

Natural Sciences in the BNCC: an analysis focused on the domains of scientific knowledge

Ciências da Natureza na BNCC: uma análise com foco nos domínios do conhecimento científico

Ciencias Naturales en la BNCC: un análisis centrado en los dominios del conocimiento científico

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Abstract

Grounded in the understanding of science as a social practice, this study examines how scientific concepts are framed within the essential learning outlined in Brazil's National Common Curricular Base (BNCC) for Natural Sciences. Our analysis focuses on the characterization of these concepts and their connections to the four domains of scientific knowledge: conceptual, epistemic, social, and material. In the elementary school curriculum, we find a predominance of the conceptual domain, while the material and epistemic domains are less frequently addressed. The social domain is entirely absent, and there is a scarcity of connections between these domains. Although the high school curriculum exhibits a greater degree of articulation, the social domain remains absent. As a result, we highlight the challenges faced by students and emphasize the need for teachers to view scientific practices not merely as content but as critical activities to be undertaken in the classroom.

Keywords: basic education, science teaching as social practice, national common curriculum base

Resumo

Embasados no ensino de ciências como prática social, analisamos como conceitos científicos são propostos nas aprendizagens essenciais expressas na Base Nacional Comum Curricular (BNCC) – Ciências da Natureza, partindo da caracterização destas e de suas relações com os domínios do conhecimento científico (conceitual, epistêmico, social e material). No currículo oficial para o Ensino Fundamental, identificamos prevalência do domínio conceitual do conhecimento científico, baixa ocorrência dos domínios material e epistêmico, ausência do social e raras associações entre eles. No Ensino Médio, há maior articulação, mas o domínio social está ausente do currículo proposto. Como implicações, indicamos desafios a serem enfrentados por estudantes e a necessidade de docentes tratarem práticas científicas não apenas como conteúdo, mas também como ações críticas a serem realizadas em sala de aula.

Palavras-chave: educação básica, ensino de ciências como prática social, base nacional comum curricular

Resumen

Desde la perspectiva de la ciencia como práctica social, este estudio examina cómo se enmarcan los conceptos científicos en los aprendizajes esenciales establecidos en la Base Nacional Común Curricular (BNCC) para las Ciencias de la Naturaleza de Brasil. Nuestro análisis se centra en la caracterización de estos conceptos y sus conexiones con los cuatro dominios del conocimiento científico: conceptual, epistémico, social y material. En el currículo de la escuela primaria, encontramos un predominio del dominio conceptual, mientras que los dominios material y epistémico son abordados con menor frecuencia. El dominio social está completamente ausente, y hay una escasez de conexiones entre estos dominios. Aunque el currículo de la escuela secundaria muestra un mayor grado de articulación, el dominio social sigue estando ausente. Como resultado, destacamos los desafíos que enfrentan los estudiantes y enfatizamos la necesidad de que los docentes consideren las prácticas científicas no sólo como contenidos, sino como actividades críticas a desarrollar en el aula.

Palabras clave: educación básica, enseñanza de las ciencias como práctica social, base curricular común nacional

Introduction

In 2017, the Common National Curriculum Base (Base Nacional Comum Curricular, BNCC) containing curriculum guidelines for Early Childhood and Elementary Education was published. In 2019, an expanded version of the document, including High School guidelines, was released. Since then, numerous studies have been conducted addressing the interests behind the consolidation of the BNCC in its published form (Tarlau & Moeller, 2020); the changes in the document across its three versions, which increasingly excluded the voices of the scientific and educational communities (Franco & Munford, 2018; Rodrigues et al., 2021); the initiatives related to teacher education (Galian et al., 2021); the components of the subject-specific guidelines (Sasseron, 2018); and the implications of the BNCC for teacher training due to the impositions described in the BNC-Training framework (Rodrigues et al., 2020).

Each of these topics remains important and warrants ongoing discussion, contributing new perspectives on the conceptual foundations of the BNCC, which directly impact subject formation. Although the document outlines directions for the various disciplines comprising the school curriculum, this text focuses specifically on the investigation of knowledge related to the Natural Sciences.¹ At the elementary and High School levels, with the goal of analyzing the presence and forms in which concepts and other elements of scientific activity appear within the BNCC competency statements – Natural Sciences (Ministério da Educação, 2018). This analysis is grounded in the characterization of essential learning as articulated in the document, aiming to identify and discuss its relationship to the foundations of science teaching as a social practice.

To this end, we begin with the understanding that Natural Sciences classes—and, consequently, the content presented in official curricula for this subject—should address the “conceptual structures and cognitive processes used in scientific reasoning”² (Duschl, 2008, p. 277 – our translation). However, the concepts, in their presentation and use in the classroom, should be accompanied by epistemic structures, tools, and social processes that support the

¹ In the text, the terms natural sciences, nature sciences, or simply science are used to refer both to the field of knowledge that studies natural phenomena and the corresponding school subject. To distinguish between the two, references to the area of knowledge will use lowercase initials, while references to the school subject will use uppercase initials.

² In the original: “the conceptual structures and cognitive processes used when reasoning scientifically”

intellectual work of scientific practice (Duschl, 2008; Stroupe, 2014), so that students may appropriate scientific knowledge and understand scientific activity as a social practice.

Thus, by calling for the analysis of the occurrence of scientific concepts in the BNCC, we are referring to facts, theories, principles, explanations, and models that constitute knowledge legitimized by the sciences (Furtak et al., 2012; Soares & Trivelato, 2019) and that should be present in the classroom as objects of knowledge to be assimilated by students, so that they may construct meaning about the natural world; but also so that students understand how this knowledge is used by scientists to reason with and about it (Subramaniam, 2023; Windschitl & Barton, 2016). Additionally, when our objective extends to how scientific concepts are presented in the official curriculum, we refer to the analytical effort to characterize and understand how the BNCC guides pedagogical work toward creating opportunities for students and teachers to use these concepts in constructing classroom understanding and for teaching practices that promote conceptual articulation and systematization (Furtak et al., 2012).

Possible Relationships Between Studies on Scientific Activity and Science Teaching

Important works on science published since the 1960s (Feyerabend, 2011; Kuhn, 1996; Latour & Woolgar, 1997) paved the way for what we now call “science studies,” that is, research on the modes of scientific knowledge production, in contrast to traditional philosophy of science. Such studies explore how social, historical, and cultural contexts are embedded in scientific activity.

Although conceptions of scientific activity that are strongly tied solely to experimental procedures persist, emphasizing the importance of the laboratory as a physically equipped space essential to the success of scientific work, research emerging from the field of science studies highlights that scientific activity is not confined to the equipment available in a laboratory. Rather, investigation involves more than just the physical setting; it requires consideration of how scientists interact with one another, with established knowledge, and with the materials at their disposal (Knorr-Cetina, 1999; Latour & Woolgar, 1997; Pickering, 1995; Rheinberger, 1997).

Dilemmas, controversies, chance events, and intellectual effort are a few examples of factors that condition and influence the generation of new scientific knowledge. This supports the argument that scientific activity is not a neutral undertaking devoid of societal relationships and reinforces the understanding that such activity is conducted in a community and, therefore, is social in nature.

By recognizing scientific activity as being carried out in and by social groups, we also acknowledge that rules, norms, materials, and values condition and influence the proposition, analysis, and legitimation of knowledge, and that, because it is social, it is subject to external influences from the social and historical realities in which researchers are embedded.

Attention to scientific research—often recognized as a synonym for experimentation—directly influences science teaching, while the association between Natural Sciences classes and laboratory activities remains common. Over time, curricular and instructional changes tied to teaching and learning structures reflect conceptions of science as logic, science as conceptual change, and science as knowledge accumulation (Lehrer & Schauble, 2006; Stroupe, 2014). In the current context, criticism has emerged as an important element in science teaching and learning, concerning contemporary conceptions of scientific activity and the role it can play in fostering students' recognition of those conceptions. In this way, it may be possible to challenge conceptions of science as a provider of fixed and absolute truths by promoting the understanding that it is a field that proposes and legitimates knowledge through ongoing processes of critical evaluation (Feinstein & Waddington, 2020; Valladares, 2021).

Aspects of scientific activity, such as those previously discussed, have also been the focus of investigation by science education researchers, who are concerned with addressing both conceptual elements and the methods of scientific activity in the classroom (Carvalho, 2018; Osborne, 2016). To this end, it is necessary to recognize both the possibilities and limitations of instructional strategies that integrate content and methods. There is, in fact, a diversity of studies seeking to evaluate the role of hands-on experiments in instructional practice, aiming to characterize the experimental activities used in Natural Sciences classes in terms of their intended objectives (Borges, 2002), the opportunities afforded for student participation (Banchi & Bell, 2008; Carvalho, 2006), student involvement in structuring investigations (Monteiro & Jiménez-Aleixandre, 2016; Trivelato, 2016), and the role of discursive interaction in constructing understanding (Franco & Munford, 2020a; Sasseron & Carvalho, 2013).

The recognition that scientific research integrates conceptual, epistemic, social, and material elements has enabled the analysis of how these domains of scientific knowledge can be considered in the planning and implementation of instructional strategies for Natural Sciences classes (Duschl, 2008; Stroupe, 2014). There is currently a purposeful movement toward framing science education as a social practice (Jiménez-Aleixandre & Crujeiras, 2017; Kelly & Licona, 2018; Sasseron, 2021; Silva et al., 2022)—that is, an approach to science that enables students to experience aspects of scientific activity by engaging in practices such as investigation, argumentation, and problem modeling.

These practices do not imply a replication in the classroom of what scientists do in their laboratories, but rather the valuing of students' critical participation, taking into account their social and cultural contexts and recognizing that knowledge about scientific topics and processes is constantly evolving. Furthermore, this participation involves not only interpersonal interaction but also interactivity with materials, so that engagement extends beyond manipulation and encompasses intellectual involvement.

Accordingly, science teaching as a social practice is grounded in critical interactions that occur within the classroom and in the epistemic relationships students establish with materials, whether instruments, tools, equipment, substances, representations, or inscriptions. In this sense, science teaching as a social practice relies on incorporating all domains of scientific knowledge into classroom learning (Silva et al., 2022), offering opportunities for building understanding of scientific topics and processes and their modes of production, thereby supporting the analysis of information and real-life situations in which science emerges.

The engagement of teachers and students in critical interactions, as well as the inclusion of scientific norms and practices in the classroom, is also advocated—albeit from different theoretical perspectives—by approaches to science education that promote scientific literacy (Roberts, 2011; Santos, 2009; Sasseron & Carvalho, 2011; Silva & Sasseron, 2021; Valladares, 2021).

In line with the development of research in science education and the evolving social issues of each period, the concept of scientific literacy has changed over the years from a perspective focused on training scientists and introducing science to the general public, to the more recent idea of scientific literacy as a means for social transformation (Valladares, 2021). In the conceptions adopted in this study, scientific literacy is understood as the intention to foster

students' epistemic agency concerning science, fostering the analysis of situations and formulation of both explanations and points of view.

Within the current context—in which science and scientific knowledge have come under strong attack from groups promoting conspiracy theories and denialist movements—the formative dimension of scientific literacy has gained renewed importance by emphasizing the development of critical attitudes for inquiry and argumentation about everyday issues related to science (Silva & Sasseron, 2021; Valladares, 2022).

Ideas for Consolidating Scientific Literacy Committed to Social Transformation

We understand that teaching Natural Sciences from the perspective of scientific literacy for social transformation (Silva & Sasseron, 2021; Valladares, 2021) can be realized when conditions are created for students to perceive science as a social activity carried out by individuals who are part of an epistemic community that engages in practices governed by norms and rules through which it is possible to understand phenomena, analyze problems, and deepen knowledge about the natural world.

To this end, activities in which students engage with these elements solely in an informative manner do not seem appropriate or sufficient; it is both valid and timely for them to participate in practices similar to those carried out by members of this epistemic community, particularly those related to investigation, argumentation, and modeling (Jiménez-Aleixandre & Crujeiras, 2017). As practices of an epistemic community, these involve various types of knowledge and processes that structure, regulate, and enable the construction of understanding, the formulation and evaluation of ideas, and the validation of proposals. Accordingly, as both explicitly and implicitly suggested, these are not notions that can be condensed into written statements or passed on solely through verbal explanation. They must be lived and experienced; thus, there is the need for an approach in which science emerges in instructional settings as a specific way of leveraging understanding of phenomena and problems, whose modes of analysis are themselves constructed and therefore open to critical scrutiny.

Building on such assumptions, Duschl (2008) proposes that learning development and assessment in Natural Sciences should focus on the integrated engagement of three domains of knowledge, namely:

- The conceptual structures and cognitive processes used in scientific reasoning.
- The epistemic structures employed in the development and evaluation of knowledge; and
- The processes and social contexts that shape how knowledge is communicated, represented, argued, and debated (p. 277 – our translation, emphasis in the original)³.

In light of these considerations, studies in the field of science education have emphasized the importance of taking the domains of scientific knowledge into account when planning and analyzing activities in which students are expected to investigate problems related to the natural world (Franco & Munford, 2020b; Lino & Sasseron, 2024; Silva & Sasseron, 2021; Soares & Trivelato, 2019).

In such studies, the characterization of the domains of scientific knowledge aligns with that presented by Duschl (2008); from this characterization, and in connection with the curriculum, these domains can be understood as follows: the conceptual domain of scientific knowledge pertains to the concepts, laws, and theories addressed in Natural Sciences classes, as well as to the processes used in scientific reasoning; the epistemic domain refers to the actions, processes, and procedures carried out to support the analysis of a situation and to assess whether those actions are suitable for understanding a given phenomenon; and the social domain of scientific knowledge involves the norms and agreements collectively constructed and upheld to support scientific activity—particularly the mechanisms of assessment.

With these three domains defined and widely used in the literature, Stroupe (2014) expands upon Duschl's (2008) propositions by discussing the role that material elements play in scientific activity, and how their manipulation, development, and incorporation into practice represent markers of epistemic agency (Knorr-Cetina, 1999; Pickering, 1995). Thus, Stroupe (2014) proposes ideas that support the defining characteristics of the material domain of

³ In the original:

- the conceptual structures and cognitive processes used when reasoning scientifically,
- the epistemic frameworks used when developing and evaluating scientific knowledge, and
- the social processes and contexts that shape how knowledge is communicated, represented, argued, and debated.

scientific knowledge, namely, the creation, adaptation, and use of physical or intellectual tools and technologies that support the intellectual work of scientific practice.

Data Organization and Analysis

Based on the introductory text for the area of Natural Sciences, which emphasizes scientific literacy, and the outline of investigative actions, an apparent alignment can be identified between the BNCC and current research in science education, as well as with the idea of science teaching as a social practice, as previously discussed. However, confirming these interpretations requires a detailed analysis of the curriculum proposal.

To this end, and aiming at understanding the occurrence and how scientific concepts are proposed in the BNCC (Ministério da Educação, 2018), we begin with the essential learnings defined for the Natural Sciences Curriculum Component at the elementary and High School levels, which, in the document, are organized by competencies and skills. While the BNCC document follows a specific framework for each stage of schooling, the knowledge of natural sciences is presented according to distinct textual formats. Similarly, the designation attributed to them varies at each stage of schooling: in Early Childhood Education, natural science topics appear within the field of experience titled “Spaces, times, quantities, relationships, and transformations”; in Elementary Education, they are referred to as “Natural Sciences”; and in High School, discussions related to this field of knowledge appear under the name “Natural Sciences and Their Technologies.”

The emphasis on concepts is not expected at the Early Childhood Education stage (Monteiro et al., 2018), and the anticipation of standardized expectations—typical of Elementary Education—by the BNCC has already been the subject of criticism among teachers and researchers in the field. Thus, based on the understanding that Early Childhood Education should not be characterized by standardized expectations or rigid age-based subdivisions (Barbosa et al., 2019), this article does not undertake a systematic analysis of the learning outcomes for that stage.

To evaluate the skills listed for Elementary Education and High School, we considered how they are articulated with the domains of scientific knowledge. For this purpose, we

developed an analytical framework (Table 1), based on the four domains defined earlier in this article and drawn from the work of Duschl (2008) and Stroupe (2014).

Table 1

Analysis Criteria for Natural Sciences Skills in the BNCC for Elementary Education and High School

Domain	Analysis Criteria	Skill	Discussion of the Analysis
Conceptual	Mention of concepts and/or cognitive science processes.	<i>(EF01CI01) Compare characteristics of different materials present in everyday objects, discussing their origin, disposal methods, and how they can be used more consciously.</i>	This domain is characterized by the presence of a concept (material characteristics) and a cognitive process (discussion).
Epistemic	Reference to the analysis of concepts and knowledge objects. The mention of criteria and standards as something to be understood but not put into practice by students; does not meet the criterion.	<i>(EF09CI16) Select arguments about the feasibility of human survival beyond Earth, based on the necessary conditions for life, the characteristics of planets, and the distances and time involved in interplanetary and interstellar travel.</i>	A domain characterized by the presence of criteria and norms (selection of arguments to support claims) that guide decision-making about what counts as an explanation.
Social	Mentions the modes of conducting the collective construction of understanding. The mention of collective knowledge construction modes as something to be understood, but not enacted by students, does not meet the criteria.	Not identified	
Materials	Mentions resources to support the understanding process. The mention of resources without any indication that	<i>(EF04CI10) Compare the indications of the cardinal points resulting from the observation of shadows cast by a rod (gnomon) with those obtained through a compass.</i>	This domain is characterized by the presence of resources (gnomon and compass) that support the process of

	they are mobilized to support the construction of understanding does not meet the criterion.		constructing understanding (comparison of different directional indications generated).
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To carry out this analysis, the authors of the present study categorized each skill individually, and afterward, in a joint meeting, validated the categorization by revisiting the definitions of each domain of scientific knowledge and the criteria established for analysis. The categorization of each skill was discussed in meetings attended by all three researchers, and in cases of disagreement regarding the classification, debates were held until a consensus was reached. At the end of this process, there was full agreement among all researchers on the classification of the skills presented in the BNCC.

The same procedure was applied for the High School level to categorize the text of the three designated competencies. This choice was due to the fact that their descriptions, more extensive than those found in Elementary Education, anticipate conceptual content that is more thoroughly detailed in the skills.

Natural Sciences: Proposal Analysis for Elementary School

In the BNCC, Natural Sciences are presented as a field of knowledge for Elementary Education, to promote students' scientific literacy, which, as stated, should take place through "access to the diversity of scientific knowledge produced throughout history, as well as gradual engagement with the main processes, practices, and procedures of scientific investigation" (Ministério da Educação, 2018, p. 321).

The investigative process is presented through modes of inquiry-based actions, which branch out from (i) problem definition, (ii) data collection, analysis, and representation, (iii) communication, and (iv) intervention. It is relevant to note that the actions related to data collection, analysis, and representation are presented in greater number and, to some extent, reflect practices already commonly found in traditional science classes, in which the focus lies on the exposition of information. Moreover, the actions in this group (ii) overlap with those in

group (iii), “communication.” We also recognize that the presence of an isolated group of investigative actions dedicated solely to communication contradicts the very concept of inquiry, whose processes are mediated and interconnected through communication among different subjects and between them and existing knowledge.

Following the presentation of the investigative actions, specific competencies for the area are introduced for Elementary Education. These competencies are broad and explore elements characteristic of the nature of science, with references to investigation, argumentation, and the modeling of natural phenomena and their relationship with society, with an emphasis on the conceptual mastery of scientific knowledge. Another core aspect expressed through them is the emphasis on developing students’ critical autonomy for action and decision-making, grounded in conceptual scientific knowledge, which would allow them to “[a]ct both personally and collectively with respect, autonomy, responsibility, flexibility, resilience, and determination” (Ministério da Educação, 2018). It is also worth noting that these competencies shed light on the intentions to foster interactions between individuals and other people, the environment, and society, which may be important evidence of the recognition of science as a field of study in which knowledge and products are present in our everyday lives.

Turning to the analysis of the proposed skills for the area (Table 2), there is a noticeable predominance of the conceptual domain, which appears in isolation in every year of Elementary School except for the 5th and 7th grades. We also underscore the absence of the social domain within the listed skills, as it was not identifiable in any instance, neither in isolation nor in conjunction with the other domains of scientific knowledge. The epistemic domain of scientific knowledge is moderately represented, but only in association with other domains and, more broadly, tends to appear integrated with the conceptual domain. The material domain, meanwhile, is infrequently addressed in the skills, whether on its own or in coordination with the others.

Table 2

Summary of the analysis conducted on Natural Sciences skills for Elementary Education in the BNCC

Grade	Total Skills	Presence of Individual Domains Only			Presence of Integrated Domains			
		C	E	M	C and M	C and E	E and M	C, E, and M
1	6	4 (66.7%)	0	0	1 (16.7%)	1 (16.7%)	0	0
2	8	4 (50%)	0	0	0	4 (50%)	0	0
3	10	5 (50%)	0	0	2 (20%)	3 (30%)	0	0
4	11	6 (54.5%)	0	1 (9.1%)	1 (9.1%)	3 (27.3%)	0	0
5	13	4 (30.7%)	0	2 (15.4%)	0	6 (46.1%)	1 (7.7%)	0
6	14	9 (64.3%)	0	0	0	4 (28.6%)	0	1 (7.1%)
7	16	2 (12.5%)	0	0	0	11 (68.75%)	0	3 (18.75%)
8	16	10 (62.5%)	0	0	0	4 (25%)	0	2 (12.5%)
9	17	10 (58.8%)	1 (5.9%)	0	0	6 (35.3%)	0	0
Total	111	54 (48.7%)	1 (0.9%)	3 (2.7%)	4 (3.6%)	42 (37.8%)	1 (0.9%)	6 (5.4%)

C = conceptual, E = epistemic and M = material

It is also worth noting that the conceptual domain of scientific knowledge is absent in only five skills—representing 4.5% of the total—and is present both as conceptual structures (theories, principles, laws, and ideas) and cognitive processes used in scientific reasoning. Structurally, the most frequent form of the conceptual domain appears in skills that compare characteristics of living beings, identify concepts through the observation of phenomena, or apply theories to justify processes—such as in “(EF07CI16) Justify the shape of the Brazilian and African coastlines based on the theory of continental drift” (Ministério da Educação, 2018).

An example that illustrates the analysis of the conceptual domain through the identification of a cognitive action is the skill “(EF04CI03) Conclude that some changes caused by heating or cooling are reversible (such as the changes in the physical state of water) and others are not (such as cooking an egg, burning paper, etc.)” (Ministério da Educação, 2018). Here, the conceptual mobilization involves identifying and comparing observable properties of matter as the basis for a cognitive classification process.

Another relevant aspect is the strong presence of the epistemic domain of scientific knowledge in integrated form with other domains, particularly the conceptual domain. Given

that the epistemic domain is associated with processes of analysis and the development of understanding, its integration with other domains reflects an intention for students to evaluate both the ideas under discussion and the materials being used.

The only occurrence of the epistemic domain in isolation from the others appears in 9th grade, in the skill “(EF09CI13) Propose individual and collective initiatives to address environmental problems in the city or community, based on the analysis of successful sustainability practices and conscious consumption actions” (Ministério da Educação, 2018). In this case, epistemic actions would support the analysis process and formulation of initiatives; however, this intellectual process would not be grounded in scientific knowledge or the use of tools, but rather in examples of best practices that students could both share and replicate.

The frequent mention of identifying and/or using materials, contrasted with the low occurrence of the material domain—whether in isolation or articulation with others—can be explained by the fact that mere mention of materials does not constitute the material domain. This is because there is no information indicating how these materials will be used; that is, whether information about them is provided or whether there would be opportunities for question generation.

Another possible way to organize the resulting categorizations is by presenting the incidence of scientific knowledge domains in the skills according to each grade and its corresponding thematic unit (Table 3). For easier presentation, the tables below exclude columns corresponding to unidentified scientific knowledge domains, whether in isolation or integrated form.

Table 3

Summary of the Characterization of Scientific Knowledge Domains in BNCC Elementary Education Skills by Thematic Unit

Thematic Units	Presence of the domains	Grade									Total
		1	2	3	4	5	6	7	8	9	
Matter and Energy	Conceptual	1	2	1	2	2	3	1	4	5	21
	Conceptual and Epistemic	0	1	2	1	3	1	5	2	2	17
	Total	1	3	3	3	5	4	6	6	7	38
Life and Evolution	Conceptual	2	0	3	3	1	3	0	4	3	19
	Epistemic	0	0	0	0	0	0	0	0	1	1
	Conceptual and Epistemic	0	3	0	2	3	2	3	1	2	16
	Conceptual and Material	1	0	0	0	0	0	0	0	0	1
	Conceptual, Epistemic, and Material	0	0	0	0	0	1	2	0	0	3
	Total	3	3	3	5	4	6	5	5	6	40
Earth and Universe	Conceptual	1	2	2	1	1	3	1	2	2	14
	Materials	0	0	0	1	2	0	0	0	0	3
	Conceptual and Epistemic	1	0	0	0	0	1	3	1	2	9
	Conceptual and Material	0	0	0	1	0	0	0	0	0	3
	Epistemic and Material	0	0	0	0	1	0	0	0	0	1
	Conceptual, Epistemic, and Material	0	0	0	0	0	0	1	2	0	3
	Total	2	2	2	3	4	4	5	5	4	33

From the above analysis, it is not possible to identify a consistent pattern regarding the occurrence of the scientific knowledge domains across thematic units, nor a pattern that would indicate increasing complexity in the emergence of these domains over the school years. It is clear that the BNCC proposal did not consider the theoretical elements used in the present study for categorization. This is a factual observation. Nonetheless, as previously mentioned, the document's introductory text explicitly emphasizes the importance of developing activities that enable students to engage in the practices and processes of scientific research.

It is important to highlight that the thematic unit Matter and Energy displays the least diversity in terms of the scientific knowledge domains represented. Given the very nature of the thematic unit, it was expected that the material domain would be prevalent; however, as previously mentioned, this was not the case. Material supports the intellectual work of practice (Stroupe, 2014) when it is subject to analysis, as the transmission of information about the material and how it should be used, created, or adapted is already embedded in the wording of various skills. In contrast, the thematic unit Earth and the Universe is structured around greater diversity and a possible increase in the complexity of integrated domain presence, although, as with the other two thematic units, there is still a notable tendency for the conceptual domain to appear, either on its own or in integrated form. It is striking how, in the wording of the skills,

the concept has become the goal in itself, without indicating the need to arrive at it. This may be one possible explanation for the predominance of this domain.

That said, it is worth noting the appearance of the material domain in isolation from the conceptual domain in only three skills. For example, in the skill “(EF05CI13) Design and build devices for distance observation (telescope, periscope, etc.), magnified observation of objects (magnifying glasses, microscopes), or image recording (cameras), and discuss the social uses of these devices” (Ministério da Educação, 2018), it is unclear which concept is being addressed, as the objective lies in the construction of devices that enable image recording, emphasizing the use of the devices rather than what is to be observed or recorded. In this sense, the characterization of the material domain arises from the chance that students themselves will engage in designing the devices and analyzing the images obtained, as opposed to following a predefined script for observation using a ready-made device, as we will explore further below.

Across all units, we identified a recurring presence of skills that reference conducting experiments; however, such mentions were not individually considered as evidence of the material domain, as we understand that this domain involves not only the creation and use of tools but, more fundamentally, how these tools support the intellectual work of practice. Accordingly, we did not treat the skills proposing the execution of scripted procedures without offering students intellectual autonomy as instances of the material domain.

Based on our theoretical framework (Stroupe, 2014), we identified the material domain in those skills in which conceptual work is sustained by the analysis and interpretation of experimental data, with experimental arrangements and observation practices serving as support for intellectual activity in the classroom. This manifests through the skill “(EF04CI09) Identify the cardinal directions based on the recording of different relative positions of the Sun and the shadow cast by a stick (gnomon)” (Ministério da Educação, 2018). We interpret this as a situation in which the student participates in the recording process, that is, the different positions are not predetermined. The materials used for recording and organizing this data function as epistemic objects (Rheinberger, 1997), serving a role and enabling the analysis of the sun’s relative positions. In contrast, the skill “(EF02CI07) Describe the position of the Sun at different times of the day and associate them with the size of the projected shadow” (Ministério da Educação, 2018) positions materials as experimental conditions (Rheinberger, 1997),

indicating that the Sun's positions have already been described and the shadow's size predefined, requiring only the association between them.

Our characterization of the material domain does not imply that all materials must be treated as epistemic objects, since in the process of supporting the intellectual work of practice (Stroupe, 2014), their roles may shift from epistemic objects to experimental conditions and vice versa—showcasing what Rheinberger (1997) describes as the mutability of object roles. Although Rheinberger's ideas stem from scientific research contexts, when applied to the school environment, this transformation of object roles allows students to engage intellectually with materials and construct conceptual understanding as a result of this engagement.

From this perspective, the use of verbs in the formulation of skills, particularly those that enable active student participation, is a critical element to consider. Despite some variety, many of the verbs used to define the skills suggest activities of low cognitive demand, such as comparing, identifying, and selecting information, with relatively few skills requiring students to perform processes both autonomously and critically.

A clear example is the sequence of skills for the 6th grade. Although some verbs appear to suggest more cognitively demanding activities, the underlying proposals tend to be low in complexity. Among the expected learning outcomes for this grade, verbs such as identify and select appear less frequently, accounting for only four of the 14 skills analyzed. In contrast, verbs referring to more complex cognitive processes—such as infer, deduce, and explain—are more prominent; however, due to the emphasis on predetermined knowledge, they fall short of ensuring students' epistemic agency.

In this grade, students are expected to “(EF06CI05) *Explain* the basic organization of cells and their role as the structural and functional unit of living beings” and to “(EF06CI09) *Deduce* that the structure, support, and movement of animals result from the interaction between the muscular, skeletal, and nervous systems” (Ministério da Educação, 2018). Nevertheless, in these skills, explaining and deducing are seemingly reduced to identifying parts and structures of the cell and bodily systems, to merely describe and recognize already established relationships.

Another example of the dilution of cognitive processes in these skills is the replacement of argumentation with the selection of ready-made arguments, as seen in the skill “(EF06CI13) Select arguments and evidence that demonstrate the Earth's sphericity” (Ministério da

Educação, 2018), a pattern that also appears in later grades in skills (EF08CI11) and (EF09CI16), proposed for 8th and 9th grade.

Natural Sciences and Their Technologies: Proposal Analysis for High School

In the BNCC, it is stated as essential for High Schools to “[e]nsure the consolidation and deepening of the knowledge acquired in Elementary School” (p. 464, emphasis in the original). Repeatedly, and in ways that clearly define its intent, the document highlights the challenge of offering a “school that welcomes young people” by establishing “learning aligned with *students’ needs, possibilities, and interests*, as well as with the *challenges of contemporary society*” (p. 465, emphases in the original).

Additionally, the BNCC organizes the High School curriculum by areas of knowledge and formative itineraries. In this text, our focus lies on the area labeled Natural Sciences and Their Technologies (CNT). Regarding the integrated formative itineraries related to CNT, it states:

Deepening foundational knowledge for the application of various concepts in social and work-related contexts, organizing curricular arrangements that allow for studies in astronomy, meteorology, general physics, molecular, quantum, and mechanical physics, instrumentation, optics, acoustics, chemistry of natural and chemical phenomena, meteorology and climatology, microbiology, immunology and parasitology, ecology, nutrition, zoology, among others, taking into account the local context and the possibilities of implementation by education systems. (Ministério da Educação, 2018, p. 477)

In terms of conceptual knowledge, the BNCC expresses its intent to deepen the themes introduced in the Natural Sciences thematic units at the elementary level through a continued focus on Matter and Energy, as well as Life, Earth, and the Cosmos. The document also emphasizes the need for CNT (Natural Sciences and Their Technologies) teaching to address the social, historical, and cultural contextualization of science and technology, research processes and practices, and the specific languages of the area.

Unlike the specific competencies described for Natural Sciences in Elementary School, the competencies at High School show a strong connection to conceptual issues, particularly in the first two, which directly reference the topics to be addressed.

We categorized these competencies according to the domains of scientific knowledge, and in all of them, we identified the explicit integration of the conceptual and epistemic domains.

Although all of them mention the individual's role in society, it is important to note that this does not constitute the expression of the social domain of scientific knowledge, since the focus lies on the influence and interaction of knowledge with society, rather than on socially established norms and standards for constructing understanding of the knowledge under discussion.

In statements such as “propose individual and collective actions that improve productive processes, minimize socio-environmental impacts, and enhance living conditions at the local, regional, and global levels” (Competency 1), the social perspective points to an articulation between science, technology, and society within the STS (Science-Technology-Society) approach. It can be argued that social practices are presented here as content, rather than practice, since the concept of the social domain extends beyond collectivity to encompass critical engagement.

Similarly, in Competency 3, the mention of the use of different media and information and communication technologies reflects their treatment as content to be worked on, rather than as a domain to be mobilized.

Also distinct from Elementary School, at the High School level, the skills are organized under specific competencies, another clear indication of the conceptual orientation that characterizes these competencies. In this structure, the BNCC seemingly suggests that the development of desired competencies follows a path defined through associated skills.

As with our analysis of the Elementary School skills, in this categorization, we considered how each skill articulated under the High School competencies (see Table 4) expresses elements related to the domains of scientific knowledge (Duschl, 2008; Stroupe, 2014).

Table 4

Summary of the Analysis of Natural Sciences Skills for High School in the BNCC

Competency	Total Number of Skills	Presence of Integrated Domains	
		C and E	C, E, and M
1	7	5 (71.4%)	2 (28.6%)
2	9	7 (77.8%)	2 (22.2%)
3	10	7 (70%)	3 (30%)
<i>Total</i>	<i>26</i>	<i>19 (73.1%)</i>	<i>7 (26.9%)</i>

C = Conceptual, E = Epistemic and M = Material

Based on the categorization performed, a tendency toward integration among the domains of scientific knowledge becomes evident, although integrations involving only two domains are more common. As in our analysis of Elementary School skills, the social domain of scientific knowledge is absent, which may further indicate that the norms and standards for knowledge analysis and construction are not perceived by the curriculum as content to be explicitly addressed in the classroom.

It is worth highlighting that Competency 3 clearly expresses the intention to offer students opportunities to engage with “different media and digital information and communication technologies (ICTs)” (Ministério da Educação, 2018). This may give the mistaken impression that the material domain is being mobilized simply by the inclusion of these technological tools. For instance, skill “(EM13CNT202) Analyze the various manifestations of life at different levels of organization, as well as the favorable environmental conditions and limiting factors affecting them, with or without the use of digital devices and applications (such as simulation software and virtual reality, among others)” (Ministério da Educação, 2018). The mere indication of technology use does not ensure that these tools support the intellectual work of practice (Stroupe, 2014). This point is already evidenced in the analysis, given that the percentages of material domain integration with other domains among the skills associated with Competency 3 are not significantly different from the integration rates observed in the skills related to Competencies 1 and 2.

It is important to emphasize that the material domain of scientific knowledge refers to intellectual tools or manuals that support the development of intellectual practice, rather than the prescribed format or procedure for carrying out activities. Thus, the material domain is mobilized in situations in which students are asked, for example, to represent ideas, concepts, notions, and modes of action—as in “(EM13CNT301) Construct questions, formulate

hypotheses, predictions, and estimates; employ measurement instruments; and represent and interpret explanatory models, data, and/or experimental results to construct, evaluate, and justify conclusions when addressing problem situations from a scientific perspective” (Ministério da Educação, 2018). Here, the material domain appears quite explicitly through the mention of the representation of explanatory models, data, and experimental results, rather than using measurement instruments, which, depending on how the activity is presented to students, may be employed merely in a manipulative and unreflective manner, thus failing to enable intellectual practice through the mobilization of the material domain of scientific knowledge.

The higher occurrence of the epistemic domain integrated with the conceptual domain may result from the verbs used to define the skills, which suggest activities involving higher cognitive demand compared to those in Elementary Education. An example of this can be found in the sequence of skills for the 3rd grade of High School, which includes verbs such as construct, develop, interpret, analyze, evaluate, and investigate. Among the skills outlined for the three years of High School, the absence of verbs such as identify, describe, and select could be observed.

An example of how skills involving cognitively demanding verbs embed practices not merely as content to be understood, but as actions to be performed by students, is the skill: “(EM13CNT303) Interpret scientific dissemination texts addressing topics in the natural sciences, available across different media, taking into account the presentation of data—in textual form as well as in equations, graphs, and/or tables—the consistency of arguments, and the coherence of conclusions, to develop strategies for selecting reliable sources of information” (Ministério da Educação, 2018).

Considerations and Implications

In our analysis, the presence of the material and epistemic domains of scientific knowledge—whether in the skills outlined for Elementary or High School—serves as evidence that curricular expectations for science teaching are changing. There is no longer an exclusive focus on the conceptual domain; however, it remains predominant and, in many cases, appears disconnected from the other domains of scientific knowledge, which may indicate traces of traditional teaching approaches. Although there is a movement toward incorporating practices

to be carried out with students, something that could promote integration among all domains, these practices are often treated as content themselves.

By advocating for articulation among domains, we are not rejecting the conceptual domain; it remains essential. However, its mobilization in isolation does not ensure student understanding, as it may simply be memorized as content. When integrated with other domains, the conceptual domain comes to be understood as the result of a process of constructing meaning, thereby contributing to actual comprehension. Therefore, addressing the conceptual domain in isolation is problematic, as it reinforces the notion that scientific knowledge consists of mere opinions and disregards the processes by which it is constructed.

The analysis also identified a low percentage of skills that include elements characteristic of the material domain of scientific knowledge. In Elementary Education, only 11 skills (9.9% of the total) were classified as presenting the material domain, either independently or in integrated form. In High School, its presence was more frequent (26.9%), and, in all instances, it appeared in integration with the conceptual and epistemic domains.

It is worth emphasizing that the material domain appeared in isolation only in skills from the 4th and 5th grades of Elementary Education. The occurrence of this domain without integration with other domains suggests an intentional focus on a particular technology, without providing opportunities for reflection on its role in constructing understanding of a given situation, problem, or phenomenon.

The attention given to the relationship students must develop with materials remains limited and tentative. These elements are still perceived as ancillary to the teaching and learning process and are often positioned merely as experimental conditions (Rheinberger, 1997), that is, considerable information is provided about them, but no space is afforded for generating questions regarding their use or implications. When materials are placed as epistemic objects, this involves evaluating their function within the given context and developing ideas about the need to replace or adapt them. Such positioning reflects characteristics of the epistemic domain and contributes to its articulation with the material domain. Thus, we propose that the material and epistemic domains emerge jointly.

Another important point to highlight is the absence of the social domain of scientific knowledge in the skills related to Natural Sciences in both Elementary and High School education. Sandoval and collaborators (2000) discuss the differences between instruction aimed

at fostering epistemic understanding of scientific activity and instruction focused on the mobilization of epistemic practices. In the former case, according to Sandoval et al. (2000), efforts in this approach are focused on presenting students with ideas about scientific activity—that is, enabling students to understand that knowledge results from investigation, that there are multiple ways of constructing knowledge in science, that there are criteria for evaluating scientific knowledge, that reciprocal relationships exist between data and theory, and that representations are aligned with interpretative frameworks for ideas. The mobilization of epistemic practices, in turn, is linked to processes for constructing and evaluating knowledge; actions that seek relationships between data and evidence; processes for perceiving and interpreting data and data patterns; actions for identifying and using representational forms specific to science; and processes for recognizing analytical criteria.

It is understood that the absence of the social domain of scientific knowledge in the skills related to Natural Sciences reflects an intentionality: that the instruction in this field prioritizes learning about what science is and how knowledge is constructed and evaluated within it, but does not engage students in practices that are intrinsic to the field. In this sense, the intended model of instruction moves away from opportunities for learning grounded in context-based practices; in other words, from a model of learning understood as “an integral and inseparable aspect of social practice” (Lave & Wenger, 1991, p. 31).

Based on the analysis of the skills associated with the Natural Sciences, we can affirm that the vision of science teaching proposed by the BNCC reflects a traditional model centered on the exposition of concepts, with limited openings for aspects of scientific practice, which are also addressed as conceptual content. From this perspective, students do not engage in the mobilization of these practices; instead, they are merely informed about them, which suppresses the possibility of constructing new understandings that could result from engaging with such practices. In other words, presenting practices as information does not guarantee the construction of new understandings; it merely reinforces the conceptions that students already carry with them.

From the analysis of the essential learning outcomes outlined in the BNCC—both for Elementary and High School—regarding their relation to the domains of scientific knowledge in the classroom, we reaffirm their dissociation. There is a marked difference between the conception of science teaching presented in Elementary and High School education. This is

because, in Elementary Education, skills that promote integration among domains are rare when compared to those at the High School level, revealing a challenge when students reach High School and are expected to engage in greater integration between the domains. How will students respond to this demand introduced by High School competencies? Will access to domains that require greater student involvement be disregarded? Will only the conceptual domain be activated, thereby maintaining an approach that privileges content over construction, and scientific practices as mere content rather than lived processes?

Finally, we emphasize that the way BNCC skills are framed underscores the urgency of rethinking teacher education so that educators are equipped to work with a model of instruction that prioritizes engagement with scientific practices. However, current educational policies point to a teacher education project that is becoming increasingly instrumental.

In this regard, CNE/CP Resolution No. 02/2019, which establishes the guidelines for teacher education in Basic Education, is centered on the idea of preparing teachers based on the competencies outlined in the BNCC, specifying in Article 2 that “teacher education presupposes the development, by the teaching candidate, of the general competencies provided for in the BNCC for Basic Education, as well as the essential learning outcomes to be guaranteed to students (...)” (Ministério da Educação, 2029). Now, if the stated competencies and essential learning outcomes embodied in the skills analyzed here fail to address science as a social practice, how can they support the preparation of teachers capable of bringing the domains of scientific knowledge into the classroom in an articulated manner? Furthermore, given the absence of the social domain among the skills defined for this area, how can teachers operate within a curriculum that assigns a place to concepts in articulation with the tools, norms, and practices of scientific work?

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