under the heading *Broad content unrelated to NOS*. It is worth noticing that *concept knowledge*, one of our sub codes in the non-coded material, counts 24 references. Both *scientific knowledge* and *concept knowledge* occurs in the competence aims (respectively 9 and 19 ref.) and in the core elements (2 and 5 ref.). Examples of references for *scientific knowledge* are:

Compare models with observations and talk about why we use models in natural science. (year 4)

Use the particle model to explain phase transitions and the properties of solids, liquids and gases. (year 7)

The pupils shall learn to understand how we use key theories laws and models for, and concepts about, energy, matter and particles to explain our physical world. (core element: energy and matter)

Social values of science

There were 26 references to the FRA-category *social values of science*, which makes it the second most referred category, just behind *scientific practices* (30 references). References related to *social values of science* were found in four of the five curriculum texts, predominantly in the competence aims. Most of the other FRA-categories appeared in only two or three of the curriculum texts (Figure 3).

We decided to apply the sub-codes *respecting environment*, *social utility* and *freedom* as described in Erduran and Dagher (2014) to get a more detailed view of the social value category. There were 23 references to *social utility*, 17 for *respecting environment* and no references to *freedom*. The sub-codes were not mutually exclusive, and there were much overlap between the two first. A number of references were connected to sustainable choices, illustrated by the following examples that were coded as both *respecting environment* and *social utility* in the different curriculum texts:

The subject shall help to give the pupils experiences of nature and the knowhow for protecting natural resources, preserving biological diversity and contributing to sustainability. (relevance and central values)

Competence in natural science can help us to find solutions to limit the climate challenges we face, preserve biological diversity and manage the earth's natural resources in a sustainable manner. (interdisciplinary topics)

Learning about Earth as a system and how people impact this system, shall give the pupils the foundation for making sustainable decisions. (core elements)

Participate in harvesting and using natural resources and discuss how nature resources can be used in a sustainable way. (competence aims, year 4)

As illustrated by these examples we see that exploring nature and learning how to respect nature are important aspects of the Norwegian science curriculum, and science knowledge is seen as a utility to achieve this goal. This is explicitly expressed in the text about relevance and central values:

Nature has inherent value that is independent of human use and influence, and natural-science knowledge can contribute to well-reasoned management.

Additionally, the curriculum texts refer to the importance of science knowledge when making decisions related to both physical and mental health, as exemplified in the interdisciplinary topics text:

In natural science, the interdisciplinary topic of health and life skills refers to providing pupils with the competence to understand their own body and take care of their physical and mental health.

Broad content unrelated to NOS

Although our emphasis in this paper was on the coverage of NOS in the Norwegian science curriculum, we were also interested in situating such context in the broader curricular and cultural context. Hence, we have identified aspects of the broader curriculum to provide a context to our analysis. In total, 52 sentences (about one-third of the curriculum) were not assigned any code. The non-coded sentences were grouped by content into subcategories to gain a deeper understanding of the content and to discover why they couldn't be coded in the FRA framework. The subcategories are *Concept knowledge* (24), *Technology and engineering* (11), *Physical, mental, and reproductive health* (7), *Explore and experience nature* (2) and *Environment, Health and Safety (EHS)* (2). Content in Technology and engineering is not assigned any codes since this study focuses on the nature of science.

Concept knowledge is the most frequent code we have assigned curriculum text that did not fit into the FRA-categories. Text we have coded as *concept knowledge* typically concerns describing or explaining well-established scientific phenomena, for example:

Give examples of some common diseases and talk about what can be done to protect the body from infectious diseases. (year 2)

Explore and describe the water cycle and explain why water is important for life on Earth. (year 4)

Explain how the geological cycle, plate tectonics and external forces help shape and change different landscapes. (year 7)

Describe the greenhouse effect and explain factors that can cause global climate changes. (year 10)

Explain how photosynthesis and cell respiration produce energy for all living organisms through the Carbon cycle. (year 10)

The pupils shall understand how the macro and micro systems in the body work together. (core element: Body and health)

By using knowledge about energy and matter, the pupils shall understand natural phenomena and see the interconnections in the natural science subject. (core element: Energy and matter)

The subcategory *physical, mental and reproductive health* has content from both the core element texts and competence aims for all years and is therefore well integrated in the curriculum. This category concerns talking about and discussing mental, sexual, reproductive and physical health to promote a better lifestyle and actions for the student's own wellbeing, for example:

Talk about what physical and mental health is, and discuss how lifestyle and well-being influence health. (year 4)

They shall also understand how the body develops and how physical and mental health can be looked after. (core element: Body and health)

Discuss questions relating to sexual and reproductive health. (year 10)

Content in the subcategory *explore and experience nature* concerns obtaining conceptual knowledge through experiencing and exploring nature:

Experience nature during different seasons, reflect on how nature is undergoing changes, and why the year is divided in different ways in Norwegian and Sami traditions. (year 2)

Explore the senses through indoor and outdoor play and talk about how the sense are used to collect information. (year 2)

Although we did not code the curriculum statements mentioned above, they provide the broader context for how the Norwegian science curriculum envisages education. As such, they help situate the interpretation of the NOS-related content. For example, the content on the physical, mental and reproductive health elements suggests a holistic approach to education, one that is also cognizant of different cultural traditions.

Conclusions and discussion

The analysis of the Norwegian science curriculum suggests that about one-third of the curriculum text was not related to NOS as represented in the FRA-framework. Where the curriculum did focus on NOS, there is a strong emphasis on scientific practices and social values (Figure 2). The findings about the emphasis on scientific practices is not surprising, given the current landscape of science education and the international recognition of this theme, particularly since the popularisation of the Next Generation Science Standards in the USA. However, the strong emphasis on the social values category is in sharp contrast to other studies (Cheung, 2020; Kaya & Erduran, 2016) that have identified relatively lower levels of curriculum statements dedicated to the social-institutional aspects of NOS.

The majority of the content related to this aspect of NOS is included in the competence aims of the curriculum. It is noteworthy that the big proportion of the emphasis on social values category was also included in the 'Competence Aims' of the curriculum rather than the generic and broad sections such as 'Relevance and Central Values'. It is likely that given the prominence of the emphasis on competence aims these curriculum standards are more likely to be included in the implemented curriculum. Observations about the emphasis on the social values of NOS can be understood when the broader content of the curriculum is considered where there is a strong commitment to themes that are traditionally absent in many science curricula from around the world. In particular, the content on mental and reproductive health and sustainable development does not seem to be only passing rhetoric in the curriculum but rather a real focus for student development and learning. The consequence of the prominence of social values of science suggests a particular orientation to NOS in the Norwegian science curriculum that takes the human element of science seriously.

The paper contributes to the relatively recent literature on NOS from the FRA perspective (Erduran et al., 2019) by highlighting how the various aspects of NOS are represented in the science curriculum that has traditionally placed a strong commitment to social justice and participation. Although the implications for the study may thus be limited given the particular cultural context in which the curriculum was designed, it is conceivable that the development of science curricula in other parts of the world may draw insights from the particular context discussed in the paper to ensure that students are provided with holistic education as part of their education and that this may include reference to the social values embedded in NOS content of the science curriculum.

The study is timely given the recent science curriculum reform in Norway where all national curricula for compulsory school and upper secondary were renewed in 2020–2022. The main aim of such reform is that all subjects should better prepare students for a changing world through increased emphasis on features like deeper learning and critical thinking (Ministry of Education and Research, 2016). These changes are also in line with descriptions of twenty-first century skills in international documents (Kennedy & Sundberg, 2020; National Research Council, 2012; OECD, 2018) which are currently influencing other curricular jurisdictions in the world (e.g. Johnson et al., 2020).

The paper has implications for curriculum reform internationally. Given previous comparable studies on NOS curriculum analyses using the FRA framework indicated a

relatively low or inexistent level of coverage of the social-institutional aspects of NOS, the statements from the Norwegian science curriculum focusing on the social aspects can potentially be of practical use for policy makers in other parts of the world. Indeed, the broader context of the Norwegian curriculum itself can provide some potentially useful suggestions for how science curricula in other parts of the world can be revised and improved. For instance, the focus on different cultural traditions and respect for the environment may be relevant themes to draw lessons from.

However, we should note that we also acknowledge the limitations of the Norwegian curriculum as well. For instance, some of the other FRA categories belonging to the social-institutional aspects are still fairly under-represented in the curriculum. Furthermore, a particular shortcoming of our analysis is that we did not investigate how the different FRA categories may have been related to each other across the various sections of the curriculum. Future studies can potentially focus on epistemic network analysis to identify connections between the FRA categories in a manner that has already been demonstrated by other researchers (Cheung, 2020).

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