Shifting Away from Global Trends? Examining the Representation of Nature of Science in the Flemish Curriculum in an International Policy Context

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Abstract

International educational initiatives increasingly emphasize the inclusion of nature of science (NoS) in the science curriculum to develop essential scientific competencies, but it remains unclear whether national curricula have followed suit. This study compared Flanders' 1997 and 2023 science curricula to explore the shifts in the inclusion of NoS elements. Using the Family Resemblance Approach (FRA) as an analytical tool, the study examined how NoS is represented across two key dimensions: the cognitive-epistemic and social-institutional systems of science. Findings reveal a decline in explicit NoS educational goals, particularly within the social-institutional system, where most categories received little or no attention in the 2023 curriculum. Such a shift moves the curriculum further away from international science education ambitions and raises concerns about its ability to foster essential science competencies for students. To address these gaps, the study proposes modifications aimed at achieving a more holistic integration of NoS in the Flemish science curriculum. This study offers insights into the misalignment between localized education policy and evolving international standards like PISA 2025, contributing to the wider conversation on curriculum reform.

1. Introduction

Science education plays a crucial role in equipping students with the knowledge and skills necessary to navigate an increasingly complex world (Erduran & Dagher, 2014; Kilag et al., 2023). One of the most widely recognized benchmarks for assessing science education globally is the Program for International Student Assessment (PISA), which evaluates 15-year-olds' competencies in science, mathematics, and reading (OECD, 2025). In Flanders, Belgium, for secondary education, PISA results serve as an essential indicator of educational effectiveness and inform policy decisions as no standardized assessments exist for science education (Flemish Parlement, 2023; Van de Looverbosch, 2024). These international assessments are cited as one of the six drivers of the 2023 curriculum reform in Flanders (European Commission, 2023). However, recent Flemish PISA results suggest cause for concern, as scientific literacy scores for 15-year-olds have dropped significantly by 19 points over the past decade, from 518 in 2012 to 499 in 2022 (OECD, 2013, 2023a). During the same period, the share of top-performing students decreased by 3.7%, while the proportion of low-performing students (i.e. those lacking the basic skills to handle everyday problems and participate fully in society) increased by 9.3%, affecting about a quarter of Flemish students in 2022. Together, these trends indicate a substantial decline in overall scientific literacy and position Flanders among the countries with the largest declines, highlighting a critical need for reevaluation and improvement of current educational strategies.

One key aspect of strengthening science education lies in fostering a holistic understanding of Nature of Science (NoS). According to Erduran and Dagher (2014), NoS encompasses epistemic, cognitive, and social dimensions of science. In other words, NoS includes understanding not only the content of science but also how scientific knowledge is constructed, evaluated, and applied within a societal context. Since 2007, PISA has progressively integrated NoS elements into its framework, distinguishing between "knowledge of science" and "knowledge about science" (OECD, 2007). Over successive assessment cycles, PISA has reinforced the importance of NoS, gradually expanding its scope and role within its tests. The upcoming PISA 2025 framework marks a shift in the way science education is conceptualized, moving away from the traditional focus on 'scientific literacy' to a broader emphasis on 'science competencies.' This transition reflects the growing recognition that science education should not only impart knowledge but also foster students' ability to critically evaluate scientific information, engage in scientific inquiry, and apply scientific reasoning in real-world contexts (OECD, 2023b). A key feature of this evolution is the increased representation of NoS elements in the *2025 Science Framework*, growing from 10 learning objectives in 2015 to 20 in 2025 (OECD, 2017, 2023b). This expansion, particularly in its emphasis on the communal and collaborative aspects of scientific practice, underscores the importance of students understanding how science operates in society (see Appendix I). The shift aligns with broader advocacy efforts in science education, which have called for a stronger emphasis on NoS to promote critical thinking and counteract growing societal polarization regarding scientific issues (Höttecke & Allchin, 2020; Manassero-Mas & Vázquez-Alonso, 2022; Weisberg et al., 2021).

Flanders in Belgium underwent a reform of secondary education, with a master plan submitted to the Flemish parliament in June 2013 (Flemish Government, 2013). Over the subsequent years, a new curriculum framework and associated educational goals were developed. The reform was gradually introduced into the formal secondary education system, and by 2023, it had been fully implemented up until Grade 12. Given PISA's ongoing expansion of NoS since 2007 and its further reinforcement in the 2025 science competencies assessment cycle, along with the Flemish government's reliance on PISA outcomes as a benchmark for educational success, a key question surfaces: *To what extent has the new Flemish science curriculum of 2023 incorporated NoS elements?* In other words, has the reformed curriculum integrated more NoS elements compared to the 1997 curriculum?

To address this question, an empirical study was conducted focusing on curriculum analysis comparing the integration of NoS elements in the governmental educational goals for science education for Grades 9 to 12 between the 1997 and 2023 curricula. We focus on these grades as they represent the final years of secondary education in Flanders (ages 15-18), aligning with international comparisons of high school curricula. For this analysis, we employ the Family Resemblance Approach (FRA) to NoS as this framework is inherently holistic in capturing different aspects of science and it can thus indicate the range of competences that need to be addressed in the science curriculum. FRA is particularly relevant as it provides a comprehensive perspective on NoS by emphasizing not only epistemic and methodological aspects but also the social dimensions of science.

The FRA framework has been applied in curriculum analyses across various countries, including Ireland, the USA, Turkey, Taiwan, South Korea, Italy, Hong Kong, and Norway (Caramaschi et al., 2022; Kaya & Erduran, 2016; Mork et al., 2022; Park et al., 2020; Yeh et al., 2019).

However, these studies have focused on the various local dynamics of curriculum reform in explicating trends in the integration of NOS in the science curriculum. As such, they provided significant insight into the overwhelming trend across the world in the underrepresentation of the social-institutional dynamics of science in the science curricula. Curriculum analyses using the FRA have thus resulted in understanding that there is a persistent trend in overemphasis on the cognitive and epistemic aspects of science, for instance as demonstrated by Yeh et al (2019). Even when there is focus on different school subjects such as chemistry, physics and biology (Kaya et al., 2024), the trends illustrate the undermining of social-institutional aspects of science. Some recent studies have highlighted a recent slight upward trajectory in some countries like China (Xie et al., 2025).

Although all these nuances about the trends in the coverage of NoS in the science curriculum using the same analytical framework of FRA have been useful, a shortcoming in the literature is the lack of understanding of the extent to which such trends cohere or not with international assessments like PISA assessments. In other words, research in this area has been nationally oriented, not drawing out any patterns in the potential alignment or lack of alignment of the national curriculum reforms in relation to international trends such as new perspectives represented in the PISA assessments.

It is worth noting that, unlike national-level analyses, education in Belgium is not organized at the federal level but is the responsibility of its three linguistic communities: the Dutch, French, and German-speaking communities. The curriculum study presented in the paper focuses on the largest of these, the Dutch-speaking community, known as Flanders. The paper aims to offer insights into the alignment between governmental science education policy and international science education recommendations and in doing so, it contributes to the broader discourse on curriculum design and offers actionable recommendations for enhancing NoS representation in science education.

2. Theoretical framework

2.1. Nature of Science in Science Education

The term *Nature of Science* (NoS) has been widely discussed in science education (e.g. Lederman & Abd-El-Khalick, 2002) and philosophy of science (e.g. Irzik & Nola, 2011), encompassing various perspectives on what science is, how it functions, and how it interacts with society. NoS education is considered essential for fostering scientific literacy, as it helps students understand not only scientific content but also the processes, epistemological underpinnings, and socio-cultural dimensions of science (Clough & Olson, 2008; NGSS, 2013; OECD, 2017). Despite a broad consensus on the importance of teaching NoS, ongoing discussions persist regarding how it should be portrayed in science education.

A historically dominant perspective in NoS education has been the *consensus view*, which identifies a set of core tenets deemed fundamental to understanding science. These tenets include, among others, the tentativeness of scientific knowledge, the role of observations and inferences, the interplay between subjectivity and objectivity, the relationship between scientific theories and laws, and the methodological plurality of scientific inquiry (e.g. Lederman et al., 2002; McComas, 2020). While this view has provided a structured and coherent framework for NoS instruction, it has been critiqued for its somewhat rigid and prescriptive nature, potentially oversimplifying the complexity of scientific practices (Allchin, 2011, 2017; Erduran & Dagher, 2014; Irzik & Nola, 2011; Matthews, 2012).

A more recent approach seeking to address these limitations is the *Family Resemblance Approach* (FRA) to NoS, which is rooted in Wittgenstein's (1953) notion of 'family resemblance'. Wittgenstein argued that certain concepts, rather than being defined by a strict set of necessary and sufficient conditions, are best understood through overlapping similarities—an idea that has been applied to the characterization of science (Irzik & Nola, 2011, 2023). Instead of viewing NoS as a fixed list of tenets, FRA presents it as a flexible and holistic framework that accounts for the epistemic, cognitive, and social dimensions of science.

The most recent version of FRA conceptualizes NoS through three interrelated pillars (Irzik & Nola, 2023):

- **Science as a cognitive-epistemic system and science as a social institution** – While these aspects are distinguishable, they are not separable. The cognitive-epistemic system includes elements such as scientific methods, explanations, and models, whereas the social-institutional system involves aspects like scientific ethics, peer review, and funding structures. The core philosophy of FRA is that these systems are inextricably linked. The inner cognitive-epistemic categories (e.g., scientific knowledge, methods) do not exist in a vacuum; they are shaped by and impact the outer social-institutional categories. For example, the Political Power Structure dictates which research topics are funded, thereby influencing the methods (e.g., randomized controlled trials vs. ethnographic studies) and knowledge generated. Conversely, new Scientific Knowledge can lead to the formation of new Social Organizations (e.g., specialized research institutes). This interconnectedness is key to understanding science as a holistic human enterprise.
- **Science categories and characteristics** – These refer to shared attributes of scientific disciplines, including their investigative strategies, reliance on empirical evidence, and theoretical frameworks.
- **Different scientific disciplines form a family resemblance** – Rather than assuming a universal structure to all sciences, FRA acknowledges that various scientific disciplines share overlapping yet distinct characteristics, much like family members resemble one another without being identical.

Drawing on Irzik and Nola's original work published in 2011, Erduran and Dagher (2014) have reconceptualized the FRA approach to NoS, introducing NoS categories and visual tools to demonstrate its practical application in science education. One outcome of this effort is the FRA wheel (Erduran & Dagher, 2014), as shown in Figure 1, which maps out interconnected categories representing the epistemic-cognitive and social-institutional dimensions of science. This model provides a nuanced and adaptable way of conceptualizing NoS, making it particularly suitable for analyzing how NoS is represented in curricula. Recent work by Irzik and Nola (2023) has further refined this FRA framework by introducing the 'reward structure' as an additional category within the social-institutional system of science, emphasizing the motivations and incentives that drive scientific research.

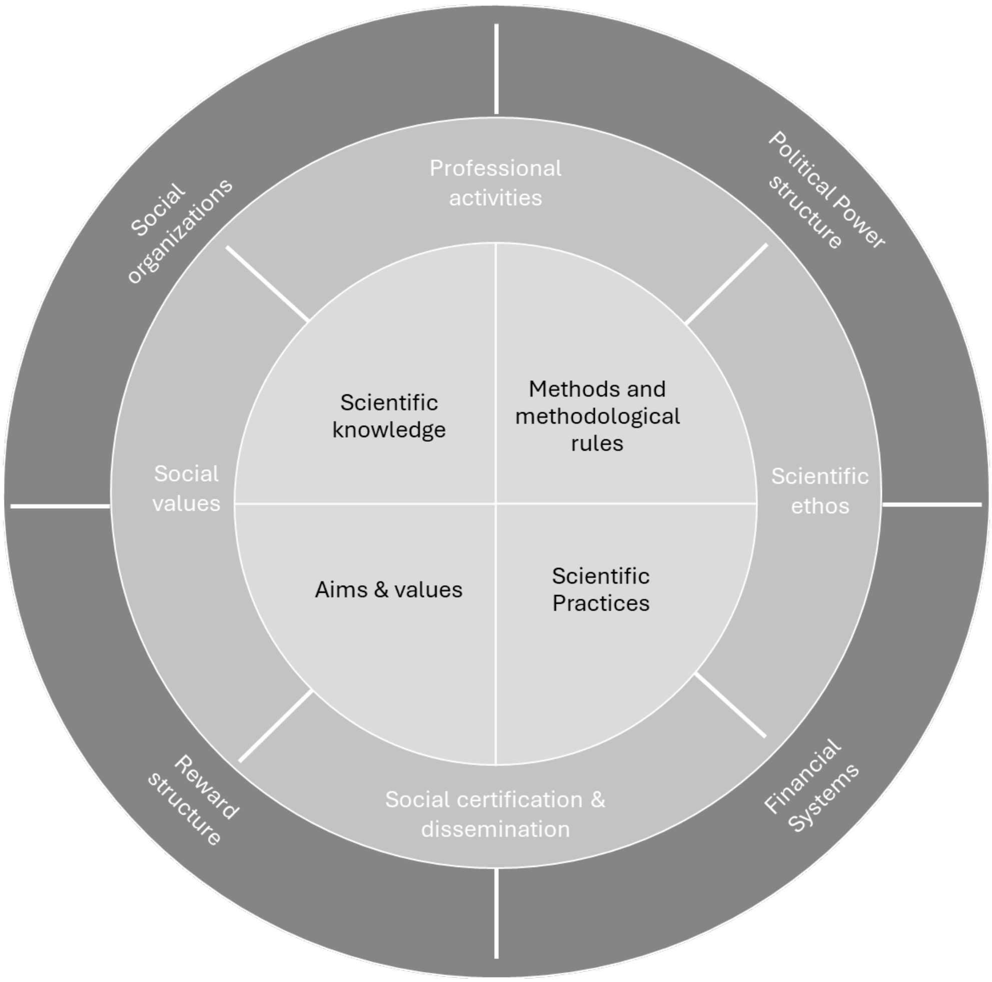

Figure 1: FRA wheel: Science disciplines as a cognitive-epistemic and social-institutional system adapted from Erduran and Dagher (2014). The inner circle represents four categories of the cognitive-epistemic system of science disciplines. The two outer rings represent eight categories of the social-institutional system of science disciplines. *Reward structure is an extra category in the social-institutional system of science disciplines proposed by Irzik and Nola (2023).

The aim of the current paper is to investigate curriculum reform across over 25 years in Flanders and hence, the most updated version of the FRA framework was used to guide the conceptualization and the empirical analysis of the science curricula. FRA offers a characterization of NoS that is holistic and wide, and as such, it matches our purpose in mapping as many changes about NoS as possible to address the key research question about the potential shifts in the curriculum over a long time. Similar arguments have been made about the application of FRA to curriculum analysis covering an extended period of time (Xie et al., 2025) as well as other issues such as the investigation of scientists' (Poor, Herman & Janney, 2025) and teachers' (Kaya & Erduran, 2024) views of NoS. This paper examines curriculum reform in Flanders over 25 years, using the latest FRA framework to guide the empirical analysis of the science curricula. FRA provides a broad characterization of NoS, making it well-suited for mapping changes over time and addressing the key research question on potential curriculum shifts. Similar applications of FRA have been used in long-term curriculum analysis (Xie et al., 2025) as well as other issues such as the investigation of scientists' (Poor et al., 2025) and teachers' (Kaya & Erduran, 2024) views of NoS.

3. Curriculum analysis

Curriculum analysis plays a crucial role in understanding how educational content is structured and how it supports teachers in delivering instruction. A well-designed curriculum can enhance teachers' content and pedagogical knowledge, while a poorly designed one can hinder effective teaching and learning (Davis & Krajcik, 2005). Furthermore, curriculum documents are essential for guiding teachers on incorporating NoS into classroom instruction (Hodson, 2014). Curriculum analysis can be conducted at different levels, examining various types of documents:

- **Macro level:** International educational standards and governmental policy documents that set broad educational goals.
- **Meso level:** School district policies and textbooks that translate standards into instructional materials.
- **Micro level:** Teacher-created lesson plans and didactic materials that shape classroom practice.

The inclusion of NoS in science curricula has been advocated for over a century, with calls for its integration dating back to the early 1900s (e.g. Central Association for Science and Mathematics Teachers, 1909; Conant, 1947; Hodson, 1988; Klopfer, 1969; Matthews, 1994; McComas & Clough, 2020). Despite this long-standing advocacy most curricula seem to have limited explicit integration of NoS elements (Kaya & Erduran, 2016; Mork et al., 2022).

The FRA has been increasingly used to analyze how NoS is represented in science curricula. Several studies have applied the FRA wheel to curriculum documents and have found that many curricula primarily emphasize cognitive-epistemic aspects of science while neglecting its social-institutional dimensions (e.g. Caramaschi et al., 2022; Cheung, 2020; Kaya et al., 2024; Park et al., 2020; Yeh et al., 2019). These findings highlight the need for a more balanced representation of NoS that reflects both the epistemic-cognitive system and the social-institutional system in which scientific knowledge is produced and applied.

3.1. Flemish secondary education and the curriculum reform

The Flemish education system is structured into three main levels: primary education, secondary education, and tertiary education. Secondary education serves students aged 12 to 18 and is divided into three two-year levels: the first level (Grades 7-8), the second level (Grades 9-10), and the third level (Grades 11-12). An optional 13th Grade is available for students seeking further specialization or specific qualifications. Secondary education in Flanders is divided into three distinct tracks: General or Academic education which prepares students for higher education, Vocational education which focuses on direct entry into the labor market, and Hybrid education, which combines elements of both, offering students the flexibility to either enter the labor market or pursue further education (Flemish Government, 2013).

Since 1997, the Flemish government has used standardized educational goals to ensure uniform learning outcomes across all schools. These educational goals define the knowledge, skills, and attitudes students are expected to develop by the end of each grade. While minor revisions were made over the years no fundamental structural changes were introduced until the comprehensive curriculum reform spanning from 2013 to 2023.

The reform of the Flemish secondary education curriculum was guided by the increasing emphasis on 21st-century skills and key competencies (Flemish Ministry of Education and Training, 2021). In contrast to the 1997 curriculum, which structured learning goals primarily around discipline-specific content, the 2023 curriculum organizes attainment targets into 16 key competencies. These competencies, roughly inspired by the recommendation on key competencies for lifelong learning by the European Parliament and Council (European Parliament and Council, 2006), emphasize interdisciplinary skills, digital literacy, and societal engagement (Flemish Ministry of Education and Training, 2021).

A major change in the 2023 curriculum is the shift from subject-specific attainment targets to a competency-based model. In the previous system, educational goals were divided into discipline-related and cross-discipline objectives. The new framework integrates these into broader competency domains, eliminating rigid distinctions between disciplines, such as Biology, History and Physical Education, encouraging interdisciplinary learning (Flemish Ministry of Education and Training, 2019).

Additionally, the 2023 reform introduced a structured, phased implementation. The Flemish Government approved the new attainment targets for the first level (Grades 7-8) of secondary education on the 13th of July in 2018, with implementation beginning in September 2019. The second level (Grades 9-10) followed in 2021, and the third level (Grades 11-12) was implemented in September 2023.

3.2. The Flemish Science Curriculum (Grades 9-12)

In 1989, Flanders gained the authority from Belgium to organize education at the community level rather than at the national level, making the Flemish science curriculum relatively new. It wasn't until 1997 that the secondary education science curriculum was established, and it initially had a discipline-specific focus, with educational goals targeting subjects like Biology, Chemistry, and Physics separately.

A significant shift began with the Flemish STEM Action Plan (2012-2020), which aimed to strengthen STEM (Science, Technology, Engineering and Mathematics) education. This initiative laid the groundwork for the extensive science curriculum reform process implemented between 2019 and 2023 (see 2.3). The reform sought to integrate STEM education into educational goals, reinforce STEM pedagogy, and emphasize interdisciplinary learning (Dep. of work and social economy, 2021).

The fully reformed curriculum of 2023 replaced the previous discipline-based structure with a competency-based approach. The 16 key competencies introduced in the new framework included five directly related to science and technology:

- Digital competencies
- Sustainability
- Physical and mental health
- Spatial awareness
- Mathematics – Science – Technology – STEM- competencies

These competencies act as a conceptual framework for building up educational goals. The Flemish educational networks under which schools are organized have the authority to expand or reformulate the educational objectives set out by the Flemish government. Teachers have to follow the curriculum elaborated by the educational network under which their school operates. Some schools teach science discipline-related educational goals in separate courses such as Biology and Chemistry, while others integrate certain subjects into broader courses such as 'Natural Sciences'. Despite these differences, all students must achieve basic STEM competencies.

To conclude, the science curriculum in Flanders has evolved from a more traditional discipline-based approach in 1997 to a competency-driven, interdisciplinary model in 2023. The continued emphasis on STEM education reflects the government's commitment to equipping students with the skills necessary for a rapidly evolving technological and scientific landscape.

3.3. PISA 2025

High-stakes assessments like the Program for International Student Assessment (PISA) significantly influence educational practices, including the emphasis teachers place on NoS in their instruction (Cheung, 2020; Jonsson & Leden, 2019; Wan & Wong, 2016). In Flanders, PISA results have been identified as a key driver for curriculum reform, citing international assessments as one of six reasons for recent changes (European Commission, 2023).

PISA's science framework has evolved notably between 2015 and 2025, particularly in its treatment of epistemic knowledge. In 2015, the framework defined epistemic knowledge as understanding the constructs and defining features of science, including:

- The nature of scientific observations, facts, hypotheses, models, and theories.
- The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce optimal solutions to human needs).
- The values of science, such as a commitment to publication, objectivity, and the elimination of bias.
- The nature of reasoning used in science, including deductive, inductive, abductive, analogical, and model-based reasoning.

Additionally, it emphasized understanding how scientific claims are supported by data and reasoning, the function of different forms of empirical inquiry, the impact of measurement error, the role of models, the importance of collaboration and critique, and the role of scientific knowledge in societal and technological issues (OECD, 2015).

By 2025, the framework expanded its focus, detailing epistemic knowledge to encompass:

- **Models:** Understanding how the natural world is represented through various models (physical, conceptual, system, and mathematical), the distinction between models and reality, how models enable predictions and explanations, and the limitations of models.
- **Data and Evidence in Scientific Claims:** Comprehending how scientific claims are supported by data, methods, reasoning, and evaluation; understanding how scientific evidence is generated; and recognizing the effect of measurement error on confidence in scientific knowledge.
- **The Nature of Scientific Reasoning:** Familiarity with different forms of empirical inquiry (e.g., experiments, fieldwork), types of reasoning (deduction, abduction, induction, probabilistic thinking), ethical dilemmas in scientific practice, and the role and limits of scientific knowledge in addressing societal and technological issues.
- **The Collaborative and Communal Nature of the Sciences:** Insight into how scientific research is funded and supported, the importance of consensus, the role of peer review, key scientific practices, the limits to certainty and confidence in scientific findings, and how scientific findings are communicated within the community and to the public (OECD, 2023b).

In total, the PISA science framework went from ten educational goals related to epistemic knowledge in 2015 to twenty in 2025. A detailed comparison of the goals related to epistemic knowledge of the 2015 and 2025 science frameworks is shown in Appendix I.

This expansion reflects the ongoing advocacy for strengthening NoS education and underscores PISA's recognition of its importance. While previous PISA science frameworks primarily aligned with NoS consensus views that emphasized the cognitive-epistemic aspects of science, the 2025 framework introduces a stronger focus on the collaborative and communal NoS. This shift resonates more closely with the FRA, which conceptualizes science disciplines as comprising both cognitive-epistemic and social-institutional dimensions. In particular, PISA's new emphasis on scientific collaboration, peer review, and consensus-building aligns with FRA categories such as social organization, social certification and dissemination, and power structures.

4. Current study

The curriculum study examines how the Flemish secondary education science curriculum integrates NoS, using the FRA as an analytical framework (Erduran & Dagher, 2014; Irzik & Nola, 2023; Kaya & Erduran, 2016). The analysis focuses on the official Flemish science curriculum documents for the second and third levels of secondary education (Grades 9–12) from both the 1997 and 2023 versions.

A directed content analysis approach is followed, counting the number of curriculum goals explicitly related to NoS in each curriculum version and, coding curriculum goals according to FRA categories, distinguishing between the categories of cognitive-epistemic and social-institutional aspects of NoS.

This study seeks to answer the following research question:

> *How does the reformed Flemish science curriculum (2023) integrate Nature of Science from the perspective of the Family Resemblance Approach? And how is it different from the old Flemish science curriculum (1997)?*
>
> *Does the reformed Flemish science curriculum (2023) align with the 2025 PISA framework Nature of Science categories? And how is it different from the old Flemish science curriculum (1997)?*

Given the growing global emphasis on NoS in science education and ongoing advocacy for its integration, we hypothesized that the 2023 curriculum would include more goals explicitly related to NoS compared to the 1997 version.

5. Methodology

5.1. Curriculum Selection

This study analyzes the Flemish secondary school science curriculum documents from 1997 and 2023 (Flemish Ministry of Education and Training, 1997, 2023). The focus is on the official educational goals set by the Flemish government for subjects classified under 'exact sciences', including: Mathematics, Computer Science, Biology, Chemistry, Earth Sciences, Physics, STEM, and Human Movement Sciences.

There are two reasons why we focus on the science curriculum of grades 9 to 12. Firstly, to align with international comparisons of high school curricula, the analysis considers the educational goals for the second and third levels of Flemish secondary education (ages 14-18). These levels correspond to Grades 9-12, which represent the age groups of high school students in, for example, the educational system of the USA. The goals for the third level (Grades 11-12) build upon those from the second level (Grades 9-10). Schools have the flexibility to decide in which specific grade a goal is targeted, as long as it is achieved before the end of the level's cycle.

Secondly, the curriculum reform aims to address challenges identified in Flemish education, which include declining student performance in international assessments such as PISA (Flemish Government, 2018). Given that PISA tests are conducted at age 15 - typically Grade 9 or 10 of Flemish secondary education - analyzing the science curriculum for those grades allows for a meaningful connection between policy intentions and international benchmarks.

The analysis focused on the entire Flemish science curriculum for secondary education students (Grades 9-12), without highlighting specific study tracks. It includes all educational goals from every track in the analysis.

5.2. Data analysis

A deductive or directed content analysis was used to analyze the curriculum documents. In directed content analysis the researcher begins by determining a coding framework, that guides the researcher's journey through the data collection and analysis. As the analysis is not data-driven or inductive, it is the coding framework that determines the categories and coding rules of the analysis (Boyatzis, 1998; Mayring, 2000).

5.2.1. Coding Framework

The coding process was guided by previous applications of FRA in curriculum analysis (Erduran & Dagher, 2014b; Kaya & Erduran, 2016; Yeh et al., 2019) with the addition of a newly proposed category, 'reward structure' (Irzik & Nola, 2023). Table 1 presents the full coding framework, including FRA categories, their descriptions, and the keywords used for classification.

	THEME	SHORT DESCRIPTION	KEYWORDS
COGNITIVE-EPISTEMIC SYSTEM	Aims and epistemic values	The key cognitive and epistemic objectives of science, such as accuracy, rationality and objectivity	aim, value, goal, accuracy, objectivity, rationality
	Practices of inquiry	The set of epistemic and cognitive practices that lead to scientific knowledge through social certification	observation, experimentation, data, explanation, model, argumentation, reasoning, classification, prediction
	Methods and methodological rules	The manipulative as well as non-manipulative techniques that underpin scientific investigations	method, scientific method, inquiry, process, hypothesis, research question, manipulation of variables
	Scientific knowledge	Theories, laws and explanations that underpin the outcomes of the scientific inquiry, they are conceptualised as a coherent network, not as discrete and disconnected fragments of knowledge	knowledge, scientific knowledge, evolution of knowledge, formulation of knowledge, theory, law, model
SOCIAL-INSTITUTIONAL SYSTEM	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 and reviewing papers	conference, article, presentation, writing, publishing, publication
	Scientific ethos	The norms that scientists employ in their work as well as in interaction with colleagues	scientific norms, ethics, bias, being sceptical, caution against bias
	Social certification and dissemination	The social mechanisms through which scientists review, evaluate and validate scientific knowledge for instance through peer review systems of journals.	peer-review, validate, evaluate, certification, dissemination, collaboration
	Non-epistemic social values	The social-values behind science, values include social utility, respecting the environment, freedom, decentralising power, honesty, addressing human needs and equality of intellectual authority	social values, society, beliefs, freedom, respect
	Reward structure*	The reward structure in science which rewards with intellectual satisfaction, recognition, career advancement, and material gains. The "priority rule" encourages first discoveries, driving progress but sometimes causing competition and ethical issues. Penalties for misconduct help maintain integrity and promote reliable knowledge.	rewards, rewards structure, nobel prize, science career, prizes, competition, penalties
	Social Organization	How science is arranged in institutional settings such as universities and research institutes and how it works together with industry or defence	university, research centre, institution, organization, industry
	Power structure	The internal power dynamics and the influence of external political interests of science, affecting which research is prioritized and who benefits from scientific outcomes	political power, research team, team leader, team members, researcher, gender, ethnicity, race, nationality
	Economics of science	The underlying financial dimensions of science including the funding mechanisms, 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	financial, funding, finance, economy, economical, budget, research topic decisions

Table 1: FRA framework (Adapted from Erduran & Dagher, 2014; Irzik & Nola, 2023; Mork et al., 2022; Yeh et al., 2019) . *Added as a new category following the suggestion made by Irzik and Nola (2023) their article: *Revisiting the Foundations of the Family Resemblance Approach to Nature of Science: Some New Ideas*.

5.2.2. Unit of analysis

Each educational goal was treated as a unit of analysis and coded based on its alignment with one or more FRA categories. Coding was not mutually exclusive, meaning that a single educational goal could be assigned multiple codes. For example:

Students can report research results and conclusions and confront them with other perspectives. (Curriculum 1997, 3th grade)

This educational goal could be categorized under both the cognitive-epistemic category of 'professional activities' and the social-institutional category of 'social certification and dissemination'.

5.2.3. Coding Procedure and Validation

The initial coding was conducted by the first author, who is fluent in both Dutch (native language), the language spoken in Flanders and English. The analysis was performed directly on the Flemish curriculum documents. The analysis focuses exclusively on explicit mentions of NoS-related aspects within the educational goals, using the English FRA framework (Table 1) as the analytical lens. NoS references that require implicit interpretation are not included in the coding process. This decision aligns with previous research (e.g. Mork et al., 2022), where only semantically explicit references were considered.

To ensure reliability, the coding approach followed the validation process described in Mork et al. (2022), where an FRA expert reviewed and refined the coding process. The validation phase led to two key refinements:

1. Some implicit NoS references were removed from the analysis.
2. The application of FRA categories was discussed and clarified, ensuring that specific codes were assigned to the appropriate FRA category.

In the first case, seven educational goals posed uncertainty regarding whether they explicitly referenced NoS. These goals were translated into English using DeepL and reviewed by the an FRA expert for final validation. Five of these goals were ultimately included in the analysis, while two were excluded because they were too implicit to be considered a NoS-related educational goal.

In the second case, five educational goals were re-examined to clarify the first author's queries about categorization through consultations with an expert on FRA. These goals were also translated into English using DeepL and reviewed by an FRA expert. One goal, "*Students can illustrate the relationship between natural science developments and technical applications*", was recategorized from 'Non-epistemic social values' to 'Aims and epistemic values.' Another goal, "*Students can distinguish characteristics of a technical approach from other approaches such as scientific, artistic, social, etc.*", which the first author struggled to categorize, was assigned to 'Aims and epistemic values' by the FRA expert. The coding of the remaining three goals stayed unchanged, as the FRA expert and the first author agreed on their initial categorization.

5.3. Reporting

To assess the integration of NoS in the curriculum, the total number of NoS-related educational goals was counted for both the 1997 and 2023 curricula. Additionally, the proportion of NoS-related goals relative to all educational goals was calculated. Finally, the distribution of FRA categories was compared between the two curriculum versions to evaluate shifts in emphasis on different aspects of NoS.

5.4 Comparison with PISA 2025 Framework

To evaluate the alignment of the old and reformed Flemish science curriculum with contemporary international standards, a secondary content analysis was conducted. The units of analysis were the educational goals previously identified as NoS-related in the 1997 and 2023 Flemish curriculum. These goals were systematically mapped against the four "Epistemic Knowledge" categories defined in the **PISA 2025 Science Framework**: (1) Models, (2) Data and Evidence in Scientific Claims, (3) The Nature of Scientific Reasoning, and (4) The Collaborative and Communal Nature of the Sciences.

The coding process utilized the explicit descriptions and sub-goals provided in the PISA 2025 framework as a deductive coding scheme (see Appendix I). Similar to the FRA coding procedure, categories were not mutually exclusive; a single educational goal could be linked to multiple PISA categories if it addressed different facets of epistemic knowledge[6]. For instance, the goal *"The students design a solution for a problem by integrating science, technology, or mathematics"* was linked to:

- Data and Evidence in Scientific Claims: As it relates to the nature of practices undertaken by scientists.
- The Nature of Scientific Reasoning: As it relates to multiple sources of knowledge, next to scientific knowledge.

The frequency of each PISA category was then calculated as a percentage of the total NoS-related goals to identify areas of international alignment or divergence.

6. Results and Finding

This section presents the findings of the curriculum analysis, comparing the representation of NoS elements in the 1997 and 2023 Flemish science curricula. It is important to note that each educational goal can be classified under multiple FRA categories, meaning a single goal may reflect different aspects of NoS at the same time. As a result, the total percentage of NoS categories combined may exceed 100%. The following subsections detail the distribution of NoS-related educational goals in each curriculum and compare their representation across both versions.

6.1. Curriculum 1997

The selection of science-related educational goals in the 1997 curriculum includes 563 goals related to 'exact sciences'. Of these, 95 goals (16,87%) explicitly include elements related to NoS. The focus of these educational goals lies primarily on the cognitive-epistemic system of science. From the 95 goals 30 goals (31,58%) are categorized under 'practices of inquiry', 26 (27,37%) under 'methods and methodological rules', 25 (26,32%) under 'aims & epistemic values', and 12 (12,63%) under 'scientific knowledge' (see Figure 2).

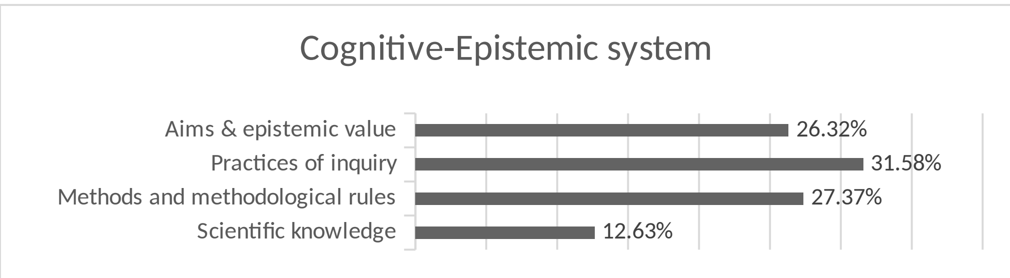

Figure 2: Relative frequency of FRA codes of the 1997 Flemish science curriculum related to the cognitive-epistemic system of science (in % of total curriculum goals related to NoS (n=95)).

Examples of educational goals that illustrate these categories include:

- Aims & epistemic values: *"The students experience the importance and necessity of proof, which is inherent to mathematics."*
- Practices of inquiry: *"Students can prepare, carry out and evaluate a research assignment with a scientific component."*
- Methods and methodological rules: *"Under guidance, students can illustrate that scientific knowledge is built up through scientific methods."*
- Scientific knowledge: *"The students indicate the coherence between different representations of the relationship between variables, including wording, tables, graphs, and formulas."*

For the social-institutional system of science, the Flemish educational goals primarily focus on the category 'non-epistemic social values', with 24 educational goals from 95 goals (25,26%). Categories with a smaller focus include 'professional activities' and 'power structure' with 11 goals (11,58%), 'economics of science' with six goals (6,32%), 'scientific ethos' with five goals (5,26%), 'social certification and dissemination' with four goals (4,21%) and 'social organization' with one goal (1,05%) (see Figure 3). Notably, no educational goals are identified under the category of 'reward structure'.

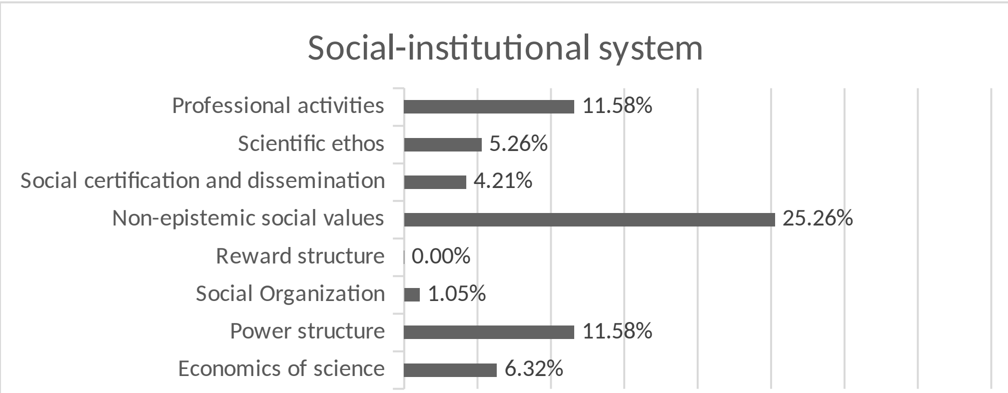

Figure 3: Relative frequency of FRA codes of the 1997 Flemish science curriculum related to the social-institutional system of science (in % of total curriculum goals related to NoS (n=95)).

Examples of educational goals within these categories include:

- Professional activities: *"Students can report research results and conclusions and confront them with other points of view."*
- Scientific ethos: *"Students can interpret natural sciences as part of cultural development and illustrate their interaction with society on an ethical level."*
- Social certification and dissemination: *"Students can express their own ideas and confront them with other people's ideas, measurements, observations, research results or scientific insights."*
- Non-epistemic social values: *"Students can, based on scientific insights, responsibly deal with safety and health in real-world situations related to substances, sound, and radiation."*
- Social organization: *"The students develop a constructively critical attitude towards technology, technical professions and companies/organizations."*
- Power structure: *"The students can explain in a simple way the impact of: political influence factors on characteristics of geographical entities."*
- Economics of Science: *"Students can interpret natural sciences as part of cultural development and illustrate their interaction with society on economic levels."*

6.2. Curriculum 2023

The selection of science-related educational goals in the 2023 curriculum includes 766 goals related to ‘exact sciences’. Of these, 42 (5,48%) explicitly include NoS elements. The focus of these educational goals lies primarily on the cognitive-epistemic system of science. From the 42 goals, 19 (45,24%) are categorized under ‘practices of inquiry’, 16 (38,10%) under ‘aims & epistemic values’, and 11 (26,19%) under ‘methods and methodological rules’ (see Figure 4). No goals could be categorized under ‘Scientific Knowledge’.

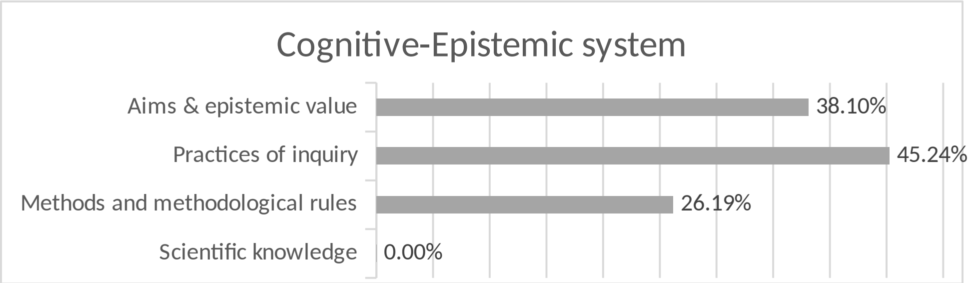

Figure 4: Relative frequency of FRA codes of the 2023 Flemish science curriculum related to the cognitive-epistemic system of science (in % of total curriculum goals related to NoS (n=42)).

Illustrative examples of educational goals include:

- Aims & epistemic values: *"Students explain the importance of randomization and representativeness in samples for making statistical inferences about a population."*
- Practices of inquiry: *"Students design a solution to a problem by integrating science, technology, or mathematics."*
- Methods and methodological rules: *"Students conduct research using a scientific method to answer questions and design solutions."*

For the social-institutional system of science, 15 (35,71%) out of 42 NoS-related educational goals fall under the category of ‘non-epistemic social values’. The only other category under which three (7,14%) educational goals could be categorized was ‘scientific ethos’ (see Figure 5). Notably, no educational goals were identified for the categories of ‘economics of science’, ‘power structure’, ‘social organization’, ‘reward structure’, 'social certification and dissemination' or ‘professional activities’.

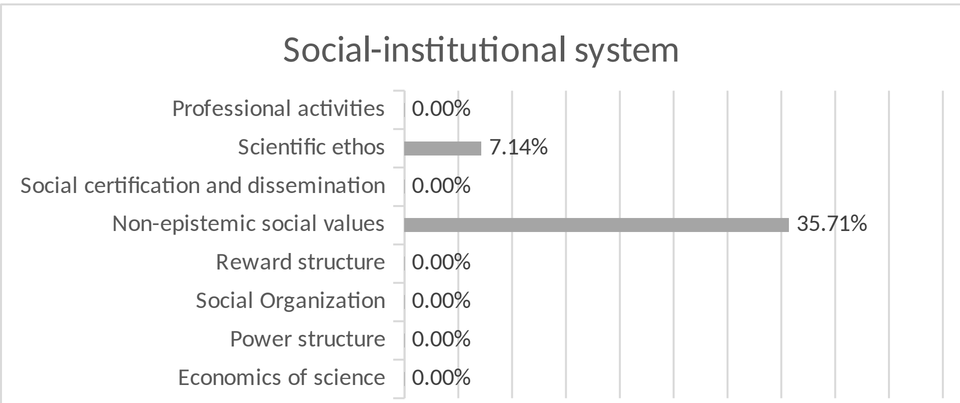

Figure 5: Relative frequency of FRA codes of the 2023 Flemish science curriculum related to the social-institutional system of science (in % of total curriculum goals related to NoS (n=42)).

Examples of educational goals within these categories include:

- Scientific ethos: *"Students respect ethical, social, and legal rules when using digital technology."*
- Non-epistemic social values: *"Students work in a safe and sustainable manner with materials, substances, organisms, and technical systems."*

6.3. Comparison of the 1997 and the 2023 curriculum

The analysis reveals a marked decrease in NoS-related educational goals. In the 1997 curriculum, 16,87% of science-related goals had a link to NoS, whereas in the 2023 curriculum, this was reduced to 5.48%. This corresponds to an absolute decrease of 11.39 percentage points. In relative terms, this equals a 67.54% reduction, meaning that in the 2023 curriculum only about one-third of the former share of NoS-related goals remains.

A comparison of NoS-related science curriculum goals shows that references to all FRA categories within the cognitive-epistemic system of science decreased with the introduction of the new curriculum (see Figure 6).

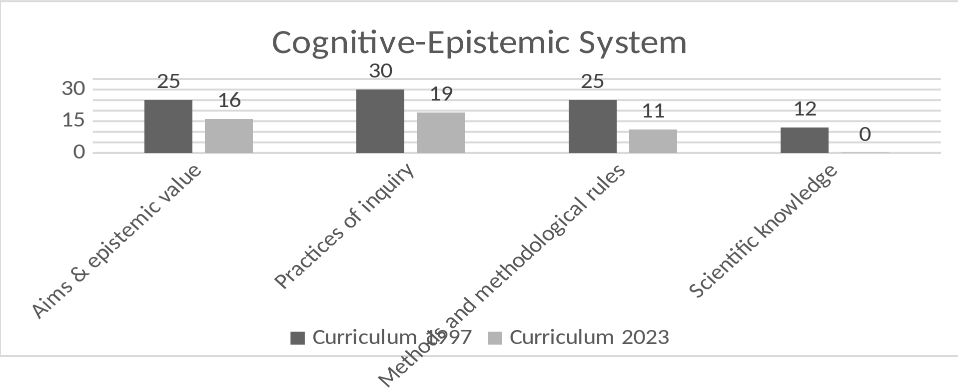

Figure 6: Frequency of FRA codes in the 1997 and the 2023 Flemish science curricula related to the cognitive-epistemic system of science.

Similarly, for the social-institutional system of science, references to all FRA categories decreased with the introduction of the new curriculum (see Figure 7). In both curricula, no educational goals were linked to the category 'reward structure'.

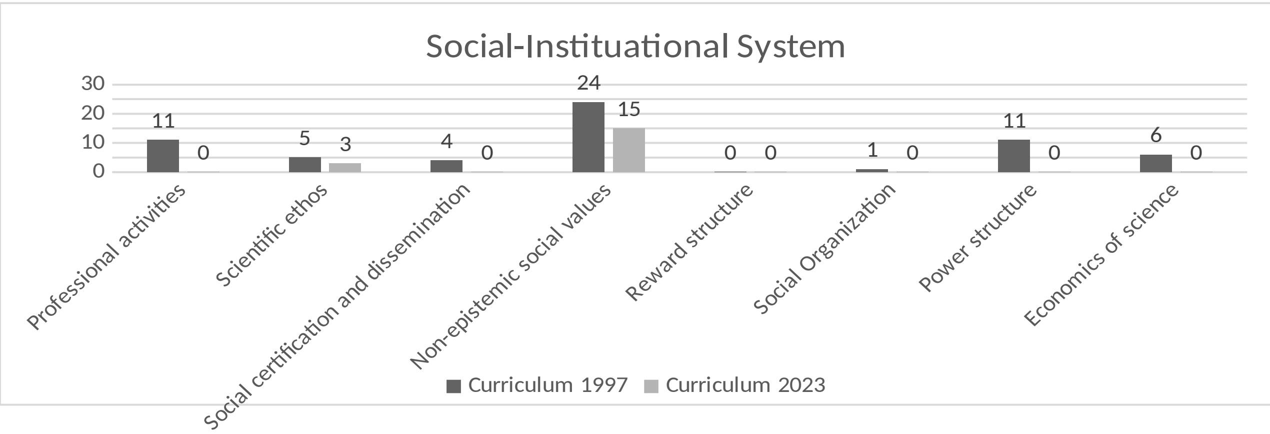

Figure 7: Frequency of FRA codes in the 1997 and the 2023 Flemish science curricula related to the social-institutional system of science.

6.4 Flemish science curriculum and the PISA 2025 Science Framework

The mapping of the 1997 curriculum goals onto the PISA 2025 science Framework reveals a distribution of educational goals focused on “Scientific Reasoning” and “Data and Evidence in Science”. However, overall, each epistemic knowledge category of the PISA framework was represented in this curriculum.

Table 2:1997 Flemish Science Curriculum vs. PISA 2025 NoS Categories

PISA 2025 NOS CATEGORY	GOALS (N=95)	% OF GOALS	EXAMPLE 1997 FLEMISH CURRICULUMM	PISA 2025 (APPENDIX I)
			students can...	students can...
DATA AND EVIDENCE IN SCIENTIFIC CLAIMS	43	45%	...express one's own ideas and confront them with the ideas of others, measurements, observations, research results or scientific insights.	... understand how scientific claims are supported by data, methods, reasoning, and evaluation.
THE NATURE OF SCIENTIFIC REASONING	55	58%	... compare scientific knowledge with other views on knowledge and illustrate the effects of science on society, and vice versa.	... understand the role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues and its limits.
MODELS	19	20%	... place a scientific model in a historical context.	...addresses how understanding of the material world is constructed using models.
COLLABORATIVE AND COMMUNAL NATURE OF SCIENCE	17	18%	... interpret natural sciences as part of cultural development and illustrate the interaction with society at ecological, ethical, technical, socio-economic and philosophical levels.	... explain how specific scientific research is decided, funded and supported.

The mapping of the 2023 curriculum reveals a more concentrated distribution, with a significant shift in priorities. While emphasis on "Data and Evidence" and "Scientific Reasoning" remains high, the "Collaborative and Communal Nature of Sciences" has been entirely omitted from the new educational goals.

Table 3:2023 Flemish Science Curriculum vs. PISA 2025 NoS Categories

PISA 2025 NOS CATEGORY	GOALS (N=42)	% OF GOALS	EXAMPLE 2023 FLEMISH CURRICULUMM	PISA 2025 (APPENDIX I)
			students can...	students can...
DATA AND EVIDENCE IN SCIENTIFIC CLAIMS	29	69%	...explain the meaning of confidence level, confidence interval, and margin of error in meaningful situations.	... understand how measurement error affects the degree of confidence in scientific knowledge.
THE NATURE OF SCIENTIFIC REASONING	27	64%	... analyze the interaction between science, technology, mathematics, and society based on societal challenges.	... understand the role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues and its limits.
MODELS	12	29%)	... explain the importance of representativeness in sampling for formulating statistical conclusions about a population.	...address how models enable predictions and explanations (e.g., statistical conclusions).
COLLABORATIVE AND COMMUNAL NATURE OF SCIENCE	0	0%	/	/.

The mapping of the 1997 and 2023 Flemish science curricula onto the PISA 2025 Science Framework reveals a significant narrowing of the curriculum's epistemic scope over time. While the 1997 curriculum demonstrated a broad, albeit uneven, distribution across all four NoS categories, the 2023 curriculum shows a more concentrated focus on data, evidence and scientific reasoning at the expense of the communal category.

Because the "Collaborative and Communal" NoS category has received increased attention in the 2025 PISA Science Framework compared to the 2015 version , these results indicate that the Flemish curriculum is shifting away from this international standard. Specifically, while the 1997 curriculum included goals related to the communal nature of science (18%), the 2023 curriculum contains no such educational goals (0%).

7. Discussion

7.1. Flemish level

The analysis of the Flemish science curriculum through the lens of the reconceptualized FRA to NoS reveals a substantial decrease in the explicit inclusion of NoS-related educational goals from 1997 to 2023. This shift raises concerns about the alignment of the new curriculum with global trends.

The study shows that while the 1997 curriculum incorporated NoS elements in 16,87% of its science-related educational goals, this number dropped to 5.48% in the 2023 curriculum. The most notable decline occurred in goals related to the social-institutional system of science, such as ‘professional activities’, ‘social certification and dissemination’, ‘power structure’, ‘social organization’ and ‘economics of science’. Following the reform in 2023, these aspects are no longer included in the Flemish science curriculum.

In both the 1997 and 2023 curricula, most educational goals were classified under the FRA categories of the cognitive-epistemic system of science. These findings align with previous research, which suggests that many curricula emphasize cognitive-epistemic aspects of science while overlooking its social-institutional dimensions in countries or regions such as Italy, Taiwan and Hongkong (Caramaschi et al., 2022; Cheung, 2020; Yeh et al., 2019).

The 1997 curriculum did, however, include educational goals for seven of the eight categories within the social-institutional system of science. The only exception was the ‘reward structure’ category, which was newly introduced in the FRA wheel in 2023. In contrast, the 2023 curriculum included educational goals for only two out of the eight categories within the social-institutional system, reflecting a significantly narrower perspective on this dimension of science. This shift is particularly concerning as it directly contradicts the revisions made to students' science competencies in the newly introduced PISA 2025 science framework. Our systematic mapping shows that while the 2023 curriculum retains a degree of alignment with PISA's technical categories—specifically 'Data and Evidence in Scientific Claims' (69%) and 'The Nature of Scientific Reasoning' (64%)—it completely fails to address 'The Collaborative and Communal Nature of the Sciences' (0%), , a category that was still represented in the curriculum goals of 1997. This total omission of the communal dimensions of science reflects a significantly narrower perspective than that advocated by the latest international standards.

The dramatic decrease in NoS elements, especially when PISA performance was explicitly cited as a major driver of the Flemish curriculum reform (European Commission, 2023), is a critical finding. This misalignment suggests a significant gap between the reform's stated goals and its outcome.

Two primary factors may explain this disconnect:

- Timing Issue: The PISA 2025 Science Framework was publicly launched in June 2023, likely after the finalization of the Flemish educational goals, which were developed between 2019 and 2023. Thus, the agencies may not have had time to fully integrate the new PISA 2025 conceptualization, which intensifies the focus on social competencies.
- Conceptual Oversight: More fundamentally, the reform appears to have overlooked or deprioritized the established NoS elements present in PISA Science Frameworks dating back to 2007. The near-total omission of social-institutional categories suggests that the agencies may have narrowly interpreted PISA's 'scientific literacy' goal as focusing primarily on scientific content knowledge, missing the essential epistemic and social dimensions.

This observed difference is highly consequential. If policymakers reference PISA to justify transformation, a curriculum that omits major components of the international framework raises serious questions about the coherence and clarity of the reform's intended educational goals.

However, it is important to recognize that PISA itself is not without its criticisms. Scholars have argued that PISA's standardized assessments may oversimplify the complexities of science education and reinforce a test-driven approach that prioritizes measurable competencies over deeper conceptual understanding (Sjøberg, 2015). Additionally, while PISA aspires to inform national curriculum reforms, its influence varies across contexts, and alignment with its framework does not necessarily equate to a well-rounded science education (Zhao, 2020). In response to these critiques, PISA developed the new 2025 Science Framework, which we reference in this study. This updated framework aims to incorporate more holistic and socially informed educational goals on epistemic knowledge, particularly those related to the collaborative and communal aspects of science (OECD, 2023b).

Naturally, critique of the new framework is still limited, as the results of the 2025 assessment will only be published in the winter of 2026. However, PISA is not alone in its effort to integrate more social dimensions into NoS education. The collaborative and communal nature of science, as highlighted by PISA, aligns closely with categories from the FRA wheel's social-institutional system, such as social certification, dissemination, and social organization (Erduran & Dagher, 2014; OECD, 2025). Regardless of the level of support for PISA, the emphasis on introducing students to the social aspects of science seems undeniably relevant.

While the 1997 curriculum reflected this vision by incorporating educational goals across nearly all social-institutional categories, the 2023 curriculum represents a stark departure from this trajectory. The finding that 0% of current goals relate to the communal nature of science is not merely a decrease, but a total removal of the social-institutional pillar as defined by international benchmarks. This regression is not only likely to affect students' ability to meet the expectations set by PISA 2025, but it also signals a broader and more troubling shift in Flemish science education. Regardless of PISA results, the significant reduction of NoS-related educational goals in the new curriculum is deeply concerning. By stripping away these foundational elements, Flemish policymakers risk undermining students' ability to critically engage with science as a socially embedded discipline.

The reduced representation of NoS elements, particularly those related to the social-institutional system, may have implications for both teaching practices and student learning outcomes. A curriculum that lacks explicit NoS references may hinder teachers' ability to effectively integrate these concepts into instruction, thereby limiting students' understanding of how scientific knowledge is constructed, validated, and communicated.

One potential reason for the reduced emphasis on NoS in the 2023 curriculum could be the shift towards a competency-based framework, which integrates scientific skills across disciplines rather than through explicit subject-specific learning objectives (Flemish Ministry of Education and Training, 2019). While this approach may offer interdisciplinary learning benefits, it risks diluting key NoS components if they are not clearly defined within the curriculum structure. Additionally, the absence of standardized assessments for NoS-related competencies in Flanders may contribute to a lower prioritization of these elements in curriculum design.

The relevance of this comparison lies in the Flemish policy context. International assessments—particularly PISA—were explicitly cited by the Flemish government as one of the six major drivers of the curriculum reform (Flemish Government, 2025), and PISA outcomes continue to be used as central indicators of educational effectiveness. In this light, the observed misalignment is noteworthy not because PISA represents a universal benchmark, but because the Flemish reform itself positions international assessments as a reference point. If policymakers use PISA as a justification for transformation, a curriculum that omits major components of the updated PISA framework raises questions about the coherence of the reform and the clarity of its intended educational goals.

To ensure that students develop a comprehensive understanding of NoS, the following four recommendations are proposed:

Recommendation 1: Explicit Inclusion of NoS Elements in the Flemish science curriculum

Future revisions should reintegrate social-institutional aspects of science, such as professional activities, social organization, and social certification and dissemination. This can be achieved through multiple approaches. First, certain goals from the previous curriculum could be reintroduced to restore important NoS elements. Second, insights from other subjects, such as the Flemish educational goals for the course 'Philosophy,' could help enrich the science curriculum. For instance, goals like *"Students reflect on knowledge using epistemological and philosophical concepts"* and "*Students examine the distinction between natural and human sciences and the unique role of philosophy*" provide valuable perspectives on NoS. However, these goals are currently only included in the human sciences track, which accounts for approximately 14% of students, limiting their broader impact on science education (Statistics Flanders 2024). Third, the Flemish science curriculum could benefit from international examples, such as the Norwegian curriculum, which places greater emphasis on the social-institutional dimensions of science (Mork et al., 2022). Finally, the PISA 2025 science framework and the reconceptualized FRA to NoS, with its twelve categories, could serve as valuable guides for developing NoS-related educational goals.

Recommendation 2: Teacher Support and Professional Development

To effectively integrate NoS into science education, teacher training programs should provide strategies that help educators identify opportunities within the existing curriculum. NoS elements could be explicitly linked to science content knowledge to ensure seamless integration into classroom teaching. For example:

- Biology: Lessons on microscope observations can prompt discussions on how scientists make observations, the role of interpretation in scientific observation, and whether observations can ever be truly objective.
- Chemistry: Teaching the atomic model provides an opportunity to explore the development of scientific models—how they evolve over time, their historical context, and the nature of models as simplifications rather than absolute truths.
- Physics: Highlighting the contributions of women in (astro)physics, such as Chien-Shiung Wu, Marie Curie, and Jocelyn Bell Burnell, can open discussions on gender recognition in science and the social dimensions of scientific discovery.

- Earth Science: When covering weather models, students can engage with questions like, "Can scientists predict the future?" Similarly, plate tectonics lessons can explore how scientific knowledge develops and changes over time.

Professional development could include workshops, peer-learning opportunities, and mentoring programs to support teachers in making these connections.

Recommendation 3: The Development of Assessment Strategies

To encourage consistent NoS integration in science education, assessment strategies must explicitly evaluate students' understanding of NoS elements. A variety of assessment methods could be employed, including:

- Formative assessments, such as classroom dialogues and reflective writing tasks, to gauge students' evolving understanding of NoS concepts.
- Project-based learning, where students engage in inquiry-based investigations that incorporate NoS elements, such as analyzing historical scientific debates or designing experiments with a focus on the limitations of scientific models.

In addition, the integration of NoS elements into a standardized science assessment could be considered. Currently, Flemish students take digital standardized tests in Dutch and Mathematics at four points during their school career. In 2024, the first secondary-level tests were conducted in Grade 8, with the same students set to take another test in Grade 12 in 2027. If NoS elements were embedded in the curriculum, they could eventually be reflected in such assessments, reinforcing their importance in science education. However, without stronger NoS integration in the curriculum itself, standardized tests will not fully capture NoS competencies, as they are aligned with government curriculum guidelines.

7.2. International level

One of the main challenges in international science education is defining its purpose. In 2006, a group of European science educators addressed this issue, emphasizing that science education across the European Union should serve all students by offering universally relevant knowledge and skills. A science curriculum should not be designed solely to train future scientists, as only a small percentage of students pursue careers in science, technology, engineering, or mathematics (Osborne & Dillon, 2008). In Flanders, for example, only 11.5% of high school graduates continue into higher education in these fields (Flemish Ministry of Education and Training, 2024; Statistics Flanders 2024).

Instead, science education should equip all students with a broad understanding of how science generates reliable knowledge, how scientific consensus is reached, and the limits of scientific certainty as emphasized in NoS education (Osborne & Dillon, 2008). For future scientists, NoS provides an essential understanding of the ethical, communal, and methodological boundaries within which they will operate. For the broader public, NoS education serves a vital civic function: it equips individuals with the tools to navigate socio-scientific issues, discern between science and pseudoscience, and understand the social certification processes that make scientific knowledge reliable (Osborne & Dillon, 2008). Therefore, we argue for NoS to be a core part of the (science) curriculum, for all.

However, this study highlights that if the integration of NoS is not explicitly prioritized in curriculum reforms, it risks being overlooked or diminished, as seen in the Flemish case. This serves as a cautionary lesson for policymakers and curriculum developers worldwide: reforms must ensure that foundational aspects of scientific competencies, such as NoS, remain central to the curriculum.

The present study contributes to the literature on curriculum analyses on NoS using the FRA framework (e.g. Caramaschi et al., 2022; Kaya et al., 2024; Xie et al., 2025; Yen et al, 2019) and presents an approach to serve as a benchmark for international comparison. Although previous analyses had provided understanding of shifts in curricula across different national reform efforts, the international dimension in comparison to a significant global assessment initiative such as PISA was missing in the literature. Although these studies provided nuanced understanding of the overemphasis on the cognitive-epistemic aspects of NoS in science curricula, it was not apparent how such trends align or not with international benchmarks such as PISA that influence countries globally.

Ultimately, if science education is to serve society as a whole and not just future professionals, then NoS must be recognized as an essential component of the curriculum. Without intentional integration at the national level with potential alignment with internationally significant policy recommendations, students risk receiving an incomplete picture of how science operates—both as a knowledge system and as a collaborative human endeavor.

8. Limitations and future research

The implications for the study may be limited given the particular local context in which the curriculum was designed. However, the inclusion of the international dimension of the PISA framework provides potential ways forward for investigating how other national contexts may or may not be aligned with significant global trends in curriculum and assessment policies. it is conceivable that the development of science curricula in other parts of the world may draw insights from this study to ensure that students are provided with holistic education as part of their education and perspective on how to ensure that there is coherence between global and local objectives of science education.

Another key limitation of this study is that the curriculum coding process was conducted by a single researcher, the first author, with validation provided by the last author in cases of uncertainty. While this approach ensures a degree of reliability, multiple coders would have enhanced the objectivity of the study and minimized potential bias in the interpretation of educational goals. This brings up concerns of the interpretation of curriculum goals as explicit or implicit. The analysis was deliberately restricted to the literal wording of the official educational goals, without considering the broader interpretive context provided in the curriculum guidelines of the school networks. There is a risk that some of the goals coded as explicit may in fact be better understood as implicit when viewed from the perspective of how teachers and curriculum developers interpret them in practice. This raises the possibility that the study overestimates the presence of NoS-related goals in the Flemish curriculum.

Although this study identifies a notable decrease in the proportion of NOS-related goals between the 1997 and 2023 Flemish science curricula, the analysis does not establish the underlying reasons for this change. While the curriculum has increased in total number of science-related goals—indicating that the decline is not attributable to a shorter or more condensed document—multiple structural or policy-related factors may still account for the reduced visibility of NOS, such as shifts in curricular design philosophy, decentralization of instructional decision-making, or the reframing of competencies under broader pedagogical priorities. Because the present study focuses on document analysis, it does not capture the decision-making processes, negotiations, or contextual influences that shaped the final curriculum. Future research involving interviews with curriculum developers, analysis of policy documents, or examination of implementation practices would provide deeper insight into the reasons behind the observed decline in NOS representation.

Further research is essential to understand how teachers interpret and implement NoS-related goals in classroom practice, as curriculum documents alone do not fully reflect instructional realities.

Comparative studies examining how different countries integrate NoS in the science curriculum could provide valuable insights into best practices. Additionally, longitudinal studies assessing the impact of reduced NoS emphasis on students' science competencies would help evaluate the long-term consequences of these curricular changes.

9. Conclusion

The analysis highlights a concerning decline in the explicit integration of NoS elements within the Flemish science curriculum, particularly in aspects related to the social-institutional system of science. While the shift towards a competency-based framework aligns with broader educational reforms, it appears to have led to a (unintended?) reduction in NoS representation. To align with international trends and support the development of scientifically competent citizens, future Flemish curriculum revisions should consider reintegrating NoS elements in a structured and explicit manner.

In the spring of 2025, Flemish 15-year-olds taking the PISA test will be the first cohort fully educated under the revised 2023 science curriculum. The results, anticipated in the winter of 2026, will offer valuable insights into the effects of these curricular changes. However, one thing is clear from this study: the new curriculum presents an even more limited and fragmented portrayal of science than its predecessor.

Appendix I

PISA SCIENCE FRAMEWORK: EPISTEMIC KNOWLEDGE

NOS CATEGORY	**2015**	**2025**
GENERAL	The constructs and defining features of science. That is:	The constructs and defining features of science. That is an understanding of:
	The nature of scientific observations, facts, hypotheses, models and theories.	The nature of scientific observations, facts, hypotheses, models and theories;
	The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce an optimal solution to human need), **and what constitutes a scientific or technological question and appropriate data.**	The purpose and goals of science (to produce reliable explanations of the natural world and to predict future events) as distinguished from technology (to produce an optimal solution to human need);
	The values of science, e.g. a commitment to publication, objectivity and the elimination of bias.	The values of science e.g. a commitment to peer-reviewed publication, objectivity and the elimination of bias.
	The role of these constructs and features in justifying the knowledge produced by science. That is:…	/
	/	More specifically, this requires an understanding of:…
DATA AND EVIDENCE IN SCIENTIFIC CLAIMS	How scientific claims are supported by data and reasoning in science.	How scientific claims are supported by data, methods, reasoning and evaluation in science;
	/	How scientific evidence is generated e.g. the nature of the practices undertaken by scientists;
	How measurement error affects the degree of confidence in scientific knowledge.	How measurement error affects the degree of confidence in scientific knowledge.

THE NATURE OF SCIENTIFIC REASONING	**The function of** different forms of empirical enquiry **and their design (observation, controlled** experiments, **correlational studies).**	Some of the different forms of empirical enquiry e.g. experiment, field work and its role, controlled experiments, pattern seeking;
	The nature of reasoning , e.g. deductive, inductive, **inference to the best explanation** (abductive), **analogical**, and **model-based** used **in science for** establishing knowledge and their goal (to test explanatory hypotheses or identify patterns)	The types of reasoning (deduction, abduction, induction, probabilistic thinking) used in establishing knowledge and their goal (to test explanatory hypotheses, or identify patterns and entities) and examples of each e.g. Newton's Laws of Motion*(deduction), Mendelian Genetics (induction), Theory of Evolution (abduction)
	The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.	The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues and its limits.
	/	The ethical dilemmas raised in scientific practice e.g. animal experimentation, conflicts of interest
MODELS	The use and role of physical, system and abstract models and their limits.	/
	/	How understanding of the material world is constructed using physical, conceptual, system and mathematical models in science; e.g., particle model of matter.
	/	The distinction between a model and reality e.g. that a model is a representation of something which may be too small to see or too large to imagine; e.g., Bohr model of the atom.
	/	How models enable predictions and explanations; e.g., Sun-Earth model of daily movements.
	/	How the limitations of models (e.g. number of variables, simple v complex models, quality of data provided) constrain their use.

THE COLLABORATIVE AND COMMUNAL NATURE OF THE SCIENCES	**The role of collaboration and critique, and** how peer review helps to establish confidence in scientific claims.	How peer review helps to establish confidence in scientific claims and is dependent on a scientific community;
	/	How specific scientific research is funded and supported e.g. government, private and the mechanisms for deciding;
	/	The importance of consensus in warranting belief;
	/	Key scientific practices undertaken by scientists to produce shared knowledge, their role and their collaborative nature;
	/	The limits to certainty and confidence in scientific findings, how it is expressed, the evolution of certainty and the role of consensus;
	/	How scientific findings are communicated within the community and to the public (e.g. pre-prints, peer reviewed journals, public communication.

Normal text – Overlapping parts between PISA Science framework 2015 and 2025.
Bold – Specific to only the PISA 2015 Science Framework
Underlined – Specific to only the PISA 2025 Science Framework

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