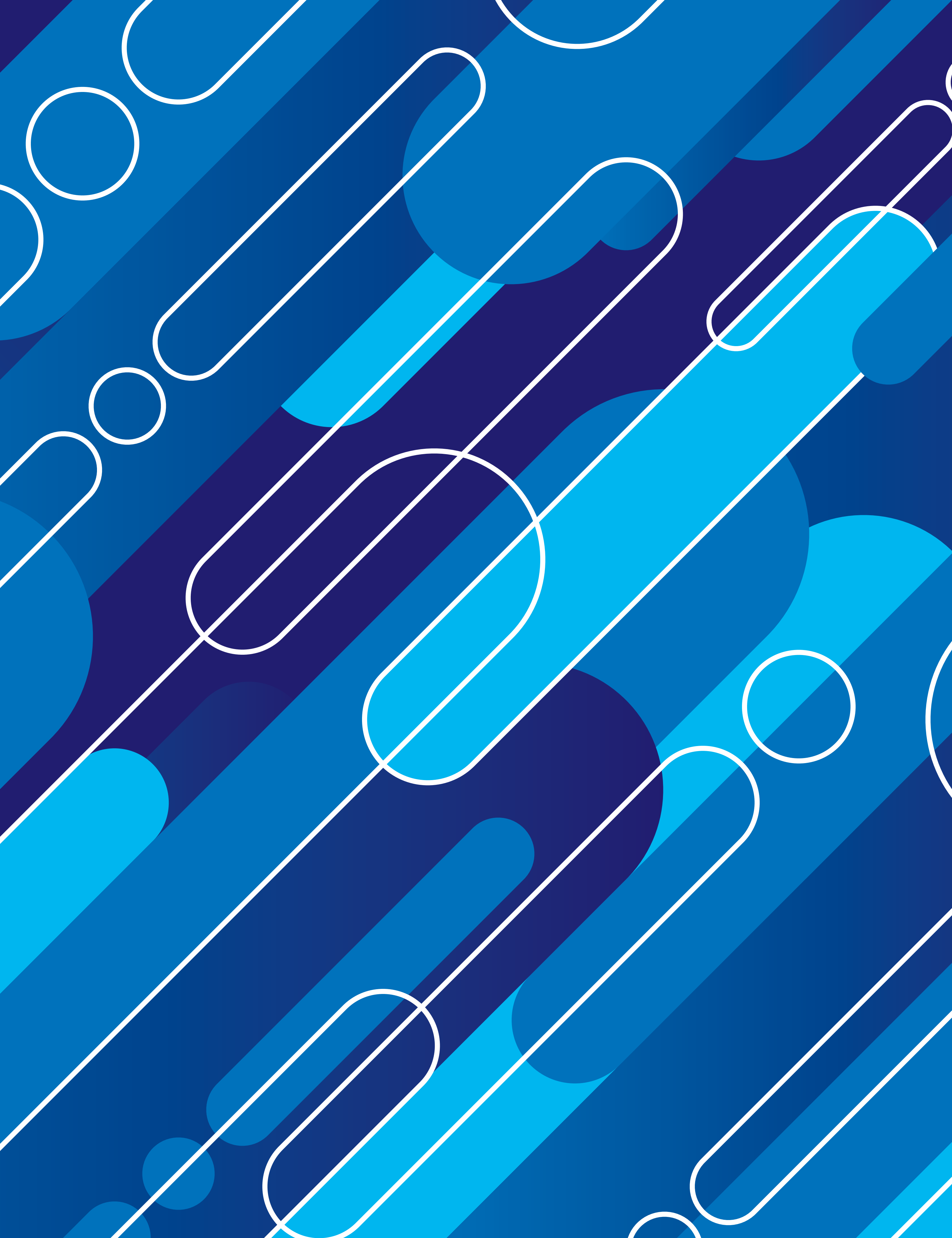
BRITISH COUNCIL

the teaching of the natural sciences and their technology in Brazilian schools

an overview of the period 2010 to 2020



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BRITISH COUNCIL

the teaching of the natural sciences and their technology in Brazilian schools

an overview of the period 2010 to 2020

Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits.

(Article 27 of the Universal Declaration of Human Rights)

The partnership with the Carlos Chagas Foundation (FCC) results from its experience in educational research. For the last 58 years, the FCC's Department for Educational Research has delivered programmes and studies in the areas of educational policy, assessment, teacher training and the work of teachers, the right to education, age, gender and race relations, focusing, amongst other aspects, on indicators of inequality. Over the years, it has sought to combine the production of knowledge with a solid contribution to the formulation and implementation of public policies, by supporting new studies, programmes and activities, always focussing on education as a fundamental right for all. Since 2015, the Gender, Race, Ethnicity: Education, Work and Human Rights research group has been working with partners wishing to investigate gender in education more deeply, examining to what extent the school (alongside the family, media, community, church, etc.) is a strategic space where educational inequality can be challenged, in the context of broadening gender equality in school and higher education and the professions. The evidence shows a lack of women in certain professions, especially in STEM (Science, Technology, Engineering and Mathematics), which has led to a series of initiatives to stimulate gender and race equality at all stages of education, from primary school to higher education, reflecting on changes in some areas.[1]

In 2020, there emerged a proposal based on a mutual interest in contributing to actions and programmes for a complete, high-quality education for children and young people through a comprehensive study of the teaching of science in Brazil, with a focus on the last decade (2010 to 2020), through an assessment of the implementation of a series of educational policies related to the curriculum and teacher training. In addition to published research and other key documents, the study would also examine quantitative data in order to gain a broad picture of the teaching of science within the current policy framework for school education. To achieve this objective, it is essential to include the relationship with diversity, gender equality, race and ethnicity.

The main objective is to present systematically produced information which could support educational professionals and researchers in discussions of educational policies and new proposals for the teaching of science in schools. We believe that with the new emphasis on In-Service Education and Training (INSET) to support the implementation of educational projects based on the National Common Core Curriculum (BNCC), it is an opportune moment in Brazilian

1
Recent academic studies on the subject includes: Betina LIMA (2017); Gabriela RESNIK et al. (2017); Katemari ROSA and Felicia MENSAH (2016); Rebeca B. FELTRIN, Janaina COSTA and Léa VELHO (2016); Márcia GROSSI et al. (2016); Betina S. LIMA, Maria Lúcia BRAGA and Isabel TAVARES (2015); Moema GUEDES, Nara AZEVEDO and Luiz FERREIRA, Luiz (2015); Gicele SUCUPIRA (2015); Érica PINTO (2014); Irunéa BATISTA et al. (2013); Michelle LIMA (2013); Lindamir CASAGRANDE and Marília CARVALHO (2012), among others.

education to strengthen science education in schools, with a particular focus on primary education, especially in the final years of that stage. It is at this stage in their education that there is a step change in the knowledge level of the children, who start to be exposed to science-related content and more complex concepts, inspiring a critical point of view and socialisation as they move into adolescence (DAVIS *et al.*, 2012).

The research described in this paper was carried out throughout 2021 and is connected to some of the central themes in the debate on educational policies, above all those related to the introduction of the BNCC, such as initial training and INSET, teaching methodologies and practices, and the impact of educational inequalities on school truancy and dropout rates, taking into account gender and race data.

A virtual meeting was held in July 2021 to build a dialogue between the researchers, education professionals working in science teaching and members of the STEM Education Hub. The meeting resulted in a shared theoretical and practical approach that contributed significantly to the research process, with challenges, viewpoints and experiences that fed into this overview.

The main results and insights set out in this paper are intended to support the other actions under the British Council's STEM Education in the School programme, with the aim of widening and strengthening collaboration between Brazil and the United Kingdom in science, technology and innovation, with a particular focus on promoting excellence in science education and a commitment to a comprehensive education for all, valuing those educational professionals responsible for delivering it and encouraging equality and diversity.

This paper is intended to give an overview of school science teaching in Brazil. It is our aim that the information and insights it contains can support moves to recognise and support the strategic importance of science education and its teaching throughout the school years.
We trust that you enjoy reading it.

São Paulo, April, 2023.

STEM Partnerships

Working Together

Diana Daste

(Director of Cultural Engagement, Brazil and Acting Country Director of the British Council)

The British Council is the United Kingdom's international organisation for cultural relations and educational opportunities. Founded in 1934 and established in Brazil since 1945, it works in the areas of Education, the English Language, the Arts and Culture. It encourages and supports the development of programmes that promote equality and quality. In the area of school education, it focuses on the teaching of the English Language and of Science and Technology, aiming to strengthen the skills of teachers and their performance in the classroom. We seek reflections and methodologies that are capable of improving the relationship between teaching and learning, and aim to increase the engagement of students in an inclusive education, as well as promoting partnerships between Brazil and the United Kingdom. In this way, we believe we contribute to human development and global citizenship.

The function and form of teaching the STEM subjects (Science, Technology, Engineering and Mathematics) has been changing throughout the world. The United Kingdom is respected worldwide for its work in the area, evaluating and documenting experiences, methodologies, policies and their application. This publication is part of the British Council's global STEM Education programme, which aims to encourage wide access to science and technology education, from the perspective of an integrated, evidence-based education.

The overall objective of the programme is to build connections between the United Kingdom and Brazil in the STEM area. The investigations and training activities are focused on citizen science, critical pedagogies, informal education spaces and inclusion (especially black girls), aiming to identify and promote methodologies which can be replicated in schools in the two countries. Computational thinking is a key skill, required to meet the challenges of engagement, resources, infrastructure and training, while in-service training (INSET) is a transformative element in education systems.

How to manage and encourage transformative processes in the STEM area? What are the strategic choices and elements needed to advance on the path towards a quality teaching and learning environment? What projects will make a difference?

It is by reflecting on these questions that we interpret the content of this publication, in order to propose high-impact interventions founded on the transformative ability of the sciences, with the teacher at the heart of the actions.

The challenge requires various sectors to engage. We invite the reader to exchange experiences and work together towards transforming education.

Data,
various conversations and reflections

Alessandra Moura
(Head of English and Schools Programmes)

The fruit of a two-year research project carried out by researchers at the Carlos Chagas Foundation, the analyses and reflections to be found in this new study are intended to contribute to the formulation of digital and natural science education policies in Brazil.

Data on the attractiveness of the teaching career, the profile of educators, as well as insights into the fundamental importance of INSET for improving the quality of education are especially relevant to the design of evidence-based public policies. To a large extent, the research consolidates information about the current situation of Brazilian STEM teaching and learning, with its foundation in a close look at Brazil's educators. This makes sense, because if the student is the central figure in the school, it is the educators who are the movers and shakers in schools. While technology and artificial intelligence advance in leaps and bounds, it is still impossible to imagine schools without teachers. Furthermore, it is clear that there must be an increased emphasis on promoting equality STEM education, especially amongst girls. They need to hear words and experience actions that encourage them to pursue STEM careers – careers that can make a major contribution to sustainable development. It is essential to combat the invisible bias that still encourages them to think that they would not be good scientists, mathematicians, engineers or programmers.

Before inviting readers to dive into this publication, it is important to point out that nothing is more valuable in the work of the British Council than the trust and collaboration we have established with the countless specialists we work with in the countries where we operate. Without them, no contribution or outcome would be possible. This is why research such as this results not only from data analysis, but from many people exchanging their experiences, knowledge and reflections. We seek to list and thank them all on the introductory pages of this publication.

As you look at the look list of names, you will be able to imagine the long and fascinating conversations we have had in reaching these results. For the British Council and our team in Brazil, it was an honour and a pleasure. We hope that this STEM baseline research will be a starting point for new partnerships and other projects that strengthen STEM in Brazil.

1 Context

why examine the teaching of the natural sciences and the technologies involved in schools?

Owning and embracing knowledge is the first step towards building a society in which people can actively participate in scientific progress and its benefits, directly influencing the way we deal with climate change, strengthen food security and healthcare and manage our scarce natural resources, as well as ensuring that significant proportion of the population is included in the pursuit of fairer and more democratic sustainable development.

However, there is discussion and a lack of a shared vision of what is understood as science and, therefore, of its benefits and uses. This discussion is not new. In 2011, Léa Velho wrote about the various paradigms which have led to the different definitions of science which have been proposed over the last few decades, based on different visions of how to develop a knowledge-based society, since there are many and diverse histories, traditions, cultural values and political and economic interests[2]. According to the author, a new concept of science is emerging in the 21st century, in which many different forms of knowledge are recognized that are related in a variable and asymmetric manner. Citing other authors, the author draws attention to the contribution of local groups with their practices and knowledge.

If the concept of science is a construction based the historical and social context of a specific period, so is the curriculum, an expression of the systematic reconstruction of knowledge.

If the concept of science is a construction based the historical and social context of a specific period, so is the curriculum, an expression of the systematic reconstruction of knowledge. Alice C. Lopes and Elizabeth Macedo (2011), when considering the different theories of the curriculum, define it as a discursive practice, which builds reality, producing historically situated socio-cultural discourses. In the case of science teaching, the attention of researchers and teachers needs to be focussed on the outdated nature of the science curricula in Brazil which are, in general, limited to the description of phenomena, systems and processes and do not enable students to construct a critical, reflexive and ethical scientific argument about the problems affecting the existence of our planet. This debate has been active for more than two decades and follows changes in educational

2
Recognizing the complexity of historical and social reality, the author shows how the concept of science has been subject to differing prevailing visions in various periods: in the 1960s, science was seen as the engine of post-war progress; in the 1960's-70, science was considered as both a solution and cause of problems; in the 1980's-90, it was a source of strategic opportunity and, finally, science is being viewed as a 21st century paradigm: concerned with the welfare of society.

policies and their regulation, especially regarding the guidelines, curricular guidelines and, now, the Common National Core Curriculum (BNCC), which continues to be subject to critical analysis (KRASILCHIK, 1980; SANTOS; MORTIMER, 2001; VEIGA, 2002; CACHAPUZ; PRAIA; JORGE, 2004; SOUZA; BASTOS; ANGOTTI, 2007; SANTOS, 2008; NASCIMENTO; FERNANDES; MENDONÇA, 2012; AMARAL, 2016; PINHÃO; MARTINS, 2016; ALBINO; SILVA, 2019; BLIKSTEIN; HOCHGREB-HAEGELE, 2017; BRANCO *et al*., 2018; NEPOMUCENO *et al*., 2021).

Educational indicators and reports from international agencies about the last decade show an overall advance in schooling, but it is necessary to look at the specificities of the different areas of knowledge in the light of the social, historical and political contexts of Brazil. Using different sets of date contained in indicators such as those produced by the Programme for International Student Assessment (PISA), we can visualise, for example, the inequality of access to science education, production and discussion. Since the start of the century, PISA has evaluated the extent of science knowledge and understanding of students from various parts of the world, including Brazil. While it has improved to some extent, in PISA 2018, the average science proficiency of young Brazilians was 404 points, 85 points below the average score for students in Organization for Economic Cooperation and Development (OECD) countries (489). In 2019, the Brazilian Ministry of Education (MEC) evaluated performance in the natural sciences for the first time by applying the School Education Assessment System (SAEB), already adjusted to meet the guidelines of the Brazilian Common National Curriculum (BRAZIL, 2017). It was a pilot study, based on an improved version of an assessment matrix tested in 2013[3]. A sample of students from the 9th year of primary education were assessed. (BRASIL, 2021). The results showed that 51.71% of students had low levels of scientific literacy, that is, up to level 2[4]. The Anísio Teixeira National Institute of Educational Studies and Research (INEP) warns, however, that the small number of elements assessed in this first assessment limits the analysis of the results.

Attention to the level of basic knowledge of the content of the natural sciences has mobilised debates on both literacy and scientific literacy and on the need to expand

51,71%

of students had low levels of scientific literacy, that is, up to level 2.

3
In 2013, the Anísio Teixeira National Institute of Education Studies and Research (INEP) put forward a proposal for a standard assessment matrix for the evaluation of natural sciences based on the Brazilian General Curriculum Guidelines for School Education and the Brazilian Curriculum Guidelines for Primary Education. Subsequently, the standard matrices for assessments and examinations were aligned with the BNCC, it being proposed that they be included in the 2019 SAEB as a pilot project. Available at: https://download.inep.gov.br/educacao_basica/saeb/2019/resultados/relatorio_de_resultados_do_saeb_2019_volume_3.pdf.
Accessed on 20 January 2022.

4
Level 2 - Functional Scientific Literacy- solves problems involving the interpretation and comparison of basic scientific information and knowledge, presented in a range of texts (tables and charts with more than two variables, images, labels), involving themes present in daily life (health benefits or risks, adequacy of environmental solutions). (SERRÃO, et al. 2016, p. 346). https://acaoeducativa.org.br/wp-content/uploads/2014/10/ILC_Letramento-cientifico_um-indicador-para-o-Brasil.pdf.

the dissemination of scientific knowledge beyond the boundaries of schools and universities. The reason for this interest includes ensuring greater and better knowledge and application of the contents of science by the general population, supporting its participation in discussion on the production of technological and scientific solutions for the most pressing problems of this century, such as the sustainability of the planet. Knowing how much scientific knowledge was acquired throughout school life and applied in everyday life meets the principles of an emancipatory scientific education, as we will see below, but also the right to access and enjoy the benefits produced by humanity and to collaborate with its development.

With this concern, the Abrammundo Institute, in partnership with the Paula Montenegro Institute and Educational Action, created the Scientific Literacy Indicator (ILC) in 2014. Inspired by the Functional Literacy Index (INAF), a well-established initiative of Educational Action, the objective of the ILC was to monitor the evolution of skill levels in the young and adult Brazilian population, measuring how much people of differing ages and level of education are able to resolve everyday situations. The results showed that

> **[...] of people between 15 and 40 years old, with more than four years of education and living in nine of the main metropolitan regions of the country, almost half (48%) were classified at the functional level of scientific literacy, while only 5% were classified as proficient in scientific literacy. (GOMES, 2015, p. 32)**

While the ILC was only applied once, it contributes to a legacy of results and with sufficient elements to justify action in the area of scientific education in Brazil. The same argument justifies the need for adequate knowledge of technical and scientific information presented by the ILC (GOMES, 2015, p. 47-48), in the words of Wildson Luiz Pereira dos Santos:

> **A citizen, in order to make social use of science, needs to know how to read and interpret the scientific information disseminated in the written media. Learning to read scientific writings means knowing how to use strategies to extract information;**

knowing how to make inferences, understanding that a scientific text can express different ideas; understanding the role of the scientific argument in the construction of theories; recognizing the possibilities of that text when interpreted and reinterpreted; and understand the theoretical limitations imposed, understanding that their interpretation implies the non-acceptance of certain arguments. (SANTOS, 2007, p. 485)

This emphasis by Santos (2007) is aligned with the concept of citizen science, which is defended by researchers who understand the need for a dialogue with all society on scientific knowledge. The groups which are part of the Citizen Science Movement, for example, are concerned with agriculture, food security, habitation, health and the environment – all of which are themes which are relevant to everyone, given the planet-wide climate and sustainability crisis affecting all peoples. The movement is concerned with the democratisation of science and removing the more highly educated population from its position of dominance over the knowledge produced by humanity, aiming for greater interaction between scientists and the lay public. Following this line of thought, space is opened for different knowledge, often rendered invisible by educational systems, where the legitimacy of knowledge is marked by dominant hegemonic epistemologies, as already mentioned, centred on a pattern of Western, male, white, heterosexual thinking, which guide curricula, didactic materials and ways of thinking and teaching and doing science (SUCUPIRA, 2015).

Critical thinking about hegemonic epistemology by feminist, black and indigenous scientists has gained force in Brazil in recent decades, In 2004, the National Science Council issued Advisory Notice No. CNE/CP 003/2004 (BRAZIL, 2004), which regulated amendments introduced by Law No 10.639/2003 and the establishment of the National Curriculum Guidelines for Education of Ethnic-Racial Relations and for the Teaching of African and Afro-Brazilian History and Culture. For example, it opens up space in the natural sciences curriculum and its related technologies for to new perspectives, historically less sensitive to the debate on the construction of scientific knowledge and on the place of popular and ancestral knowledge.

Researcher and teacher Anita Canavarro Benite combines her work in bioinorganic medicinal chemistry with the training of future Chemistry teachers to promote the decolonization of the Chemistry curriculum. She proposes an epistemological rupture by including and articulating knowledge derived from the African legacy to specific Chemistry content. Along with Marysson J. R. Camargo and Anita Canavarro Benite, she undertook a practical research activity involving recently graduated teachers and 9th year students in a state primary school. They introduced out pedagogical interventions that linked iron forging on the African continent with the concept of the transformation of matter and characteristics of chemical phenomena involved in forging iron (CAMARGO; BENITE, 2019). Not only is there a historical record of foundries and forging in West Africa in the 13th century AD, but there is also evidence of the discovery of fire in Kenya[5].

It is important to emphasise that the recognition of structural racism and of sexism and gender discrimination in education and in the fields of knowledge is related to the addressing of historical inequalities affecting women in the STEM areas. Physicist Katemari Rosa (2015) has been one of the voices active in several formative spaces promoting the visibility of black women in Physics, drawing attention to the under-representation of black people in the natural sciences, be it in the academic literature, in scientific events or in the classroom. In a survey of recent research and data on gender, education and science, researchers Vanessa Sisolo, Thais Gava and Sandra Unbehaum (2021) show the relevance and current status of the debate, policies and actions on the topic. A number of programmes and projects have been developed in Brazil in the last two decades by both public institutions and civil society. Although several initiatives take into account the relevance of gender equality, addressing the educational inequalities that affect boys and girls differently in school education faces several obstacles, challenges which have increased in the recent period of political and economic crisis in Brazil, more evident in the last three years, with significant negative impacts on the country's social, scientific and cultural development.

In proposing this critical and proactive vision for the natural sciences so that it may assume its role within the teaching of African and Afro-descendant history and culture, these initiatives clearly identify the urgent need to open up both higher education and school education to a broader range of views and concepts of science knowledge and practice. This concept meets the intrinsic objectives of scientific literacy, which is to form citizens with a critical and questioning view of the world, as clearly defended by Sasseron and Carvalho in 2011.

In its publication *Cracking the code: girls' and women's education in Science, Technology, Engineering and Mathematics* (STEM)(2018), UNESCO highlights the fact that only 30% of female higher education students in the world are enrolled in STEM courses, representing 35% of the students following careers in the sector. The report goes on to say:

Many girls are held back from developing themselves because of discrimination, by the diverse biases, social norms and expectations that influence the quality of education they receive, as well as the subjects they study. The under-representation of girls in STEM education has deep roots and puts a damaging brake on progress toward sustainable development. (UNESCO, 2018, p. 10)

5
MACHADO, C. E. D., Ciência, tecnologia e inovação africana e afrodescendente, apud Camargo and Benite (2019).

Data and studies also point to what is called vertical segregation, that is, the participation of women in science decreases as they rise through the stages of education, career and profession, in other words, the higher the level of power and prestige, the fewer the number of women. For this reason, whenever possible, we sought to identify the presence of a gender and race perspective in the scope of all documents considered in this mapping exercise.

The current situation, more specifically since the approval of the BNCC in 2017, is timely. It offers an opportunity for an articulated movement involving civil society, education professionals and researchers and movements, groups, and social collectives to think critically, aiming to contribute to the strengthening of science teaching based on a legacy of research, data and reflections available.

30%

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of the students following careers in the sector.

Dimensions of the panoramic study of science education in school education

methodological procedures

The intention was to produce a State-of-the-Art survey of articles published under the search descriptor "science teaching".

The main scope of the research is to organise information that will provide a comprehensive view of science education in Brazilian school education, highlighting the principal factors and challenges that persist, examining the topic from three dimensions:

1. Legal framework:
In the survey of the Brazilian legal framework relating to the teaching of science, the main documents that organize and guide education systems were listed, with emphasis on the Brazilian Common Core Curriculum (BNCC) (BRAZIL, 2017a; 2018); the Brazilian Curriculum Guidelines for Initial Teacher Training for School Education and the Brazilian Common Curriculum for Initial School Teacher Training (BRAZIL, 2019b); National Curriculum Guidelines for the continued education of teachers of Basic Education and Common National Base for the continued training of teachers of Basic Education (BNC-continuing education) (BRAZIL, 2020), which integrate the analysis.

2. Research published in academic journals - SciELO (Scientific Electronic Library Online).
A review of the academic production published in journals on the SciELO platform, a portal that gathers, organises and publishes complete texts of the main Brazilian academic journals on the internet. The intention was to produce a State-of-the-Art survey of articles published under the search descriptor "science teaching". Documents prepared by civil society organizations (technical reports, guides, recommendations, diagnostics) were also included. A non-exhaustive bibliographical survey of initial teacher training was carried out in order to provide evidence of recent activity in the teaching of science.

3. National School Education Census (CEB) and National Higher Education Census (CES) databases
National statistical data from the National School Education Census (CEB) and National Higher Education Census (CES) databases were analysed, both of which were carried out by INEP, including information published in the Statistical Synopses of School Education and consultations of other available studies. Whenever possible, these data were disaggregated by gender, race/colour and region in order to give visibility to diversity and to potential inequalities. The aim is to provide a general view of science education, especially initial teacher training, as well as the data available on schoolteachers and students.

Methodological procedures

The research was essentially bibliographical and documentary in nature and sought to inventory and describe aspects previously identified as fundamental for the understanding of a certain field of knowledge. In this case, the teaching of the natural sciences and their technologies, limited to school education and focussed on teacher training, teaching methodologies and teaching practices. The limits of the study should be emphasised. It is not intended to be a full State of the Art survey, as the subject General Science is multidisciplinary, covering the areas of Biology, Chemistry and Physics over the final years of primary education and the whole of secondary education. Each subject area has its own epistemological and methodological perspectives. In this sense, we sought to gather elements that allow us to identify characteristics and conceptions that can contribute to the dialogue about the complexity surrounding the teaching of the natural sciences, as it has been conceived and proposed by current educational policies, in particular with the implementation of the BNCC.

The main category, covering both the sources themselves and their analyses, is "science teaching." This is the scope of our panoramic survey. The specific subjects – General Science, Biology, Physics, Chemistry – are not the object of this research or study, except with regard to the analysis of statistical data regarding teacher training and the effectiveness of the teaching of the natural sciences, based on the censuses of higher and school education.

The general procedures adopted considered the following points: 1) Delimitation of the study object in terms of time and space; 2) Definition of the sources of information to be used for each of the dimensions: defined as legal frameworks, academic research and other documents and statistical databases; 3) Organization of the data collected and of the information under the three predefined dimensions; 4) Production of the chapters corresponding to the three dimensions defined; 5) Technical workshop with peers in the area of science in order to discuss the draft report; critical reading by the British Council; 6) Consolidation of the final document, with recommendations.

The research was essentially bibliographical and documentary in nature and sought to inventory and describe aspects previously identified as fundamental for the understanding of a certain field of knowledge.

Establishing the field of study of the academic articles

One of the considerations when mapping the teaching of the natural sciences and their technologies in Brazilian school education was to examine what the academic literature has had to say about the field over the last decade. The intention behind a State-of-the-Art survey is to systematize knowledge, aiming to highlight the main themes, as defined by both the number of articles published, trends and privileged aspects (FERREIRA, 2002).

With regard specifically to the survey of academic articles on science teaching, the procedures were as follows: 1) Definition of the reference base; 2) Definition of sub-descriptors for the survey of published articles, under the principal descriptor "science education"; 3) Reading and analysis of the abstracts of articles to establish the adequacy of the selection and the period defined; 4) Selection of the articles most relevant to the scope of the research; 5) Organisation of the database of bibliographical references; 6) Analysis, with a synthesis of the studies that were specifically concerned with initial training and INSET, Teaching Methodologies, where the focus was primary education.

As a first step, the inventory involved the identification of scientific articles published in academic articles indexed on SciELO. This platform includes articles published in the main Brazilian education journals, where the criteria for inclusion are highly rigorous. The collection includes journals evaluated as A1, A2 and B1 in accordance with the *Qualis-Periódicos* tool, which classifies the academic production of post-graduate programmes. It should be said that the area of education benefits from a considerable number of academic publications, given that there is a total of 193 post-graduate programmes in the area throughout Brazil. This means that the systematic review in this paper does not correspond to the totality of journals currently being published, as it is limited to those articles and their respective journals included in the SciELO collection[6].

The initial survey was carried out in March 2021 and the term "science education" was the main descriptor. The application of this descriptor resulted in 281 articles, which were considered the primary reference database and organised in an Excel spreadsheet. The second step was to establish a set of descriptors for use in advanced search filters in the primary database. Sixteen descriptors were applied which, when associated with the descriptor "teaching science +", generated new thematic lists, as shown in the following table.

6
This research did not include theses and dissertations, which would have required more time and a larger team. Also due to the project schedule, it was not possible to include other virtual platforms that also collate academic journals such as Redalyc (an Ibero-American database of bibliographic data and a digital library of open access journals), EDUC@ and the Capes Journal Portal.

Chart 1 Subdescriptors - Teaching of science + descriptor

Additional descriptors	281
1. Currículo [Curriculum]	19
2. Desigualdade [Inequality]	2
3. Didáticas [Didactic]	15
4. Discriminação [Discrimination]	1
5. Diversidades [Diversities]	9
6. Educação básica [School education]	3
7. Ensino fundamental [Primary education]	18
8. Ensino médio [Secondary education]	8

Additional descriptors	281
9. Extensão (projetos de) [Extension courses]	3
10. Formação continuada [INSET]	4
11. Formação de professores [Teacher training]	42
12. Gênero [Gender]	9
13. Licenciaturas [Teacher Training Degrees]	1
14. Metodologias [Methodologies]	7
15. PNLD	5
16. Racismo [Racism]	2
Total articles per keyword	148
Total unclassified articles	133

Source: Prepared by the authors on the basis of a survey of the SciELO platform. Consulted in March 2021.

An analysis on the basis of the 16 previously defined descriptors revealed an excess of 133 articles that did not fit into any of the descriptor combinations in this first exercise. The next step was, therefore, to produce an organised database of all 281 articles on the basis of the 16 descriptors, this time applying the keywords set by the authors of the articles.

This reorganised database included the following information: the complete reference of the article, the access link, year of publication, abstract, author keywords, search defined descriptors. From this worksheet, it was possible to identify the main journals dedicated to the topic of science teaching. Table 2 below shows that there is a concentration of publications in journals located in public higher education institutions in the Southeast of Brazil, specifically the journal *Ciência & Educação* published by the Graduate Programme in Science Education of the Faculty of Science of the Júlio de Mesquita Filho São Paulo State University (UNESP), Bauru[7]. The next-ranking journal, in terms of the most published articles related to the teaching of science was *Ensaio, Pesquisa em Educação em Ciências*, published by the School of Education of the Federal University of Minas Gerais (UFMG), Belo Horizonte. The survey did not identify any journals published in the Northeast of Brazil, while one in the North of Brazil was included. The important role of the periodical published in the name of the Sociedade Brasileira de Física (Brazilian Society of Physics) should also be highlighted. It is important to stress that the SciELO platform does not include all the journals published in Brazil in the area of education, and these data should therefore be considered in relative terms, even if they express the notorious regionalisation of higher education in the country.

7

Published since 1995, the publication includes topics related to science and mathematics education, but also studies that generate knowledge about the teaching and learning of Physics, Chemistry, Biology, Geosciences, Astronomy, Health Education, Environmental Science and related areas (Qualis A1).

CHART 2 REGIONAL DISTRIBUTION OF JOURNALS PUBLISHING THE ARTICLES LOCATED IN SCIELO – DESCRIPTOR: SCIENCE TEACHING

NOME DOS PERIÓDICOS	Nº DE ARTIGOS	REGIÃO	UF	INSTITUIÇÃO
Revista Brasileira de Estudos Pedagógicos (RBEP – Inep, Brasília–)	1	DF	CO	Inesp
Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas (MCTI/ Emílio Goeldi Paraense Museum, Belém do Pará)	1	North	PA	MCTI/MGoeldi
Ciência & Educação (UNESP, Bauru, Post-graduate Programme in Education for Science, Faculty of Science)	153	Southeast	SP	Unesp
Ensaio, Pesquisa em Educação em Ciências (UFMG, Faculty of Education, Belo Horizonte)	63	Southeast	MG	UFMG
Educação em Revista (on-line) (FAE/UFMG)	15	Southeast	MG	UFMG
Educação e Pesquisa (Faculty of Education/University of São Paulo (USP)	6	Southeast	SP	USP
Cadernos CEDES (Cedes – Centre for Education and Society Studies, State University of Campinas (Unicamp), Campinas, SP)	2	Southeast	SP	Unicamp
Estudos Avançados (Institute of Advanced Studies, USP)	2	Southeast	SP	USP
Ensaio: Avaliação e Políticas Públicas em Educação (Cesgranrio Foundation, Rio de Janeiro)	2	Southeast	RJ	Cesgranrio
Cadernos de Pesquisa (Carlos Chagas Foundation (FCC), São Paulo)	2	Southeast	SP	FCC
Pro-Posições (Unicamp – Faculty of Education, Campinas, SP)	1	Southeast	SP	Unicamp
Educação & Sociedade (Journal of Science in Education; Cedes – Centre for Education and Society Studies, State University of Campinas (Unicamp), Campinas, SP)	1	Southeast	SP	Unicamp
Trabalho, Educação e Saúde (Scientific Journal of the Joaquim Venâncio Health Polytechnic School, Oswaldo Cruz Foundation, Manguinhos, Rio de Janeiro)	1	Southeast	RJ	Fiocruz
Scientiae Studia (USP)	1	Southeast	SP	USP
História, Ciências, Saúde – Manguinhos (Casa de Oswaldo Cruz, Oswaldo Cruz Foundation, Rio de Janeiro)	1	Southeast	RJ	Fiocruz
Paidéia (Faculty of Philosophy, Science and Literature, USP, Ribeirão Preto, Post-graduate Programme in Psychology)	1	Southeast	RJ	USP
Papéis Avulsos de Zoologia (Zoology Museum, USP)	1	Southeast	SP	USP
Educação & Realidade (Federal University of Rio Grande do Sul (UFGRS) – Faculty of Education, Porto Alegre)	2	South	SP	UFGRS
Revista Brasileira de Ensino de Física (on-line), Brazilian Society of Physics	18	National		SBF
Revista Brasileira de Educação (ANPEd – National Association of Post-graduate Studies and Research in Education)	2	National		ANPEd
Revista Brasileira de Educação Especial (Brazilian Association of Researchers in Special Needs Education)	2	National		ABPEE
Revista Brasileira de História da Educação (Brazilian Society of the History of Education)	1	National		SBHEd
SUM OF ARTICLES	**281**			

Source: Prepared by the authors on the basis of a survey of the SciELO platform. Consulted in March 2021.

The articles were then reclassified on the basis of a combination of the descriptors, authors' keywords and abstract reading, resulting in the categories for analysis in the following table:

Chart 3 Categories for organisation of articles

Category	Description	N - 279
Literacy and science literacy	Science literacy	11
Curriculum	Teacher training curriculum and school curriculum	5
Themes related to inequality, rights and inclusion	Gender, ethnic/racial relations, racism, human rights, citizenship, inclusion, popular and traditional knowledge	22
Science education + specific disciplines	Teaching Environmental Science, Biology, Computing (IT)	7
Teacher training	Initial training, INSET and teacher identity	56
History	History of science, history of science teaching, history of education, history of physics, history of education in science, history of school disciplines	19
Teaching methodologies and practices	Pedagogical practices; didactic, didactic sequences	91
Textbook and National Textbook Plan	Analysis of textbooks and the National Textbook Plan	16
State of the art	Literature reviews: theses and dissertations on different subjects related to science teaching	28
Other themes	Themes that did not fit into the defined categories	24

Source: Prepared by the authors on the basis of a survey of the SciELO platform. Consulted in 2021.

In this reorganisation of the data, we sought to reclassify each article as precisely as possible, preferably in only one category, one that fully expressed the main focus of the research approach published. Any classification, however, is arbitrary to some extent, due to the objectives of the study.

The articles corresponding to the period 2010 to 2020 were then reclassified, limited to a more recent research period , considering the post-LDB, NCP, etc. period. In addition, the themes which recurred most frequently were selected, but also those that met objective 3 of the mapping exercise to at least some extent. *Identify and analyse critical aspects and specific highlights of the field of teaching the natural sciences and its technologies with emphasis on themes, such as initial training and INSET; school and extracurricular curricula (museums, laboratories, fairs, science Olympics and competitions); science teaching (effective and inclusive science teaching methodologies); access to scientific knowledge and scientific dissemination.*

The final organisation, discussed in detail in Chapter 6, prioritised five themes: Teacher training; teaching methodologies and practices; Curriculum; Literacy and scientific literacy; Themes related to inequalities, Rights and Inclusion. However, articles present in the State of Art category, related to reviews of literature or the work of a specific author, were included under some of the chosen themes, when relevant.

Attention should be drawn to the concentration of articles in category Teaching Methodologies and Practices, 91 (32.6%), which refer especially to the method of teaching, the use of tools and techniques, and also reflections on teaching practices. Another highlight is the group of 56 articles (20%) on teacher training and teacher identity.

Chart 4 Category and final number of articles included in the organisation

Category	N	N-2010-20	Analysis
Teacher Training	56	23	12
Teaching Methodologies and Practices	91	55	28
Curriculum	5	05	4
Literacy and Science Literacy	11	09	6
Themes related to Inequality, Rights and Inclusion	22	19	14
Total	**185**	**112**	**64**

Source: Prepared by the authors on the basis of a survey of the SciELO platform. Consulted in March 2021.

3

The teaching

of science within the legal framework: curricular references

The regulations and guidelines that underpin educational policies through specific legislation, commonly referred to as the legal framework (laws, decrees, resolutions, etc.), expresses a historical process of society defining the political, economic and sociocultural aspects of what it desires for education in Brazil.

Responsibility for the Brazilian educational system is shared between the federation (education guidelines and regulations), the states/Federal District (responsible for primary education, in collaboration with the municipalities, and secondary education) and the municipalities (responsible for primary and nursery education), each with specific responsibilities and regulations but acting in collaboration, especially with regard to the provision and quality of teaching. However, the entire existing educational system, including the attributions of each federal entity, is within the framework established by the Federal Constitution (CF) of 1988 and the Law of National Education Guidelines and Bases (LDB) of 1996, the latter aiming to regulate and direct the curricular structure of the schools. In this topic, the aspects that affect science education will be highlighted within the legal framework of Brazilian education.

The inclusion of science education in school education is strongly related to the process of curricular renewal in the 1950s and 1960s, which aimed to both strengthen science education and prepare Brazilians to exercise citizenship and to work. In the following decades, this movement grew with the 1971 Law of Guidelines and Bases, which included the compulsory teaching of science, initially in secondary education and then at all levels of schooling. The process was consolidated with the LDB (1996) with the National Curriculum Parameters (NPC) and the educational policies of the first decade of this century. As the comprehensive educational development of children becomes more prominent, science education became associated with the "debate of the great social themes, emphasising the importance of literacy and scientific literacy for the effective exercise of citizenship" (GARVO; SLONGO, 2019, p. 693).

In the field of education , the Constitution and the other regulatory documents that derive from it highlight school education as an important vector, both for the access of people to the knowledge produced by humanity and goods and services and to generate a workforce capable of ensuring the future economic and social development of Brazil. With regard to the specific field of natural sciences and their technologies, it is important to cite Constitutional Amendment No. 85, which amends and adds provisions in the Federal Constitution to stimulate scientific and technological development and innovation. In essence, it establishes a number of constitutional provisions that make it possible to link the state with public and private entities. One of its main objectives is to boost national research and the creation of technological solutions that improve the performance of the productive sector. In the educational field, this amendment is intended mainly to benefit higher education, with the possibility of direct financing of research and innovation projects.

National Curriculum Parameters – PCN

The PCN (BRAZIL, 1998) has contributed significantly to supporting and guiding the school curriculum, defining as objectives of primary education to develop in students the capacity to position themselves in a critical, responsible and constructive manner in different social situations, based on the understanding of citizenship concepts such as social and political participation, as well as the exercise of political, civil and social rights and responsibilities. Besides knowing the fundamental social, material and cultural aspects of Brazil, developing the critical questioning of reality – using the various languages and knowing how to differentiate their sources – formulating problems and addressing them, through logical thinking, creativity, selecting procedures and verifying their appropriateness.

According to the PCN, the role of the natural sciences is to support an understanding of the world and its transformations, situating people as active individuals and an integral part of the universe. The concepts and procedures of the natural sciences provide more explanations of the phenomena of nature, broaden the understanding and questioning of the different ways of intervening in the natural world, and also to the understanding of the most varied ways of using natural resources. In Primary Education, the suggested core themes are Environment, Humanity, Technological Resources, Earth and the Universe. The first three core themes are developed in all four stages of education; the Earth and Universe theme is developed only in the last two stages (BRAZIL, 1998). While not being compulsory, the PCN, in any case, supported the schools' pedagogical policy planning (PPPs) and guided the National Textbook Programme (PNLD), guiding the evaluations of textbooks.

In 2000, the National Curriculum Parameters for Secondary Education, in turn, arose from the reform of this final stage of school education, which, according to the document itself, highlights two factors as triggers: (i) the structural changes resulting from the so-called "knowledge revolution", changing the way in which work and social relations are organised; and (ii) the growing expansion of the public school system, in particular the last stage.

The document is organised in four parts, the first being formed by the legal framework, defining the "new secondary education", including the presence of the Education Guidelines and Bases Act of 1996. The others are subdivided into three major areas of knowledge, focusing on the learning focus, skills and abilities, and directions and challenges of each of the areas. (LOPES; MACEDO, 2006).

Specifically, considering the sciences, Patrícia Pino, Fernanda Ostermann and Marco Antonio Moreira (2005) attribute to the parameters an attempt to present a constructivist vision for knowledge. However, these authors warn, the concept of science would be described as if it were "a recipe that takes us step by step to scientific laws". According to them, this assumption can lead to the idea that the right way of doing science is to follow an empirical-inductive programme. Supporting the criticism of Pino, Ostermann and Moreira (2005), Carlos Alberto Souza, Fábio da Purificação de Bastos and José André P. Angotti, consider that the curricular changes are not enough for these new concepts to reach the students, since "the insertion of scientific-technological education in the school curriculum has encountered difficulties, since a proposal for curricular change demands a set of related actions directed toward and by those subject to the educational process" (2007, p. 80). These criticisms are reinforced by current approaches, also related to the BNCC in recent articles, such as those by Estevão Antunes Júnior, Cláudio José de Holanda Cavalcanti and Fernanda Ostermann (2021), who presented an analysis of science teaching as guided by the BNCC. Focusing on the final years of primary education, drawing attention to a certain direction of the document toward an incipient perspective of the interaction with the STS – Science, Technology and Society movement,

[...] that aligns with voices that strengthen the idea of scientific neutrality and the myth that scientific development always brings, as a consequence, technological development and social well-being. Or even the perspective of utilitarian science, which emphasises too much the study of scientific concepts conditioned to their pure and simple application in everyday life. (ANTUNES JÚNIOR; CAVALCANTI; OSTERMANN, 2021, p. 1342)

In any case, the PCN has supported the inclusion of socially relevant themes in the areas of knowledge, contributing to the strengthening of a political agenda aimed at recognising and redressing historical inequalities in education. In this sense, changes were incorporated into the LDB with the aim of enforcing the right to education for more people for longer and on the basis of the principles of equality, freedom and tolerance, plurality of ideas, valuing the out-of-school experience and its links with work and social practices. An emblematic example in this regard is Law No 10.639, of 2003, as amended by Law No 11.645, of 2008, which establishes the teaching of Afro-Brazilian and indigenous history and culture in all schools, public and private, from primary to secondary education. Wider discussion of ethnic and racial issues is fundamental to all areas of knowledge; therefore, besides critically examining the history of Brazil and its resulting cultural and social structure, it also seeks to give visibility to the wisdom and knowledge of underprivileged groups in society. The discussions about non-hegemonic epistemologies in science have gained strength and legitimacy in the educational area through the implementation of this law.

The discussions about non-hegemonic epistemologies in science have gained strength and legitimacy in the educational area through the implementation of this law.

With regard to science teaching, the strategies proposed aim for an understanding of the concept of nature and its scientific and technological representation, including questioning the uses of this knowledge in relation to the society and culture to which we belong.

Marzani Garvão e Iône Slongo (2019), tracing the history of science as a discipline in the official school curriculum in Brazil, point out that in the curricular reforms of the early 1960s there was a focus on science education as preparation for work and the experience of the scientific method. Over the last few decades, however, the focus has shifted to “the comprehensive education and development of the child”, associating the “teaching of science with the debate on the great social themes, emphasising the importance of scientific literacy and understanding for the effective exercise of citizenship” (GARVO; SLONGO, 2019, p. 698).

This process of reflection is linked to recent understandings and achievements in the educational field: if, at first, science was considered a neutral activity by those concerned with it, free from value judgements, as social issues arose, environmental and economic issues were related to scientific production and a critical and reflexive movement emerged in the fields of sociology, anthropology and education. One of the exponents of this view is the sociologist Thomas Kuhn, whose classical publication "The Structure of Scientific Revolutions" (1962) significantly influenced studies in the field of STS, as part of the critical movement. According to Estevão Antunes Júnior, Cláudio José de Holanda Cavalcanti and Fernanda Ostermann (2021, p. 1341),the STS movement emerged at

> **[...] the mid-20th century, with the aim of placing Science and Technology (ST) on a more democratic basis, mainly due to the cold war and associated with the space race. This movement was, however, linked to the European and American scenario, which prompted engineers and scientists to establish a critical approach to thinking about ST in the Latin American context.**

As with so many movements concerned with building knowledge in Brazil, controversies and debates emerged. The STS perspective has been especially important in the discussion and formulation of education laws and regulations in Brazil, ensuring that there are debates and discussions about the fundamental issues in order to understand the direction of science education in school education. It can be considered one of the strategic areas in terms of forming a population that is critical, aware and participatory. In the articles covered by this survey, the presence of the STS movement is quite significant, as will be seen below, especially when the subject is science literacy and understanding. It is committed to a critical perspective of the *status quo*, its epistemological reference being the teachings of Paulo Freire, which also influence the Citizen Science movement, which seeks to bring together scientists and society in general, very present in Brazilian science education. This debate has encouraged analysis of the national science education curriculum.

Brazilian Common Curriculum

The Brazilian Common Curriculum (BNCC) is founded in Article 210 of the Constitution, which sets out the need to establish the minimum content to be covered in primary education and ensures a universal school education standard. Approved in 2017 for nursery and primary education and in 2018 for secondary education, it defines the essential skills and knowledge to be made available to all children and young people in Brazilian school education, as established in Article 9 of the LDB. All public and private schools must, in theory, ensure that their curricula have a minimum content in common. The intent of this legislation is to reduce inequality in learning and to ensure the same opportunity for access to knowledge established as relevant by the LDB. The expectation is that it will be implemented as a collaborative effort between federal,

> **[...] state and municipal educational authorities to renew the curriculum, while respecting the freedom and autonomy of the schools and educational authorities, by means of consultative processes involving the schools and surrounding communities, strengthening the democratic principle in schools and ensuring the relevance of the curriculum to the needs and characteristics of the region in which they are based. (CENTRO DE REFERÊNCIAS EM EDUCAÇÃO INTEGRAL – CREI, 2019, p. 11)**

The common curriculum was given a legal basis in the LDB/1996 (Article 26) and, according to the document, it is guided by ethical, political and aesthetic principles aimed at comprehensive education and the construction of a just, democratic and inclusive society, as is based on the General National Curriculum Guidelines for School Education (2010, Article 14) and in the Federal Constitution itself (1988, Article 10).

The BNCC was supposed to be implemented between 2019 and 2020. However, with the start of the Covid-19 pandemic at the beginning of 2020 and the resulting financial and political crisis in Brazil, the implementation has been delayed, but continues throughout 2022, with an emphasis on INSET, specifically those working in secondary education.

It may be that this period of transition is extended, as the context remains critical and, in the case of the municipal and state education systems, there remain several challenges to complete all the stages involved in introducing the curriculum, including public consultations, teacher training, timetable alterations and school infrastructure, as well as addressing the impact of suspending the classroom-based classes, the return to in-person education and the effects of the pandemic on the learning process.

One of the most incisive insights is the fear that the BNCC will not be able to engage in dialogue with other issues of the Brazilian reality, such as the challenges it faces in relation to learning and performance, running the risk of becoming dead in the water even before it is introduced (GIROTTO, 2019). In the context of the curriculum, the criticism concerns the standardisation proposed in the common curriculum and the possible risks involved in establishing a rigid structure for both assessment purposes and to underpin teacher training, minimizing the diversity of social contexts and identity (GIROTTO, 2019; DIOGENES; VALOYES; EUZEBIO, 2020). In addition, there is the question of ensuring effective processes are in place to implement the common curriculum at all stages, especially in secondary education, such as ensuring student participation and the use of technologies in both the preparation and implementation of the activities proposed in the school.

Science Teaching and the BNCC

The BNCC is structured around a series of fundamental learning goals that should be accessible to all and achieved as the student passes through the various stages of their school life. In summary, it is based on the rights to knowledge, competences and skills which relate to concepts and content organised in thematic units.

The specific BNCC propositions for the Natural Sciences (BNCC – S) is organised into three themes – the Earth and the Universe, Life and Evolution and Matter and Energy. It is clear about how the themes should be addressed,

One of the most incisive insights is the fear that the BNCC will not be able to engage in dialogue with other issues of the Brazilian reality.

how they should be inserted into the different school stages and in the different curricular components. Many of the propositions of the PNC were kept, though differing in emphasis and detail (BRANCO et al., 2018; ANTUNES JÚNIOR; CAVALCANTI; OSTERMANN, 2021). The main objective of the document can be resumed as offering students at different stages of their education the opportunity to experience the processes that lead to science literacy, by providing them with gradual and progressive access to specific content, in a manner defined as working with a 'spiral curriculum', where the same topics are revisited in greater depth in succeeding stages of education, and an investigative approach. As they follow the curriculum, students' experiences and interests with regard to the natural and technological world should be valued until the end of their school education helping them, especially in secondary education, to build the skills and autonomy they require to operate in the society we live in.

The current curriculum design contextualizes the local, social, and individual reality already found in the Curriculum Guidelines (DCN), which were drawn up the National Education Council (CNE) in the 1990s, which were updated in the 2000s. This scope was expanded in 2010 by the new DCN, with the addition of inclusion, the appreciation of differences and a concern for plurality and cultural diversity, recovering and respecting the various manifestations of each community (CNE/CEB No. 7) (BRAZIL, 2010c).

Considering that the educational concept enshrined in the BNCC prioritizes interdisciplinarity, transdisciplinarity and transversality, the curriculum proposals should aim at the development of the student as a critical, responsible and ethical being, able to make scientifically based decisions that can impact on the transformation of the society in which they are inserted by means of actions.

With regard to primary education, the curricular concern with the natural sciences is scientific literacy, which is defined as "the ability to understand and interpret the world (natural, social and technological), but also to transform it, based on theoretical contributions to the full exercise of citizenship" (BRAZIL, 2018, p. 321). This reference presupposes an articulation between several fields of knowledge and teaching practices that stimulate scientific interest and curiosity. This concern can be found in the academic literature and in studies that investigate both initial training and INSET, as well as in studies of teaching practices and methodologies.

However, the implementation of the BNCC-C and the scope of its assumptions presupposes an alignment with the initial training curricula and a systematic approach to INSET. In addition to the presence of an infrastructure that is not necessarily found in the other documents that compose the legal framework of education in Brazil. Girotto (2019), questioning the absence, for example, of a science lab in most schools, warns of the challenge of effectively realizing the proposals of the curriculum, interfering in the relationship between theory and practice. In fact, data extracted at a later stage from the school census confirm the absence of laboratories in Brazilian schools, not only scientific laboratories, but also computer laboratories, which require financial investment, as well as specialised maintenance and staff.

In terms of content, secondary education is concerned with the extension and systematisation of the essential conceptual knowledge gained during primary education: the social, cultural, environmental and historical contextualisation of the sciences; the processes and practices in research, and the language of the natural sciences, with a focus on the disciplines of Biology, Chemistry and Physics. It is important to point out that the text related to this stage was approved at a later stage because it was linked to an educational reform (Law No 13,415) (BRAZIL, 2017c), which introduced a new model for secondary education, increasing the minimum number of school hours from 800 to at least 1,000 per year (to be achieved by 2022) and defining a new, more flexible curriculum that includes the National Common Curriculum Base (BNCC) and the opportunity for secondary students to opt for different learning paths for each area of knowledge and on technical and professional training.[8]

With regard to the natural sciences and its technologies, the expectation is that in secondary school the knowledge gained in primary education will be widened and deepened, developing the student's ability to understand life and the planet and to reflect and argue, face challenges and be positive.

8

Completion of secondary education should be achieved within a maximum of 1,800 school hours delivered under the New Secondary Education regime (LDB, Article 35-A, para. 5).

The idea that natural sciences and their technologies should refer to current local and global concerns is paramount in order to prepare young people to solve problems. The overall subject will be addressed through the specific areas of Biology, Physics and Chemistry, developing a deeper understanding of Matter and Energy, Life and Evolution, and the Earth and the Universe, developing on the content of the primary education curriculum. Because the BNCC is not intended to cover the specific content of each discipline, the challenge of including specific knowledge when preparing reference curricula will be the responsibility of the education authorities.

The BNCC is silent about the practical aspects of its implementation. As it states, this is a "national reference for the formulation of curricula of the school systems and networks of the states, the Federal District and the municipalities, and the pedagogical proposals of the schools" (BRAZIL, 2017a). Therefore, the document is a guide for educational policies and pedagogical projects focusing on the development of the competencies required from a comprehensive education. To this end, it suggests the formation of the citizen by means of a non-linear path, in which students can revisit themes and problems, deepening their understanding as their cognitive processes mature, so that they are respected as individuals actively involved in the process, and that their choices and decisions are valued.

Nevertheless, it is necessary to provide the opportunities and conditions to experience investigating practices, so that students can exercise and expand their repertoire through observations and the organisation of information through collaborative work and logical reasoning, so that they understand the situations explored in depth and know how to translate the knowledge they gain into wider contexts.

The flexibility proposed by the format of the new secondary education is intended to take account of the plurality of interests of students. However, the curricular references set by the Ministry of Education (MEC) are insufficient for the preparation of learning paths that prioritize not only education for practical purposes, but also an educational process that includes the development of investigative skills related to the scientific knowledge appropriate to the age group. The challenge lies in giving meaning to general school education by creating learning pathways which are integrated with a knowledge of the practical application of the student's studies, focused on the needs of their future work and life.

The BNCC, even before it was given final approval and the start of its introduction, mobilised researchers and teachers from the field of education, but also from the specific areas that are part of science teaching, such as Physics, for example, who were concerned with the complexity of the new curriculum proposal and its feasibility. Zanatta and Neves (2016) comment that the BNCC alone will not be able to improve the quality of teaching and learning, and therefore stress the importance of changes in the curricula of teacher training degrees, in order to include the development of the skills and competences that the school should prioritise. In addition, they point out that:

Some aspects of the natural sciences should be explored more, such as the epistemological character of science, the question of interdisciplinarity, the amount of content and the relational connection between the content taught, as well as the timetable hours devoted to each discipline. (ZANATTA; NEVES, 2016, p. 9)

jIn addition, the authors point out that Biology, Physics and Chemistry content in primary education all form part of a single knowledge area – General Science. Even in the final years of secondary education, the BNCC (now approved and being introduced) maintains the overall perspective of integrating specific knowledge into its general natural sciences and its technologies curriculum. The impact of the transition from primary to secondary education is known, when each of the subjects included in the natural sciences has its own units of knowledge, even though they should be integrated into the overall syllabus, as recommended in the BNCC.

Other authors say that the role of creativity is not included in the production of knowledge, nor is the role of theories and their relationship with research (LEITE; RITTER, 2017), and it does not make clear the relationship between experimentation, modelling and theories. They signal frustration over the persistence of a view of science that is limited to experimentation as the principal way of understanding the work and processes of science. A concern that is common to many authors is the apparent demotion of learning based on historically systematised content to give space to skills and abilities (WHITE; ZANATTA, 2021). In passing, it should be said that the pedagogy already found in the PNC is restated in the BNCC, especially for secondary education, taking into account the proposals for the reform of secondary education. The question is that details of the specific skills and abilities required for each of the school disciplines are not given (VIEIRA; NICOLODI; DARROZ, 2021).

Even though the view that the ability to interpret and understand the world from the basis of scientific theories is extremely relevant is clear in the BNCC, the document does not explain what actions and conditions need to be in place so that it can actually happen. The studies identify the lack of an important discussion on the minimum conditions required, including teacher training, giving value to scientific knowledge, improved access to educational and structural resources in schools (WHITE et al., 2018). The criticisms, concerns, and gaps that have been pointed out will feed new research in the coming years that will address the process of introducing the BNCC. Between disruption and continuity, this dynamic, which involves the critical analysis of educational policies, is fundamental to evaluating the results of the precepts of the BNCC as they are translated into pedagogical policy plans. It is necessary to understand and observe the introduction of the BNCC and its subsequent impact. This process will require coordinated actions, involving all aspects, from updating teacher training degree curricula to investment in INSET, the focus of which needs to be on teaching methodologies and practices, to giving attention to ensuring appropriate conditions for the work of the teacher and school infrastructure. One area that should not escape any analysis of the results of this curricular change in Brazilian education is recognition of the significant social and economic inequalities that affect children and young students, which is also expressed in the unequal distribution of public resources dedicated to schools, which contributes to the persistance of regional inequalities (ENCINAS; DUENHAS, 2020).

Training Science Teachers -

from the Legal Framework to the Challenges of Professional Development

Initial teacher training - advances and challenges

Over the last decade, the issue of initial teacher education has become more prominent in Brazil as the result of new regulations and specific educational policies which aim to improve the quality of Brazilian education and the educational indicators. This context has stimulated a series of studies and systematic approaches intended to support a broad diagnosis of teaching in Brazil (GATTI; BARRETTO, 2009; GATTI; BARRETTO; ANDRÉ, 2011; GATTI et al., 2019).

The educational regulations and policies governing teacher education are the focus of various challenges and criticisms by the academic community. One of the most incisive relates to the regulatory framework, which is prescriptive and requires that the curricula of teacher training courses be restructured, disregarding the complex nature of the thinking behind the degree courses in pedagogy and teacher training and the diverse nature of the contexts the trained teacher will be required to work in, as well as the social and cultural plurality of students (RODRIGUES; PEREIRA; MOHR, 2020).

In their book *Políticas docentes no Brasil: um estado da arte* (2011) [Teaching Policies in Brazil: the State of the Art], Bernardete Gatti, Elba de Sá Barretto and Marli André discuss questions which strengthen our understanding of the current position. The authors point out the link between teacher-related policies and other educational policies, including financing, assessment and initial teacher training, in this case the drafting of teacher training degree curricula.

According to Bernardete Gatti (2014), in the second half of the 20th century, the public school systems expanded rapidly over a short period of time. This increased the need for teachers but this demand was not accompanied by an adequate, up-to-date teacher training structure. (GATTI, 2014, p. 35).

The educational regulations and policies governing teacher education are the focus of various challenges and criticisms by the academic community.

The National Curriculum Guidelines for Initial Teacher Training for School Education and the Common National Requirements for Initial Teacher Training for School Education (BRAZIL, 2015d; BRAZIL, 2019b) emerged during these discussions and called into question the references currently used to guide the training of teachers.

Some important points in the document reaffirm the importance of broad-based teacher training, such as the issues related to the LDB (9394/96), updated in 2014, the PCN and the FC, which describe the inclusion of comprehensive themes in teacher training, in addition to theoretical and practical concepts that contribute to forming citizens through high-quality education free from dogmas and preconceptions. Among the core themes highlighted in the document, which were widely discussed in the meetings where the National Education Plan (PNE) was drafted, was the subject of teacher training, underpinned by the

Ensuring broad-based teacher training while, at the same time, providing the specialised training required to ensure safety and quality shows the complex process of building a professional teaching force.

> **[...] deliberations of the 2010 and 2014 National Education Conferences (Conae), as well as a long process involving studies, consultations and discussions, innovative experiences and proposals, research results, educational indicators, assessments and perspectives on initial training and INSET for school education, from the perspective of the challenges facing the Brazilian State to ensure effective quality standards for the training of the teaching force [...] (BRASIL, 2015d, p.4)**

Ensuring broad-based teacher training while, at the same time, providing the specialised training required to ensure safety and quality shows the complex process of building a professional teaching force. Some texts recognise the issues impacting on teacher training, partly due to the strong specialist degree culture see in pedagogy courses, as well as teacher training courses that are out of touch with the reality of Brazilian schools, according to Patrícia Almeida et al. (2020, p. 16):

> **It should be remembered that teaching teachers to teach is a complex task, which is challenged for teacher training courses and, in particular, for the trainers themselves, who are the protagonists of teaching practices through their concepts, explanations and approaches to teaching the curriculum to future teachers.**

For this reason, it is essential to understand the experience of initial teacher training. With this in mind, a group of researchers recorded a number of inspiring training experiences. Gisela Tartuce and Marina Nunes (2020), in writing about training practices of a teacher of the anthropology of education, resonates with texts that do not neglect the learning to be found in a community of practice. Following the same line, they cite Beserra (2016) for whom continuing teacher training needs to happen between a

> **[...] group of people who share the same vocation. Formed informally to carry out various tasks, such communities can also be created formally to develop knowledge of a specific area. The members learn from each other by sharing their experiences, *enabling all of them to develop as a result.* (BESERRA, 2016, p. 97, apud TARTUCE; NUNES, 2020, p. 35, our emphasis)**

Following this rationale, Gatti warns us that "there is no coherence between the policies for initial teacher training and the needs of school education and its quality, especially in the early years" (2014, p. 38). She warns us while legislation requires the universities responsible for teacher training to reform their curricula,

> **[...] this matching of the curriculum to the current needs of school education cannot be done solely to the regulations and decrees, although that is important, but is a process that must also be done as part of the normal routine of the university. In order to do this, it is important to overcome deep-rooted concepts and habits perpetuated over time and to be able to innovate. Here, the creativity of higher education institutions, their managers and teachers is being challenged – the challenge is not minor, when faced with both an academic culture accustomed to playing internal power games and the interests of large corporations. (GATTI, 2014, p. 36)**

The offer of teacher training courses has kept pace with the expansion of school education in Brazil, but there are many gaps in what is offered by the universities and colleges, as well as a misalignment between theory and practice. This observation is linked to the fact that the curriculum for initial teacher training requires updating and reformulation to address the challenges of scientific literacy with quality.

According to Gatti (2014), the problem with the curricula of initial teacher training courses is they are generally related to the fact that there is no centralised and specific approach to the training of new teachers or an explicitly stated shared professional profile, to the extent that

[...] although most of the pedagogical projects for teacher training courses, be they specifically of pedagogy or of other areas of knowledge, have an abstract view of the professional they intend to train. The area in which the teacher will work is not considered or used as a reference when constructing the curriculum and the courses. This reveals a dissonance between what is presented in the pedagogical projects and the set of disciplines offered and their contents. Ideas do not materialise in the training actually offered, while theory and practice are not integrated. (GATTI, 2014, p. 39)

The lack of definition of an overarching professional profile for the teacher implies little structuring and standardisation of basic training courses for teachers, as Gatti points out, which leads to a disconnection between the curricula available in universities and the practice required on a day-to-day basis. In the view of the author, therefore, there is a strong need for the actual field of work of teachers to be a reference for their training. The author explains that the teacher training model dates from the 20th century, inspired by the scientific concepts of the 19th century, with little margin for innovation:

[...] only a superficial coating of pedagogical training and its foundations is offered in these courses, which cannot be considered as an effective training programme for professionals who work in present-day schools. (GATTI, 2014, p. 39)

She also comments on the issue of the constant expansion of the offer of distance learning courses (hereafter EAD). If we consider the data from the Census of Higher Education, it shows that in 2009, 70% of the pedagogy courses were EAD, in addition to 61% of the teacher training courses in Mathematics and 55% of the Language and Literature teacher training courses. In addition, the census shows that 58% of teacher training graduates studied am EAD course.

EAD is a solitary activity, which requires that those studying are proficient in reading and interpreting texts, abilities which are not always favoured by digital interaction with course tutors and mentors. There is also a lack of social contact and of an academic culture that promotes dialogue and interaction between students from the same area and others, in addition to diverse experiences, such as participation in student movements and in university life in general. In addition to the difficulties associated with EAD and the gap between the concept of teaching and the actual training offered by universities, there is an additional difficulty in the case of science teachers:

Science educators have historically faced a series of challenges that include *following scientific and technological discoveries,* constantly introduced into daily life, and making scientific advances and theories understandable to primary school students, *making them available in an accessible way.* This requires a sound theoretical and methodological approach to knowledge and dedication to (trying) to keep up to date while exercising their profession. For many educators, such challenges are compounded by *shortcomings in their teacher training courses, be they from public or private universities* – because the speed with which concepts develop and new technologies emerge makes teacher education “obsolete” a few years after grad

Not only do the problems lie in the way courses are updated – or are not updated – or in the fact that the concept of education seems to be outdated in relation to current trends in pedagogy worldwide, but the challenges of renewing the specific area of the natural sciences exposes weaknesses in the initial training of teachers.

In addition, according to Natany Assai, Fabiele Broietti and Sergio Arruda (2018), a gap can be seen in the view of supervised placements as part of teacher training. The authors present a panoramic state of the art review of the research on the theme and identify that few of them consider placements as integrated formative spaces involving the collaboration of various people. After 2008, and based on the legal frameworks of 2009, 2015 and 2016, with the guidelines for teacher training, more academic studies regarding institutionalised placements as university policy have been published, especially after the implementation of the Institutional Introduction to Teaching Programme (PIBID), established by Decree No. 7.219 of 24 June 2010 (BRAZIL, 2010c), which clearly states that its purpose is to support a certificated introduction to teaching programme aiming at improving the performance of school education and, more recently, the pedagogical Resident programme. They are programmes aimed at students training to become teachers, offering paid placements in state schools. The focus is building the teacher's identity through experiences and practices in the school environment in a collaboration between the school system and the university.

Although mandatory, Gatti (2014, p. 40) has some concerns regarding the placements which are part of all teacher training courses:

[...] most of the placements involve observation: the students look for school placements on their own, without a work plan and collaboration between higher education institutions and schools is absent. Frequently their supervision is general and just a bureaucratic process, depending on the number of teacher trainees to be supervised by just one teacher at the higher education institution.

The curriculum of the teacher training programmes be rethought in order to achieve the effective integration of theory and practice, rethinking the concept and practical application of the mandatory placement.

It is essential, according to this author, that the curriculum of the teacher training programmes be rethought in order to achieve the effective integration of theory and practice, rethinking the concept and practical application of the mandatory placement. Although studies have shown significant improvements, since 2008 there has been a clear need to update the placement programme and to adapt it to meet the theories, methodologies and practices directing current educational policies, such as the BNCC. In this regard, and citing other studies on the subject, Assai, Broietti and Arruda (2018, p.2) argue that the placements should enable the student to reflect on professional activity and help them develop a critical view of the "school dynamics of existing relationships in the institutional field and to enable the development of new knowledge".

Following the same approach, in a recent survey-based study of pedagogical practices in schools, Patrícia A. Almeida, Gisela L.B.P. Tartuce, Bernardete Gatti and Liliane Bordignon recommend strengthening the

> **[...] partnerships between higher education institutions (HEIs) and schools through placements and other curricular components, in order to provide real experiences to future teachers in the state school networks. All the actions mentioned benefit from the HEI-school partnership. (ALMEIDA et al., 2021, p. 137)**

INSET (In-Service Education and Training) – an engine for teacher development

The life cycle of education professionals only starts with their initial training, supervised placements or educational residencies being part of the cycle. It features strongly in many studies of initial teacher training as a continuous process of learning and exercise, leading to the concept of Professional Teacher Development (PTD), referring to the idea of cycles or phases of professional development (ALMEIDA et al., 2020).

Claudia Davis *et al.* (2011), in a review of the literature on INSET, point to the recurrent justification due to the limitations of initial training. It would therefore have the main function of closing gaps, updating and improving teaching. Bernardete Gatti (2014) points in the same direction – to the difficulty of reversing the effect of poor initial teacher training:

> **Remedying the impact of poor initial teacher training is not something that can be done in days or months. Even with all the technology available, when it comes to training professionals, short cuts are not possible. It is not possible to implant knowledge chips into humans. *This is something that has to be undertaken over a long period of skills development and professional maturity*, just as with our physical and physiological growth. (GATTI, 2014, p. 42; our emphasis)**

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In this sense, the author establishes an expectation in the face of the challenges in implementing INSET programmes that, in some way, are able to build upon the initial training as part of PTD. However, it should be pointed out that there is no consensus about or definition of the term "INSET". As Gatti stated earlier, in 2008 (p. 57), the concept is sometimes reserved for structured courses, sometimes for a wider definition:

> **[...] under this label, comes a diverse range of courses, including courses that lead to the award of a professional diploma at the secondary or higher education level. Many of these courses include an element of distance learning, ranging from an entirely virtual format via the Internet, to blended learning involving printed material.**

The author contextualises the emergence of so many INSET courses, especially in the South and South-east of Brazil, as the consequence of a widespread "discourse about the need to update and renew" (2008, p.58) which led to a variety of institutions becoming involved in INSET, from private entities to NGOs, foundations, and government at all levels. She argues, however, that some of these initiatives were reacting to and compensating for identified issues:

> **[...] concrete problems in the education systems inspired INSET initiatives, especially in the public sector, following the revelation, through various means (research, recruitment of state teachers, assessments), that the initial teacher training courses did not (and still do not) provide an adequate basis for their professional activity. (GATTI, 2008, p. 58)**

Educational reforms, the expansion of state education, combined with the attempt to overcome the fragility of initial teacher education already pointed out by the cited academic studies (GATTI, 2008; GATTI; NUNES, 2009; DAVIS et al., 2011), among many others, have been contributing to the fact that initial teacher training and INSET are gaining increasing interest in the sector, with the expansion of studies, but also with specific regulations, guidelines and policies, Like the Common National Basis for INSET (BNC) (2020), which expands on the National INSET Curriculum Guidelines for School Teachers (BRAZIL, 2020).

There are specific aspects of teacher training, understood as a continuous process capable of supporting the professional development of teachers and teachers, which should not, of course, restrict it to initial training. However comprehensive the initial training may be, it is limited to the needs of academic education and is focused on the development of skills, attitudes, values and knowledge that enable future teachers to build their identities and knowledge.

On the other hand, INSET needs to be built upon the structure established in the first years of professional development, being linked to teaching practice,

> **[...] so that the knowledge and skills built during initial training can be reviewed and reconstructed throughout their career, in a process that promotes the professional development of the teacher. It emerges, therefore, as a possibility of continuing the process of building teaching professionalism, providing the teacher with options to increase their awareness of the educational needs of their students as well as their own needs and difficulties, so that, through critical reflection, they build alternatives to overcome them. (LEONE, 2011, p. 240)**

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Although, in theory, INSET seems to be a good solution, specialists such as Nascimento et al. (2000), in dialogue with Blaszko and Ujiie (2019), ponder on the general ineffectiveness of INSET, since

> **[...] the courses proposed, most of the time, are short-lived and *do not relate to the daily life and reality of the school* ; the subjects addressed do not contemplate the actual needs of teachers; there is *a mismatch between theoretical studies and practical activities*; A large number of courses do not cover the various disciplines in the school curriculum, such as the teaching of science, among others. (BLASZKO; UJIIE, 2019, p. 3; our emphasis)**

A key point raised by Louzano et al. (2010) concerns the need for INSET to be part of a broader policy of teacher training, because if it is not conceived together with issues such as attracting teachers and the quality of education, the training will be ineffective.

Other research points to the fundamental role of teachers in the process of reproduction, but also in relation to confronting gender and race inequalities (REZNIK *et al*., 2017; ROSA; MENSAH, 2016; among others), both because of the multiplier effect on student education, by example and reference on the choice of future careers, and also because of its role in promoting quality education that allows access to higher education.

Training Science Teachers

The legal framework, which took as its starting point the 1988 Constitution, shows that the regulatory aspects of Brazilian education are still in preparation and being improved. The current focus on the school curriculum and the initial training of teachers and INSET – which also implies dealing with the training curriculum – creates a favourable moment for critical reflection on science teaching.

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It can be said that the challenges for the operationalisation of curricular policies in normal schoolwork so that the students are able to interact actively in building science and technology knowledge are still considerable. Claudio Dantas, Neusa Massoni and Flávia Santos (2017) discuss this scenario from the basis of an analysis of assessment policies in science teaching and point to the need to bring theoretical discussions into teacher practices. According to them, if, on the one hand, we are currently going through a productive moment with regard to theoretical discussions and the drafting of regulations for the teaching of science in schools, this is not the case in the schools themselves. While sharing this proposition, we should add two further major challenges to be faced in the coming years. The first of these is the effective implementation of the BNCC in order to ensure scientific literacy in the different stages of education; the second is related to teacher training, aiming to qualify teachers to meet the needs of the school curriculum.

According to Fabrício do Nascimento , Hylio Laganá Fernandes and Viviane Mendonca (2010), it is important to understand the changes in perspective regarding the teaching of science in Brazil to understand the limits and challenges of scientific and academic progress in the country:

Considering the social and environmental problems caused by scientific and technological progress, it is necessary to open up science to public knowledge, demystify its traditional essentialist and philanthropic image, and question its application as inevitable and beneficial in the long run (VEIGA, 2002). A new social contract is necessary, in order to build a science socially committed to the real needs of the majority of the Brazilian population and not limited to accumulating knowledge and advancing without any concern for the direction. From this perspective, science and technology would no longer be seen as autonomous activities that follow only an internal logic and would be understood as processes and products in which non-technical aspects, such as values, personal and professional interests, economic pressures, among others, play a decisive role in its production and use. (NASCIMENTO; FERNANDES; MENDONÇA, 2010 p. 227)

In this passage, the authors defend the importance of teaching that science is at the service of society right from the first stages of a university education. Of late, we have experienced various challenges that directly impact the way in which educational and scientific policies and, more specifically, those relating to teachers, are being considered. For example, the National Campaign for the Right to Education (2021) presented a study on the impacts of austerity measures and labour, tax and administrative reforms, and how they extended the structural inequalities experienced and aggravated in recent years in the context of the pandemic. All have multiple layers, such as changes and reduction of the role of the State, the relaxing of formal labour conditions and the dismantling of those public services which are guaranteed and universally assured to all Brazilians. It may be that current policies adopted will have a major negative impact on how we think of the school and do/teach science in Brazil.

Professional master's degrees and the Teaching of Science

The professional master's degree is a postgraduate qualification that, unlike an academic master's degree or doctoral studies,

[...] can be attributed to the influence of the educational policies proposed by international organizations, such as the Organization for Economic Cooperation and Development (OECD) and the World Bank (WB), for central and peripheral countries, aiming to improve education to meet the needs of the world market and to the next step in the internationalisation of capitalism. In this view, INSET is seen as the cheapest and most efficient way to train teachers; and improving the quality of education is attributed exclusively to teachers through the school performance of students in general, as measured by large-scale testing. (OSTERMANN; RESENDE, 2015, p. I)

What distinguishes this approach is that the intention is to provide technical rather than scientific training for the profession. Ostermann and Resende (2015) criticise this approach, especially in relation to the policy of implementing this form of training, which

> **[...] leaves aside the issue of the teaching career being unattractive. It is with this concern that more critical voices have pointed out that all teaching education policy should be fully integrated into career structures, from ensuring adequate living wages to adequate working conditions which, according to Maués (2011), are not part of the OECD agenda. (OSTERMANN; RESENDE, 2015, p. I)**

The authors identify some problems with the professional master's degree, beyond the structural issue of the teaching career, which makes it unattractive to individuals seeking to progress in a career structure that does not exist. As an example, they speak of the fact that it is universities that offer these master's degrees, when it would be more beneficial for the student to study in the school itself by forming communities of practice, collectives (KUENZER, 2011, *apud* OSTERMANN; RESENDE, 2015). They also point out that this type of degree tends to be content-heavy, favouring technical rather than pedagogical specialists. For the authors:

> **On the other hand, we believe that training should be aimed at those professionals who can reflect on the relationship between education and society, including current aspects of Brazilian education, such as: curricular policies, the purposes of secondary education and science education for society. If this guidance were to be followed, it would be appropriate to identify the problems facing schools and to shape the theoretical and methodological frameworks according to the nature of these problems (OSTERMANN; RESENDE, 2015, p. (II)**

With this thought, the authors propose that the model be revisited to train professionals with a more critical and integrated view of society. In addition to the criticisms of the pedagogical model, they also question the efficiency of the professional masters course, believing that this type of postgraduate course will not necessarily guarantee professional improvements, nor will it help overcome the shortage of teachers, since most of those who graduate from a professional masters course do not remain in the schools where they originally taught, often migrating to higher education or to the Federal Institutes of Education, Science and Technology.

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> **One of the great problems we identified with professional master's courses is not mentioned [by Ostermann and Resende, 2015], which would be to take the logic of a dual education (the classical separations between introductory and the technical, the insistent difference between education for the better off groups and education for the worker) to the postgraduate level. (BOMFIM; VIEIRA; DECCACHE-MAIA, 2018)**

While emphasising the successes they have identified in professional masters at the Federal Institute, with a focus on Physics, the authors also raise a number of criticisms.

> **The contradictions of the professional masters, especially those designed for state teachers, are enormous, but some are not exclusively theirs, but emanate from the overarching policies that are imposed on education in Brazil: the need for immediate results, the need to reach large numbers without establishing the structure required, the urgency of numbers, the prioritisation of some sectors to the detriment of others, the idiosyncrasies of managers, the almost total lack of planning, the proselytism of some groups, precarious working conditions, the relaxing of rules, the focus on academic work, among others. In many situations, it seems to us that these elements are behind the various proposals for professional master's degrees, and that is why constant vigilance is needed. However, it is not by proposing an INSET programme instead of what is understood to be the "precarious continuous education" of a professional master's programme, or by characterising the training of those studying for a masters as being technical or excessively ideologizing the destiny of those who graduate, saying that they are leaving school teaching, or even hypothesising the role and reach of the professional masters (such as solving the problems with Brazilian school education), that we will overcome all challenges and inconsistencies. (BOMFIN; VIEIRA; DECCACHE-MAIA, 2018)**

These remarks by the authors point to the need to improve the professional master's courses, above all by: (i) reforming the curricula and integrating training with practice, both from the point of view of the individual activities and in relation to building a local community of school practice; (ii) updating course methodologies, focusing on pedagogical development beyond the technical aspects; (iii) linking of the qualifying of teachers to attractive career paths.

An extensive set of quantitative data on teacher training degrees and teaching function follows, based on information provided by INEP and derived from the Census of Higher Education. An examination of public policies for teacher education, whether initial or in-service and associated with recent data, contributes to giving an idea of the scale, complexity and challenges of training science teachers in Brazil.

5 A picture of the last decade of school science teaching from the Census of Higher Education (CES) and Census of School Education (CEB)

An important aspect to be considered when reflecting on science teaching is to consider how the legal frameworks, the BNCC, INSET programmes and the researched literature itself relates to the reality experienced in initial teacher training degrees and to that in classrooms, based on the profiles of science teachers.

The picture to be presented here refers to a specific period of time, with an emphasis on the last decade (2010-2020). The information refers to the years 2010, 2015 and, in particular, the figures for 2019, based on the Census of Higher Education (CES)[9], and 2020 from the Census of School Education (CEB)[10], produced by INEP. The years 2010 and 2015 help to show the changes observed in the access, frequency and destination of undergraduate teaching degree students, the provision of school laboratory facilities and in profile of teachers in schools.

The ample set of quantitative information included here aims to provide a macro view of Brazilian higher education, with a focus on the teaching degrees for those wishing to teach the natural sciences and its technologies. The fall in the number of students enrolling for these degrees, the participation of EAD, and the demographic and geographical characteristics of the students are important to help us understand the profile of future schoolteachers. From another perspective, it is also important to understand the matching of the training provided to the reality the teacher faces in the classroom.

Two axes of analysis were highlighted: (i) initial teacher training, based on data on teacher degree courses related to the teaching of the sciences; (ii) the provision of science and computer laboratories for school students and the profile of teachers working in the classroom.

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The Census of Higher Education has been carried out since 1995 in all higher education institutions in Brazil. More information available at: https://www.gov.br/inep/pt-br/areas-de-atuacao/pesquisas-estatisticas-e-indicadores/censo-da-educacao-superior. Accessed on 17 Feb 2021.

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Also called a School Census, data started to be collected from schools in 1996. More information available at: https://www.gov.br/inep/pt-br/areas-de-atuacao/pesquisas-estatisticas-e-indicadores/censo-escolar. Accessed on 17 Feb 2021. The difference in years is due to the non-availability of CES data when the information is collected.

A picture of the last decade of school science teaching from the Census of Higher Education (CES)

The following analysis consists of disaggregated data from the Higher Education Census (CES) for six specific teacher training degree courses: **Training of General Science Teachers, Biology Teachers, Physics Teachers, Chemistry Teachers, Mathematics Teachers and Computing (IT) Teachers.** In addition to the subject directly involved in teaching the natural sciences, Biology, Physics and Chemistry, we extend the spectrum with information on Mathematics, General Science and Computing to present a more reliable picture of science teaching in school education, with a focus on the students/teachers who will be active in the final years of primary education and in secondary education.

It should be noted that the course nomenclature was changed by INEP in 2018 with the reordering of the names, for example: Chemistry – Teacher Training. However, it was decided to maintain the identification used in 2010 and 2015 censuses, which is based on the Eurostat/UNESCO/OECD International Classification.

Information from the Synopses of Higher Education was used to construct a general panorama on the basis of data on those entering the selected the courses and those graduating. Microdata were processed using the Statistical Package for the Social Sciences (SPSS) programme, examining data on gender and colour/race , as well as data on the location of the courses.

The choice of teacher training degree courses includes those that offer academic training for the teaching of the subjects included in the area of natural sciences and its technologies in school education, with the addition of Mathematics and Computing.

Student Enrolments on In-person and EAD Courses in Public and Private Institutions

The data analysed refer to information on enrolment rates by teaching mode and by administrative category, considering 2019 (Tables 1, 2 and 3). and the variation between the administrative category and the teaching mode for the periods 2010 to 2015 and 2015 to 2019 (Tables 4 and 5). The choice of these periods is due to the changes observed and described in the literature (RISTOFF, 2016; VIEIRA, 2017), which point to an expansion of the higher education network at the start of the second decade of the century, especially of federal and private institutions. However, other studies show that there is still significant stratification and heterogeneity in the quality of school education[11] (HERINGER, 2013; RIBEIRO; GUSMÃO, 2011).

Enrolments are higher for classroom-delivered degree courses, as shown in **Table 1**. In the set of degrees selected for the overview, courses such as General Science, Biology, Physics and Chemistry are mostly classroom-based. However, there is an expansion in the number of EAD courses, offered mainly by private institutions, partly as a possible reflection of the economic crisis that began in 2014 and worsened in the following years (MANCEBO, 2017; SOUZA; ALVES, 2018). Attention is drawn to the percentage of EAD enrolments in Mathematics courses (46.5%) and Computing courses (46%).

The largest number of enrolments in teacher training courses, covering those who qualify as teachers of the natural sciences in schools, are found in Mathematics and Biology courses, and the lowest number is in Computing and General Science courses.

Policies for the expansion of primary and secondary education and, subsequently, the creation of several new Federal universities and scholarship programmes have contributed to the expansion of access to higher education in recent decades.

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As shown by the project Excellence with Equity supported by the Lemann Foundation, Itáu BBA and Credit Suisse Hedging-Griffo Institute, 2016.

Table 1: Distribution of enrolments in HEIs by course modality, Brazil and selected degrees, 2019[12]

	Course mode – 2019				
	Classroom-based	%	EaD	%	Total
Total enrolment – Brazil – higher education	6.153.560	71,5	2.450.264	28,5	8.603.824
Total for all selected teacher training courses	**181.357**	**68,4**	**83.795**	**31,6**	**265.152**
Science Teacher Training	9.927	95,2	503	4,8	10.430
Biology Teacher Training	58.623	73,9	20.686	26,1	79.309
Physics Teacher Training	24.196	80,2	5.979	19,8	30.175
Chemistry Teacher Training	31.459	81,7	7.058	18,3	38.517
Mathematics Teacher Training	51.244	53,5	44.545	46,5	95.789
Computing Teacher Training	5.908	54,0	5.024	46,0	10.932

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019.

It is worth making a comparison between these data and those presented in the study by Bernardete Gatti, Elba de Sá Barretto and Marli André (2011) on enrolment in the Higher Education Census (2009) referring to EAD courses: in that year the enrolment rate for Mathematics was 28.3%; Chemistry, 14.7%; Physics, 19.5%; and Biological Sciences, 18.3%. What is observed is an expansion in the last ten years of this type of teaching training, especially for Mathematics. A possible explanation may be that the other disciplines require laboratories for practical activities, which for private HEIs would increase the cost of the courses, an aspect already pointed out by Bernardete Gatti, in an article published in 2014 (p. 38; our emphasis):

The concern that educators and researchers express about EAD is not about the modality itself, which, as we have already said, is rich in possibilities, but about the way it has been developed in Brazil and its relevance to different types of training. EAD courses *require teaching teams with good training in the area and also specific aspects of teaching in this modality; sophisticated and agile technologies; well-produced and tested materials*; well-installed delivery facilities; well-trained monitors or tutors, both in the knowledge of areas and in the use of educational technologies, supported and monitored systematically; well-designed control systems with adequate personnel; consistent learning assessment, etc. These aspects are not always to be found in EAD courses in Brazil.

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Table reading orientation: The sum (100%) is in the row. The analysis refers to each of the selected degree courses. Brazil Enrolment – Total HEIs refers to the set of enrolments in all undergraduate courses offered in that year.

In the same article, the author reports that "61% of the teaching degrees in Mathematics are delivered via EAD". The base years for the census, as are the metrics. In this scenario, the analysis refers to the enrolled students who are studying for different teaching degrees, which is different from Gatti, who uses the percentage of teaching degree courses as a measure, where each course may have a different number of enrolments.

When the enrolment data for the courses delivered using the different modalities are related to the status of the institution (federal, state or private), it reveals the important role of public higher education in the classroom-delivered mode for teacher training aimed at teaching science in basic education, as shown in **Table 2**. When considering the *status* of the institution as a reference, the first aspect to be noted is the high incidence of EAD enrolment in private HEIs, at 93.6% (Table 2). The proportion of EAD courses in public HEIs is minimum, at 3.3% in federal institutions and 3.0% in state institutions. 68.8% of total enrolments in classroom-based teaching degrees are in private HEIs. Federal institutions are responsible for 20.4% of enrolments in classroom-based courses, double the number of enrolments in state institutions, at 9.5%.

Looking at the distribution of the enrolments in teacher training degrees in Table 1, the smallest number of enrolments was in Computing and General Science courses, at 10.933 and 10.430 respectively. 95.2% of General Science degree enrolments were in classroom-based courses, 54% in Computing (Table 1). Table 2 demonstrates that the majority of the courses were in federal HEIs: at 84.1% for classroom-based Computing courses and 54.8% in EAD Computing courses. The majority of the General Science courses are classroom-based, at 84.7%. The classroom-based Biology and Mathematics teacher training degrees in Federal HEIs had the largest number of enrolments, at 29,718 and 28,233 respectively, as against 9,562 and 5,023 in private institutions. In other words, three times more students are enrolled in classroom-based Biology courses and almost five times more in Mathematics courses.

Inverse reasoning can be applied to EAD courses, where private HEIs that have a significant participation in the training of teachers for teaching science, especially in the courses for teachers of Biology, Physics and Chemistry. In these institutions, classroom-based courses are less common than in public institutions, the maximum rate, for Biology, being 16.3%. All other courses in the selected group are below 10% (Table 2).

Although higher education in Brazil is predominantly private (75.8% of total enrolment in HEIs), most of the students in teacher training degree courses for the natural sciences and their technologies are enrolled in classroom-based courses in federal HEIs, at 61.2% (Table 2). The only case where enrolments in federal and private HEI teacher training degree courses get close is the case of Mathematics, at 37,799 and 35,144 respectively (summing classroom-based and EAD courses, Table 2).

Table 2: Distribution of enrolments in HEIs by course modality, Brazil and selected teaching degrees, 2019[13] [14]

Sector and Modality	**State**								**Private**				**Total**			
	Federal				State Government											
	Classroom-based		**EaD**		**Classroom-based**		**EaD**		**Classroom-based**		**EaD**		**Classroom-based**		**EaD**	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
All Brazil.	1.254.065	**20,4**	81.189	**3,3**	582.134	**9,5**	74.451	**3,0**	4.231.071	**68,8**	2.292.607	**93,6**	6.153.560	**71,5**	2.450.264	**28,5**
All Selected	111.061	**61,2**	21.677	**25,9**	50.095	**27,6**	11.254	**13,4**	17.619	**9,7**	50.671	**60,5**	181.357	**68,4**	83.785	**31,6**
Teacher Qualified in:																
General Science	8.404	**84,7**	347	**69,0**	1.278	**12,9**	155	**30,8**	148	**1,5**	1	**0,2**	9.927	**95,2**	503	**4,8**
Biology	29.718	**50,7**	3.968	**19,2**	18.331	**31,3**	4.025	**19,5**	9.562	**16,3**	12.638	**61,1**	58.623	**73,9**	20.686	**26,1**
Physics	17.755	**73,4**	2.685	**44,9**	5.580	**23,1**	586	**9,8**	774	**3,2**	2.703	**45,2**	24.196	**80,2**	5.979	**19,8**
Chemistry	21.981	**69,9**	2.359	**33,4**	7.317	**23,3**	627	**8,9**	2.037	**6,5**	4.004	**56,7**	31.459	**81,7**	7.058	**18,3**
Mathematics	28.233	**55,1**	9.566	**21,5**	16.726	**32,6**	4.793	**10,8**	5.023	**9,8**	30.121	**67,6**	51.244	**53,5**	44.545	**46,5**
Computing	4.970	**84,1**	2.752	**54,8**	863	**14,6**	1.068	**21,3**	75	**1,3**	1.204	**24,0**	5.908	**54,0**	5.024	**46,0**

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019.

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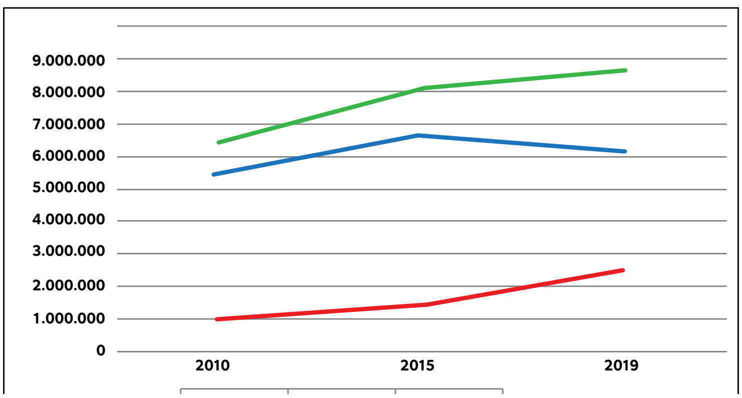
Reading the table: Percentage per modality per subject, summing to 100% Each of the selected teacher training degrees is analysed by sector and modality (classroom or EAD). For example, classroom-based courses are 84.7% + 12.9% + 1.5% = 99.1%. The information is totalled by line. The total Brazil enrolment number.

14
Given the low number of municipal institutions offering the courses (1% in 2019), they were disregarded.

A key analysis for understanding the enrolment picture for the selected teaching degrees is to consider the variation in a given period, as described below, in **Tables 3** and **4** for the periods 2010 and 2015; 2015 and 2019. It is important to consider the number of students in each course, due to the impact on variations in each of the defined periods. For this purpose, **Chart 1** shows, as an illustration, the changes observed in the total number of enrolments for the classroom-based and EAD modalities.

The growth observed between 2010 and 2019, shown in Chart 1, is due to the EAD modality, which increased from 930,000 enrolments to 2.5 million. The increase in classroom-based courses occurred between 2015 and 2010, with more than 1 million enrolments, as can be seen in **Table 3.a**, as well as a small drop in new enrolments between 2019 and 2015 of almost 480,000.

Variation in enrolment for the classroom-based and EAD modalities, according to the selected years, Brazil.



	2010	2015	2019
Classrom based	5.449.120	6.633.545	6.153.560
Ead	930.179	1.393.752	2.450.264
Total	6.379.299	8.027.297	8.603.824

Fonte: Elaboração das autoras com base nas sinopses do Censo da Educação Superior 2019.

Table 3.a: Distribution of enrolments in HEIs by course modality and selected teaching degrees, Brazil – 2010 to 2015[15]

		Total	Computing (IT)	Biology	General Science	Physics	Mathematics	Chemistry
Classroom-based	2010	5.449.120	5.681	77.818	11.793	19.505	59.464	29.233
	2015	6.633.545	6.328	67.129	10.650	21.288	54.170	31.143
	Variation	**21,7%**	**11,4%**	**-13,7%**	**-9,7%**	**9,1%**	**-8,9%**	**6,5%**
EaD	2010	930.179	2.760	19.087	1.313	5.871	23.328	4.309
	2015	1.393.752	4.667	16.185	796	3.024	28.567	4.027
	Variation	**49,8%**	**69,1%**	**-15,2%**	**-39,4%**	**-48,5%**	**22,5%**	**-6,5%**
Total	2010	6.379.299	8.441	96.905	13.106	25.376	82.792	33.542
	2015	8.027.297	10.995	83.314	11.446	24.312	82.737	35.170
	Variation	**25,8%**	**30,2%**	**-14,0%**	**-12,7%**	**-4,2%**	**0,0*%**	**4,8%**

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2010 and 2015.

15 Table reading orientation: Each cell represents the variation in enrollment between 2010 and 2015. For example, for General Science, the calculation is: 10,650 (N 2015) - 11,793 (N 2010) = -1,143 / 11,793 = -9.7%. *The value of 0.0% is the rounded number 0.06% (55 students), due to the precision factor used in the tables

The first period analysed – 2010 to 2015 – presents two distinct scenarios: an increase of 25.8% in the total number of enrolments in Brazil, with emphasis on the EAD modality, with an increase of 49.8% (Table 3.a). There is a decrease in enrolment in most of the teaching degrees selected for analysis: enrolments in three courses (General Science, Biology and Physics) decreased, one remained stable (Mathematics), while Computing had a significant increase (30.2%) and Chemistry enrolments increased by 4.8%.

In private HEIs, the change is due to a reduction in the offer of classroom-based courses and a transfer to the EAD modality, with the exception of Biology (EAD – 12.8%) and General Science (EAD – 98.7%) courses. All classroom-based courses in private HEIs had negative rates, ranging from -33.4% in Physics to -82.5% in General Science (Table 3.b).

On the other hand, the offer of classroom-based courses in the six courses in federal HEIs increase while EAD declined, except for Computing, with growth of 48.7%. State-funded HEIs show a drop in the classroom-based offer in four of the six courses, with a minimal increase in Chemistry and Biology, with a slight variation of 1.1% , but growth in the EAD offer in four of the six courses: Computing, Chemistry, Biology and General Science (Table 3.b).

The largest increase in enrolment in Computing courses was in federal HEIs: a 104% growth, concomitant to a decrease in state (-14.5%) and private (-21.9%) enrolments (Table 3.b).

Table 3.b: Distribution of enrolments in HEIs by course modality and selected teaching degrees, Brazil – 2010 to 2015

Sector		Course mode	Period and Variation %	Selected group of teacher training courses					
				Computing (IT)	Biology	General Science	Physics	Mathematics	Chemistry
Public	Federal	Classroom-based	2010-2015	1.731	19.238	4.753	12.007	20.294	13.894
				4.435	26.485	7.627	14.750	23.719	19.132
			Variation	156,2%	37,7%	60,4%	22,8%	16,9%	37,7%
		EaD	2010-2015	1.586	5.954	892	4.926	11.700	3.129
				2.358	3.191	318	1.748	9.169	2.008
			Variation	48,7%	-46,4%	-64,4%	-64,5%	-21,6%	-35,8%
		Total	**2010-2015**	**3.317**	**25.192**	**5.645**	**16.933**	**31.994**	**17.023**
				6.793	**29.676**	**7.945**	**16.498**	**32.888**	**21.140**
			Variation	**104,8%**	**17,8%**	**40,7%**	**-2,6%**	**2,8%**	**24,1%**
	State Government	Classroom-based	2010-2015	2.583	18.006	4.293	5.773	19.671	7.292
				1.441	18.204	2.471	5.347	17.010	7.367
			Variation	-44,2%	1,1%	-42,4%	-7,4%	-1,1%	1,1%
		EaD	2010-2015	141	2.631	341	488	3.319	305
				887	3.809	477	252	1.971	616
			Variation	529,0%	44,8%	39,9%	-48,4%	-40,6%	101,9%
		Total	**2010-2015**	**2.724**	**20.637**	**4.634**	**6.261**	**22.990**	**7.597**
				2.328	**22.013**	**2.948**	**5.599**	**18.981**	**7.983**
			Variation	**-14,5%**	**6,7%**	**-36,4%**	**-10,6%**	**-17,4%**	**5,1%**
Private		Classroom-based	2010-2015	1.365	37.430	2.336	1.673	17.022	7.607
				452	20.223	408	1.099	10.727	4.274
			Variation	-66,9%	-45,9%	-82,5%	-33,4%	-36,9%	-43,8%
		EaD	2010-2015	1.033	10.475	80	457	8.287	866
				1.422	9.134	1	1.024	17.402	1.356
			Variation	37,7%	-12,8%	-98,7%	124,0%	110,0%	56,6%
		Total	**2010-2015**	**2.398**	**47.905**	**2.416**	**2.130**	**25.309**	**8.473**
				1.874	**29.357**	**409**	**2.123**	**28.129**	**5.630**
			Variation	**-21,9%**	**-38,7%**	**-83,1%**	**-0,3%**	**11,1%**	**-33,5%**

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2010 and 2015.

The period from 2015 to 2019 coincides with a worsening of the economic, social and political crisis faced by Brazil. This context is reflected in the rate of growth of higher education, four times lower than that observed between 2010 and 2015, with a drop in the offer of classroom-based courses of -7.2% and very significant growth in enrolment in EAD of 75.8% (Table 4.a). However, the rate of change in enrolment numbers – 36.8% for General Science – shows that there was no offer of courses in EAD and even in the classroom mode there is a variation of – 6.8%. It is worth pointing out that the General Science teaching degree courses are for all years of primary education.

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Each cell represents the variation in enrolments between 2015 and 2019. For example: for General Science the calculation is: 9,927 (N 2019) – 10,650 (N 2015) = -723/10,650 = -6.8%. Note: Given the low number of municipal institutions offering the courses (1.5% in 2015 and 1.0% in 2019) they were not included.

Table 4.a: Distribution of enrolments in HEIs by course modality and selected teaching degrees, Brazil – 2015 to 2019[16]

		Total	Computing (IT)	Biology	General Science	Physics	Mathematics	Chemistry
Classroom-based	2015	6.633.545	6.328	67.129	10.650	21.288	54.170	31.143
	2019	6.153.560	5.908	58.623	9.927	24.196	51.244	31.459
	Variation	**-7,2%**	**-6,6%**	**-12,7%**	**-6,8%**	**13,7%**	**-5,4%**	**1,0%**
EaD	2015	1.393.752	4.667	16.185	796	3.024	28.567	4.027
	2019	2.450.264	5.024	20.686	503	5.979	44.545	7.058
	Variation	**75,8%**	**7,6%**	**27,8%**	**-36,8%**	**97,7%**	**55,9%**	**75,2%**
Total	2015	8.027.297	10.995	83.314	11.446	24.312	82.737	35.170
	2019	8.603.824	10.932	79.309	10.430	30.175	95.789	38.517
	Variation	**7,1%**	**-0,6%**	**-4,8%**	**-8,9%**	**24,1%**	**15,7%**	**9,5%**

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2015 and 2019.

In the figures, the overall increase in enrolments between 2010 and 2019 impacts on the selected teacher training degree courses, although at a lower rate. Of note is the predominance of federal HEIs in classroom-based courses and the move by private-sector HEIs into EAD.

Table 4.b: Distribution of enrolments in HEIs by course modality and selected teaching degrees, Brazil – 2015 to 2019

Sector		Course mode	Period and Variation %	Selected group of teacher training courses					
				Computing	Biology	General Science	Physics	Mathematics	Chemistry
State	Federal	Classroom-based	2015-2019	4.435	26.485	7.627	14.750	23.719	19.132
				4.970	29.718	8.404	17.755	28.233	21.981
			Variation	12,0%	12,2%	10,1%	20,4%	19,0%	14,9%
		EaD	2015-2019	2.358	3.191	318	1.748	9.169	2.008
				2.752	3.968	347	2.685	9.566	2.359
			Variation	16,7%	24,3%	9,1%	53,6%	4,3%	17,5%
		Total	**2015-2019**	**6.793**	**29.676**	**7.945**	**16.498**	**32.888**	**21.140**
				7.722	**33.686**	**8.751**	**20.440**	**37.799**	**24.340**
			Variation	**13,7%**	**13,5%**	**10,1%**	**23,9%**	**14,9%**	**15,1%**
	State Government	Presencial	2015-2019	1.441	18.204	2.471	5.347	17.010	7.367
				863	18.331	1.278	5.580	16.726	7.317
			Variation	-40,0%	0,7%	-48,3%	4,3%	-1,7%	-0,7%
		EaD	2015-2019	887	3.809	477	252	1.971	616
				1.068	4.025	155	586	4.793	627
			Variation	20,4%	5,7%	-67,5%	132,5%	143,2%	1,8%
		Total	**2015-2019**	**2.328**	**22.013**	**2.948**	**5.599**	**18.981**	**7.983**
				1.931	**22.356**	**1.433**	**6.166**	**21.519**	**7.944**
			Variation	**-17,0%**	**1,6%**	**-55,4%**	**10,1%**	**13,4%**	**-0,5%**
Private		Presencial	2015-2019	452	20.223	408	1.099	10.727	4.274
				75	9.562	148	774	5.023	2.037
			Variation	-83,4%	-52,7%	-63,7%	-29,6%	-53,2%	-52,3%
		EaD	2015-2019	1.422	9.134	1	1.024	17.402	1.356
				1.204	12.638	1	2.703	30.121	4.004
			Variation	-15,3%	38,4%	0,0%	163,9%	73,1%	195,3%
		Total	**2015-2019**	**1.874**	**29.357**	**409**	**2.123**	**28.129**	**5.630**
				1.279	**22.200**	**149**	**3.477**	**35.144**	**6.041**
			Variation	**-31,8%**	**-24,4%**	**-63,7%**	**63,7%**	**24,9%**	**7,3%**

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2015 and 2019.

The six selected private-sector courses maintained the trend observed in the first five years of the decade (2010-2015), with a drop in enrolments in classroom-based courses. and increased enrolments in EAD in four courses, except for Computing (-15.3%) and General Science (there was only one enrolment in EAD in both 2015 and 2019)[17] (Table 4.b).

The six classroom-based courses in federal institutions saw a growth in enrolments, from 10.1% in General Science and 20.4 in Physics, while the EAD modality also saw growth (4.3% in Mathematics and 53.6% in Physics) (Table 4.b.)

Table 4.c shows the variation in the overall totals of the selected teacher training courses and by sector. There was a drop in classroom-based enrolments over the decade of -10.9%, while EAD enrolments increased by 47.9%. The overall increase over the period was small, at 1.9%.

Table 4.c: Distribution of enrolments in HEIs by course modality and selected teaching degrees, Brazil – 2010, 2015 and 2019

	2010	2015	2019	Variation 2010-15	Variation 2015-19	Variation 2010-19
Classroom-based	203.494	190.708	181.357	-6,3%	-4,9%	-10,9%
EaD	56.668	57.266	83.795	1,0%	46,3%	47,9%
Total	260.162	247.974	265.152	-4,7%	6,9%	1,9%

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2010, 2015 2019.

The values presented in the timeline between 2010 and 2019, in particular the increase in teacher training degree courses in publicly funded HEIs, notably in federal institutions, may be understood as a result of public policies implemented by the federal government, among them the five-year Programme to Support Plans for Restructuring and Expansion of the Federal Universities (REUNI), created in 2007 by Decree No. 6,096 (BRAZIL, 2007b), with a five-year duration. The data presented here demonstrate a greater increase in places on offer between 2010 and 2015 (Table 3.b), with a variation between -2.6% (Physics) and 104.8% (Computing), compared to 2015 and 2019 (Table 4.b), with an increase of 10,1% (General Science) to 23.9% (Physics). The first interval coincides with the period the REUNI programme was operating.

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Given the lack of enrolments, it is considered that no EAD General Science teacher training degree courses were offered.

It is worth pointing out that REUNI was launched in the context of the Education Development Plan (PDE) (BRAZIL, 2007a) for higher education, which also included: National Student Support Plan (PNAE), University for All Programme (PROUNI) and the reformulation of the Higher Education Student Fund (FIES), the latter two intended to fund students enrolled in private HEIs (SILVEIRA et al., 2021). Most of the articles analysing REUNI identified by Silveira et al. (2021) are case studies. Of 187 articles, 114 were specific to an experience at a specific university.

The table below, adapted from information provided by Martins (2019), shows the changes in the profile of federal HEIs during the REUNI programme.

Table 5: Overall Results of REUNI – Brazil – 2007 to 2012

	Number of courses	Places offered	Enrolments			Number of teaching staff	Number of technical staf	Funding
			Daytime courses	Nighttime courses	Total			
2007	2.660	139.875	139.998	139.998	578.536	56.440	88.801	440.031.705
2012	4.672	239.942	251.196	251.196	885.716	71.247	98.364	1.991.826.164
Variation – %	**75,6**	**71,5**	**44,7**	**79,4**	**53,1**	**26,2**	**10,8**	**352.6**

Source: Prepared by the authors on the basis of data from Martins (2019).

Of note is the substantial increase in the resources made available (352.6%), part of which were used to establish new federal universities and to extend and refurbish existing ones. Enrolment increased by 53.1%, most of which were in night classes (79.4%), while the overall number of courses increased by 75.6%.

The relationship between REUNI and teacher training courses was found in Pinto (2012, p. 101):

Decree No. 6096 of 24 April 2007, which established REUNI, included the aim to increase the number of places available on degree courses for students to study at night, mainly in teacher training degree courses, given the lack of secondary school teachers of Chemistry, Physics, Mathematics and Biology.

Another important aspect in analysing the programme is the course completion rate, which can contribute to increasing the number of qualified General Science teachers in schools. We opted to focus on analysing the course completion rate data in the 2019 census, aiming for an overview of the current situation. The following data compares the total enrolment rate with the course completion rate for all HE in Brazil (**Table 6**), with the corresponding rates for the group of teacher training courses selected for this review (**Table 7**).

Table 6: Comparison of Enrolment and Completion Rates, Brazil – 2019

	Enrolments	Graduates	E/C Rates in%
All Brazil HE Enrolments	8.603.824	1.250.076	14,5
Total for all selected teacher training courses	265.152	30.437	11,5
Course:			
General Science	10.430	1.151	11,0
Biology	79.309	11.426	14,4
Physics	30.175	2.459	8,1
Chemistry	38.517	3.945	10,2
Mathematics	95.789	10.670	11,1
Computing (IT)	10.932	786	7,2

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019.

As in previous tables, the division by sector in **Table 7** shows the predominance of federal institutions in teacher training courses in the selected group. Summing the classroom-based and EAD modalities, they are responsible for 58.8% of those who graduate. It is clear that a significant percentage of teachers graduating come from classroom-based courses (67.9%), and that over half of them come from federal institutions (50.8%). This impact on the participation rates of each of the courses.

The overall complete rate in Brazilian higher education is only 14.5% of total enrolment, according to Table 6. Of these, 74.7% are in classroom-based courses (Table 7). Considering the selected group of teaching degree courses, only 11.5% of the total number of enrolments completed the course in 2019 (Table 6), most of them in the classroom-based modality (67.9%), while in the EAD courses, the rate was 32.1% (Table 7). To understand the low success rate in higher education, including data on those who successfully graduate, further analysis is required, which will not be undertaken at this stage. However, a possible hypothesis is the cost of higher education to the students, above all given the increase in private-sector higher education, and for the need for young students to balance study with work due to social inequality.

Table 7: Distribution of enrolments in HEIs by sector and course modality, Brazil and selected teaching degrees – 2019[18]

	State								Private				Total			
	Federal				State Government											
	Classroom-based		EaD		Classroom-based		EaD		Classroom-based		EaD		Classroom-based		EaD	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Total Brazil - 1.259.076	144.828	**15,5**	4.845	**1,5**	79.998	**8,6**	7.008	**2,2**	694.831	**74,4**	303.871	**96,1**	934.037	**74,7**	316.039	**25,3**
Total selected courses - 30.437	10.308	**50,8**	784	**8,0**	5.621	**27,7**	523	**5,3**	4.022	**19,8**	8.455	**86,4**	20.275	**67,9**	9.784	**32,1**
Teacher Training:																
General Science	769	**69,3**	14	**34,1**	275	**24,8**	26	**63,4**	15	**1,4**	1	**2,4**	1.110	**96,4**	41	**3,6**
Biology	3.691	**42,6**	185	**6,7**	2.464	**28,4**	194	**7,0**	2.239	**25,8**	2.375	**86,1**	8.667	**75,9**	2.759	**24,1**
Physics	1.278	**69,8**	100	**15,9**	439	**24,0**	15	**2,4**	109	**6,0**	513	**81,7**	1.826	**74,5**	628	**25,5**
Chemistry	1.809	**60,6**	97	**10,1**	698	**23,4**	15	**1,6**	446	**14,9**	838	**87,3**	2.953	**75,7**	960	**24,6**
Mathematics	2.357	**42,5**	324	**6,3**	1.650	**29,8**	232	**4,5**	1.194	**21,5**	4.565	**89,0**	5.201	**51,9**	5.128	**48,1**
Computing (IT)	404	**78,0**	64	**23,9**	95	**18,3**	41	**15,3**	19	**3,7**	163	**60,8**	518	**65,9**	268	**34,1**

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019.

The Biology courses have the highest graduation rate, at 11.426, which represents 14.4% of the total number of enrolments (Table 6). Most of these students are in classroom-based courses (75.9%), mainly in the federal HEIs (Table 7). Two teacher training courses have graduation rates below 10% in relation to the enrolment rate: Computing/IT (7.2%) and Physics (8.1%, Table 6). Those who graduated from these two courses have studied mainly in the classroom-based mode (74.5% and 65.9%, respectively), and 69.8% studied at federal HEIs (Table 7).

Mathematics, however, has the largest number of enrolments, at 95,789, but ranks second in the number of successful graduates, at 10,670. These are divided between classroom-based (51.9%) and EAD (48.1%) (Table 7). Of those who graduated in EAD Mathematics teaching courses, 89.0% studied at private sector institutions.

18
Percentage per modality, summing to 100% Each of the selected teacher training degrees is analysed by sector and modality (classroom-based or EAD). For example, for science courses overall, the sum for the classroom-based mode is 69.3% + 24.8% + 1.4% = 95.1% (remembering that enrolment for courses run by municipal institutions was disregarded). Enrolments Brazil – Total HEI refers to the set of enrolments for all undergraduate courses offered in the year, disregarding the municipal HES values due to their low participation in the total of those graduating (1.2% in 2019).

Table 8: Distribution of enrolments in HEIs by enrolments and graduates, by sector and course modality, Brazil and selected teaching degrees – 2019[19]

Sector and Modality	2019							
	Classroom-based %				EaD %			
	Federal		Private		Federal		Private	
	Enrolments	Graduates	Enrolments	Graduates	Enrolments	Graduates	Enrolments	Graduates
Comparison of Enrolment and Graduation Rates Brazil	**20,4**	**15,5**	**68,8**	**74,4**	**3,3**	**1,5**	**93,6**	**96,1**
Teacher Training								
Biology	50,7	42,6	16,3	25,8	19,2	6,7	61,1	86,1
Physics	73,4	69,8	3,2	6,0	44,9	15,9	45,2	81,7
Chemistry	69,9	60,6	6,5	14,9	33,4	10,1	56,7	87,3
Mathematics	55,1	42,5	9,8	21,5	21,5	6,3	67,6	89,0

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019.

To complete these first analyses, Table 8 presents a comparison between the rates by sector and modalities for enrolled students and graduates for 2019[20]. This table was constructed from the information in Tables 2 (enrolments) and 6 (graduates). Comparing the columns of enrolled students and graduates, a drop is observed between the participation of the graduates in the federal population compared to that of the total enrolled (20.4% and 15.5%). The opposite situation is to be seen in the private HE sector: regardless of the modality and the course, the graduation rates exceeded those of the enrolled. How are these differences to be understood? Are they related to the different paths followed in public sector HEIs as opposed to the private sector (where the cost to the student is always an issue), and does the quality of the courses vary? Does the private sector make it easier for students to graduate? There are some possibilities to be considered and that require new studies, such as the comparison of students' performance in the National Student Performance Survey (ENADE) by sector and modality.

19
Orientation for reading the table: The sum of percentages is in the row for each of the conditions (enrolment and graduate), separated by classroom-based and EAD. For example, for Biology, the sum for classroom-based courses is: 50.7% + 16.3% = 67.0%, remembering that enrolments in state institutions, which represent 31.2%, was excluded.

20
We chose to present only the comparisons for federal and private HEIs (excluding state funded HEIs) and the courses with the highest rates (excluding Computing and General Science).

Profile of the students studying in the selected teacher training courses

A profile of the students on the basis of the microdata provided by INEP follows, considering gender, colour/race and location of the selected courses[21].

The impact of gender and colour/race on access to HEI has already been analysed in the literature (ARTS; RICOLDI, 2015; BELTRAO; TEIXEIRA, 2004; CARVALHO, 2009; ROSEMBERG, 2002): there are more women studying in higher education, but in courses considered to be less prestigious, related to the education and care sectors. Black students follow the same profile as women, despite still being in a minority in undergraduate courses. These markers of inequality should be analysed in their intersectionality, on the basis of four groups: white women, black women[22], white men and black men, as already used by Rosemberg (2001) and Artes (2013). The intention is to explore the selected teacher training courses on the basis of a cross-sectional analysis of the data.

One aspect to be highlighted, before the results are presented, is the no-response rate for the colour/race criteria in the students' questionnaire for the Higher Education Census - CES[23]. In 2010, the no-response rate (which includes "the student did not want to declare" and "does not have the information") was 68.5%, making robust analysis impossible on the basis of this data. The CES information for 2015 and 2019 indicates a reduction in the no-response rate. In 2015, the rate was 35% and in 2019 it was 17%. This improvement in the response rate is the result of the efforts of the INEP team, sensitising the HEIs of the importance of establishing the racial profile of the students. Due to the difference in no-response values between the years, it was decided to present only the 2019 information.

Table 9 shows the percentage distribution of total enrolment in Brazil and of the degrees selected by gender and colour/race. There is a small increase in black women in teaching degrees and a difference of 9.9% for black men in comparison with the all-Brazil data, while white women and men have a lower presence in teaching degrees, especially women, with a differential of 8.2% in relation to the all-Brazil data. Higher education has become more accessible to women, and a potential career as a fully qualified schoolteacher, with a teaching degree, presents itself as an opportunity for black people of both sexes.

Table 9: Distribution of enrolments in HEIs by gender, colour and race, Brazil and selected teaching degrees – 2019[24]

	Brazil %	Selected %
White women	29,9	21,7
Black women	27,3	28,4
White men	22,8	20,1
Black men	20,0	29,9

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019**.**

21
See information available at: https://www.gov.br/inep/pt-br/acesso-a-informacao/dados-abertos/microdados/censo-da-educacao-superior. Accessed on 24 Feb 2021.

22
Summary of the Black and Mixed Race responses.

23
For a more detailed discussion, see Artes (2020); Senkevics, Machado an

24
Table reading orientation: summed to 100% by column.

The following table shows the variance by teaching degree. Black women are more present in Biology, General Science and Chemistry courses, while black men are more present in Computing, Physics and Mathematics. Only 9.5% of students studying Computing are white women, while 44.1% are black men. Only for Physics is there a clearly marked gender difference: there are close to twice as many white men as white women and black men as black women.

No relevant differences were observed in 2019 in the comparison by teaching modality, classroom-based and EAD, and by geographic region for the gender and colour/race cut.

The distribution by funding sector does, however, show a difference by gender and colour/race. The four groups are more present in the federal HEIs, as already indicated in the results described in the analysis of teacher training courses on the basis of the 2019 synopsis, but black women and men are less present in private-sector HEIs, at 20.2% and 21.7% respectively, and, consequently, higher in the federal HEIs.

Table 10: Distribution of enrolments in HEIs by gender, colour and race, Brazil and selected teaching degrees – 2019[25]

Selected teaching degree enrolments by gender and colour	White women %	Black women %	White men %	Black men %
General Science	15,4	41,3	10,6	32,7
Biology	29,5	36,8	14,4	19,4
Physics	12,5	18,2	29,2	40,1
Chemistry	23,3	31,2	18,2	27,3
Mathematics	19,7	23,0	23,1	34,2
Computing (IT)	9,5	21,2	25,2	44,1

Source: Prepared by the authors based on the Synopses of the Census of Higher Education 2019.

Table 11: Distribution of enrolments in HEIs by gender, colour/race and funding sector, Brazil and selected teaching degrees – 2019[26]

	Public %		Private %
	Federal	**State Government**	
White women	43,4	21,2	34,7
Black women	59,1	20,5	20,2
White men	44,9	21,8	32,7
Black men	58,9	19,3	21,7
Total	52,8	20,6	26,3

Source: Prepared by the authors based on the microdata of the Synopses of the Census of Higher Education 2019.

The following table indicates a lower presence of black students in EAD courses, which can be understood if it is the lower presence of courses given in this modality in the North and Northeast regions of Brazil is considered, see Table 15 below. However, black student have a prominent participation in federal HEIs, as shown in Table 11, which in turn are concentrated in the Northeast region, and a lower presence in private institutions, in which white students predominate, especially in the Southeast region.

25
Table reading orientation: summed to 100% by line, by selected teaching degree course.

26
Table reading orientation: summed to 100% by line, by gender/colour.

Table 12: Distribution of enrolments in HEIs by gender, colour/race and modality, selected teaching degrees – 2019[27]

	Classroom-based %	EaD %
White women	66,3	33,7
Black women	74,4	25,6
White men	64,5	35,5
Black men	71,3	28,7
Total	69,7	30,3

Source: Prepared by the authors based on the microdata of the Synopses of the Census of Higher Education 2019.

Table 13: Distribution of enrolments in HEIs by region, Brazil and selected teaching degrees – 2019[28]

	Brazil %	Selected %
Centre-West	9,0	8,0
North-East	17,9	30,2
North	5,4	11,8
Southeast	43,6	30,9
South	24,0	19,1

Source: Prepared by the authors based on the microdata of the Synopses of the Census of Higher Education 2019.

Table 14: Distribution of enrolments in HEIs by sector and regions, selected teaching degrees – 2019[29]

	State		Private %
	Federal	State Government	
Centre-West	9,7	8,1	5,2
North-East	38,0	40,5	4,1
North	16,3	12,2	2,8
Southeast	25,1	28,9	47,3
South	10,8	10,2	40,6

Source: Prepared by the authors based on the microdata of the Synopses of the Census of Higher Education 2019.

The following three tables clarify this result. Comparing the total number of enrolments in Brazil with that of selected courses, there is a lower concentration of teaching degrees in the Southeast and a higher concentration in the Northeast (Table 13), as well as a higher concentration of public HEI courses in the Northeast and private-sector HEI courses in the Southeast and South (Table 14). Just to contextualize these data, but with reservations, the results of the National Household Sample Survey (PNAD) of 2019 indicate that the participation by colour/race in the Brazilian population is: Northeast, 24.7% white and 74.4% black; Southeast, 50% white and 48.9% black. Thus, the values observed for the selected teaching degrees should be analysed in the context of the differences between the population profile (and, consequently, of students) by Brazilian region.

27
Table reading orientation: summed to 100% by line, by gender/colour.

28
Table reading orientation: summed to 100% by column, by geographical region.

29
Given the low number of municipal institutions offering the courses (1.5% in 2015 and 1.0% in 2019) they were not included.

As already described, the lower number of EAD teacher training courses on offer in the North and Northeast leads to a lower number of black students for this modality. This lower offer can also be explained by the economic profile of these regions, where students lack the resources to pay for courses in private HEIs.

To understand the profile of the students it is essential to analyse a broad set of characteristics and social markers that define the choice or not of a particular teaching degree. Although the selected teaching degree courses are similar in terms of their area of interest, the analyses indicate important differences in their sector, modality and student profile by gender and colour. Some of the courses have more women, while others have more men, and there are differences in the colour of the student population, with more black students in the selected courses.

The data show that the majority of the students in the selected teacher training courses study in classroom-based courses in federal institutions.

The following data from INEP school education censuses show the characteristics of the teachers, based on their activities in classrooms and their teaching functions, both broken down by sector and by gender/colour and the suitability of their training to teach the disciplines offered, supporting an analysis, with an emphasis of the final years of primary education and of secondary education.

Table 15: Distribution of enrolments in HEIs by region and modality, selected teaching degrees – 2019[30]

	Modality %	
	Classroom-based	Ead
Centre-West	78,2	21,8
North-East	85,6	14,4
North	89,1	10,9
Southeast	53,8	46,2
South	47,7	52,3
Total	68,4	31,6

Source: Prepared by the authors based on the microdata of the Synopses of the Census of Higher Education 2019.

30
Table reading orientation: summed to 100% by line, by geographical region.

Teacher Profile – School Education Census (CEB)

In order to establish the teacher profile, we examine to what extent the teachers in the classroom are suitably trained to deliver STEM courses, including Mathematics as teachers of that subject also deliver Physics and Chemistry lessons. The data on teacher profiles is mainly derived from the 2020 CEB, although some data from the 2015 CEB is included, as shown below.

The data is organised by sector (public or private) and the geographical location of the school, as well as gender and colour, which allows the teaching force to be classified into four groups for analysis: white women, black women, white men and black men. The data are limited to information on the profile of primary and secondary school teachers. The intention is to examine the data and critically analyse the adequacy of teacher training. To this end, we used the adequacy indicator of the education teacher training developed by INEP, according to Technical Note 020 (BRAZIL, 2014b).

It is also worth highlighting the prioritization of information regarding CEB 2020 in relation to changes made in nomenclature and codes and in the variables describing teacher qualification compared to previous censuses. Two comparisons are made with CEB 2015: variation by geographical region and by sector (public or private).

In analysing the data in the CEB on teachers, one can either view it by individual subject taught or by the teaching function.

According to Carvalho (2018, p. 7):

When working with the data from the CEB, it is necessary to differentiate between the concepts of teacher and teacher function: i) when referring to the teacher, the individual teacher is considered, identified in the CEB by an individual code; ii) when it comes to the concept of teaching function, it is referring to the function of this teacher in the classroom (on the census data collection reference date). This function can be exercised by the same individual teacher in more than one class, in more than one school, at more than one stage, etc. In other words, statistics relating to teacher functions can include the same individual more than once.

As the intention is to characterise those teachers who are working in school classrooms , it seems more pertinent to consider all the individual classes, schools and sector in which each teacher works. Therefore, we examine the teaching function, which allows us to have a more accurate view of school science teaching in Brazil.

In order to do this, a key element is to know if the teacher teaching a subject to a specific class of students has the appropriate training to do so. To this end, we used the teacher training suitability indicator developed by INEP, according to Technical Note 2014. This document states that:

According to the legal framework presented, the assessment of the suitability of the teacher's training depends on their area of activity, that is, on the school stage(s) and subject(s) they teach. Therefore, ultimately, what is being evaluated is the teaching offered by the school and its teaching staff to the students. (BRASIL, 2014b, p. 4)

Suitability of Teacher Training for the Individual STEM Subjects in School Education

Based on the legal framework presented in the INEP document, four categories were applied to the training of the teacher in relation to the subject they teach, where 1 is that they have received suitable training (in accordance with the education regulations) and 4 is the least suitable training for teaching the subject (Table 7). For this study, the profiles were analysed by the five subjects included in the research (Mathematics, General Science, Biology, Physics and Chemistry).

Chart 5: Training Suitability Categories for Teachers in Relation to the Subject they Teach

Grupo	Descrição
1	Teachers with a teaching degree in the same subject they teach, or a B.Sc. or equivalent in the same subject and a Postgraduate Certificate in Education (PGCE) or equivalent.
2	Teachers with a B.Sc. or equivalent in the same subject they teach, but who do not have a teaching degree or PGCE or equivalent.
3	Teachers with a degree in another subject.
4	Teachers who have not got a degree.

Source: Adapted from Technical Note No. 020 (BRAZIL, 2014b).

It is important to emphasise that the suitability of teacher training is related to each of the subjects taught. Thus, hypothetically, if a teacher with suitable training in Mathematics also teaches Physics to the same class, they will be considered qualified in relation to one subject and not qualified in relation to the other. Therefore, for these cases, it was not possible to categorise the suitability of their training, as it would fall between Group 1 (for Mathematics) and Group 3 (for Physics). In this situation, in which it was not possible to evaluate the suitability of the teacher training, they were not included in the tables, which is why the percentages (by line) do not sum up to 100%. However, it should be stated that, for both the final years of primary education and for secondary education, this unsuitable rate in training is 6.5% in 2020 and 6.6% and 5.6% in 2015, respectively.

To illustrate the construction of the four groups, Tables 8 and 9 present the subjects offered and the HE courses considered suitable (to have a teaching degree in the subject that they teach or a B.Sc. or equivalent with a PGCE or equivalent) so that the teachers are classified in Groups 1 and 2, respectively.

Chart 6: Training considered suitable for the teacher to be classified in Group 1, by subject taught.

Subject	Code	Name of HE Course	Requires PGCE
Mathematics	0114M011	Mathematics - teacher qualification - Teaching degree	
	0541M012	Mathematics - B.Sc.	X
General Science	0114B011	Biology - teacher qualification - Teaching degree	
	0114C021	Natural Sciences - teacher qualification - Teaching degree	
	0114F021	Physics - teacher qualification - Teaching degree	
	0114Q011	Chemistry - teacher qualification - Teaching degree	
	0531Q012	Chemistry - B.Sc.	X
	0533F012	Physics - B.Sc.	X
	0511B012	Biology - B.Sc.	X
	0588P012	General Science (Natural Sciences, Mathematics, Statistics) - B.Sc.	X
Chemistry	0114C021	Natural Sciences - teacher qualification - Teaching degree	
	0114Q011	Chemistry - teacher qualification - Teaching degree	
	0531Q012	Chemistry - B.Sc.	X
Physics	0114C021	Natural Sciences - teacher qualification - Teaching degree	
	0114F021	Physics - teacher qualification - Teaching degree	
	0533F012	Physics - B.Sc.	X
Biology	0114B011	Biology - teacher qualification - Teaching degree	
	0114C021	Natural Sciences - teacher qualification - Teaching degree	
	0511B012	Biology - B.Sc.	X

Source: Adapted from Technical Note No. 020 (BRAZIL, 2014b).

Chart 7: Training considered suitable (B.Sc. without PGCE), by subject taught, for the teacher to be classified in Group 2

Subject	HE Course Code	Name of HE Course
Mathematics	0541M012	Mathematics - B.Sc.
General Science	0531Q012	Chemistry - B.Sc.
	0533F012	Physics - B.Sc.
	0511B012	Biology - B.Sc.
	0588P012	General Science (Natural Sciences, Mathematics, Statistics) - B.Sc.
Chemistry	0531Q012	Chemistry - B.Sc.
Physics	0533F012	Physics - B.Sc.
Biology	0511B012	Biology - B.Sc.

Source: Adapted from Technical Note No. 020 (BRAZIL, 2014b).

The other teachers with HE degrees where the course is not included in the previous tables were classified in Group 3. Teachers who do not have a degree, Group 4.

The information given below is organised by education stages. Table 16 presents the distribution of the teaching functions for the individual subjects by education stage. As only the subjects of Mathematics and General Science are taught in the final years of primary education, the analyses for this stage will be excluded for both subjects. In the results for secondary education, the four subjects included in the curriculum are included. In the case of the initial years of primary education, as already mentioned, it was not possible to verify whether the teachers with a teaching degree have the expected additional training. The figures noted for teachers of Mathematics for secondary education should include participation in other stages (initial years and final years). In terms of numbers, the largest number of teaching functions are found for Mathematics, in the secondary education column.

Table 16: Distribution of teaching functions by education stage in the selected subjects – 2020

Subject	Primary education (initial years)		Primary education (final years)		Secondary education	
	n	%	n	%	n	%
Biology	13	0,0	8.640	2,9	290.131	97,1
Physics	36	0,0	11.029	3,7	287.379	96,3
Chemistry	3	0,0	9.907	3,3	288.337	96,7
Mathematics	730.323	45,6	566.174	35,4	304.007	19,0
General Science	718.247	56,8	546.550	43,2	64	0,0

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

Suitability of teacher education for primary education (final years) – Mathematics and General Science

Table 17 shows the distribution of the groups by suitability of teacher training for Mathematics and General Science. The General Science teaching function has the most suitable training rates, at 6% above that for Mathematics. The most significant finding can be found in Group 3 (teachers with a degree in a non-STEM subject), where 20% of those teaching Mathematics fall. Who are these teachers? Teachers qualified in Physics and Chemistry who teach Mathematics in the final years of primary education? While they can be considered as having training in allied subjects, it is not considered the most suitable.

Table 17: Distribution of teacher functions by training suitability group and the subjects of Mathematics and General Science, for the final years of primary education – 2020[31]

	Group 1	Group 2	Group 3	Group 4
Mathematics	58,8%	1,6%	20,3%	8,2%
General Science	65,1%	2,1%	13,1%	8,0%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

Information that helps with the characterization of the teachers by funding sector, as described in Table 18.

The differences between Mathematics and General Science are striking for the State-funded schools and private schools, in relation to Group 1 (best suitability). The federally funded schools, as described earlier in this chapter, are the ones that give the best working conditions and the greatest teacher training suitability for both subjects, but they serve a limited number of students in comparison with state and municipal networks. If we look specifically at the State-funded schools, responsible for educating a significant number of students, eight out of ten science teachers are considered to have suitable training, 10% more than that of Mathematics teachers.

31 Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

The difference in Group 1 comes from Group 3, teachers with an HE degree which is not in the subject they teach (22.0%). In municipal schools, which include most of the teaching functions, the indices that stand out and require further study refer to science teachers without an HE qualification, above 10% for both disciplines. In private schools, the reality does not match what is expected either. Almost 20% of Mathematics teachers do not have training in the subject they teach.

Table 18: Distribution of teacher functions by training suitability group, subject and sector for the final years of primary education (2020)[32]

Sector	Subject	Group 1	Group 2	Group 3	Group 4
Federal	Mathematics	85,5%	9,5%	3,1%	1,3%
	General Science	83,1%	6,6%	8,7%	0,9%
State Government	Mathematics	67,8%	1,3%	22,0%	2,9%
	General Science	80,8%	2,0%	8,4%	2,7%
Municipal	Mathematics	51,2%	1,2%	19,4%	11,9%
	General Science	51,9%	1,6%	17,8%	12,1%
Private	Mathematics	61,6%	3,2%	19,1%	8,3%
	General Science	71,2%	4,2%	8,8%	6,8%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

Of significance in this diagnosis on the teaching of science in schools is the disaggregation of information from statistical, academic or non-academic sources on the subject, relating to gender and colour/race. Therefore, the distribution of teacher functions according to sex and colour declared in the CEB 2020 was examined. As a starting point, it is important to understand the participation of these groups by subject and educational stage. The literature report that the teaching profession in the early years of school education is largely exercised by women (ROSEMBERG; MADSEN, 2011; CARVALHO, 2001). Above all, this applies to primary education. White women predominate in General Science (43.8%) and Mathematics (35.3%) for the final years of primary education. White

32
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included .

men are to be found in Mathematics, but less so in General Science, where the presence of black women and men is to be found. General Science is taught by more women of all races (72.6%) than men (27.4%). The dominant presence of women in General Science teaching in primary education is matched by a similar presence in the Biology teaching degrees, as shown in the ENADE report for 2017 (BRASIL, 2017b, p. 50):

It was found that students in Biological Science teaching degree courses were mostly female, in both classroom-based courses and those delivered using the EAD modality (71.9% and 69.9%, respectively).

Table 19: Distribution of teacher functions by gender, colour and subject in the final years of primary education – 2020[33]

Subject	White men	Black men	White women	Black women
Mathematics	20,2%	22.2%	35,3%	22,3%
General Science	14,0%	13.4%	43,8%	28,8%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020. Note: In producing the information on colour/race in the table, the following categories were not included: no response, yellow (Asian) and indigenous. The black and mixed-race responses were summed into the Black cate

The suitability of teacher education also has a relationship with gender and colour/race, with more white women and men in Group 1 than black women and men. On the other hand, there are more black men and women in Group 4 – those teachers without a degree.

Considering the suitability of the teaching qualification of white women, General Science has 15% more white women teachers than Mathematics. This can be explained by the fact that 22.1% of Mathematics teaching is provided by white women with a degree in another area (Group 3). The most concerning thing is that 10% of black women without a higher education (Group 4) teach Mathematics and 11% of black men without a higher education teach General Science.

33
Table reading orientation : Each of the selected subjects sums to 100% by line.

Table 20: Distribution of teacher functions by training suitability group, subject and gender/colour for the final years of primary education -2020[34]

		Group 1	Group 2	Group 3	Group 4
White men	Mathematics	83,0%	2,3%	11,6%	2,2%
	General Science	79,0%	2,1%	10,0%	2,7%
Black men	Mathematics	61,1%	1,6%	19,3%	9,3%
	General Science	54,2%	1,9%	18,4%	11,0%
White women	Mathematics	63,2%	1,2%	22,1%	2,7%
	General Science	78,4%	1,9%	8,1%	2,4%
Black women	Mathematics	52,5%	1,3%	18,2%	10,0%
	General Science	61,8%	1,9%	19,3%	7,9%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020. Note: In producing the information on colour/race in the table, the following categories were no response, yellow (Asian) and indigenous. The black and mixed-race responses were summed into the Black category.

The differences observed in the table above may explain, in part, the results found in Table 21, regarding the distribution of teacher suitability by demographic regions. According to data from PNAD/IBGE 2019, the participation of Blacks in the Brazilian population by region is: Center-West – 62.9%; Northeast – 74.4%; North – 79.5%; Southeast – 49.9% and South – 19.9%[35]. Thus, the North and Northeast regions, with predominance of Blacks, would also have the worst indicators of suitable teacher education, as shown in the table below. Less than half of the teaching functions of the Northeast region have the most suitable training (Group 1), with the same situation applying to Mathematics and General Science. About 24% of General Science and Mathematics teachers have a degree in an unrelated area and 15% have no higher education qualification. This is of concern. The best results are for the teaching of General Science, in the South (78.2% in Group 1) and Southeast (83.4% for Group 1).

Thus, the differences in the suitability of training for men and women, black and white, necessarily involve recognising that the conditions of schooling and careers are socially and racially distinct in the different regions of the country. It can be said that this condition already begins at school, in schools with poorer infrastructure (in the case of science and computer laboratories), as will be presented below.

34
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

35
Information is available at: https://sidra.ibge.gov.br/tabela/6408#resultado. Accessed on 9 April 2021.

Table 21: Distribution of teacher functions by training suitability group, subject and geographical region for the final years of primary education – 2020[36]

		Group 1	Group 2	Group 3	Group 4
Centre-West	Mathematics	70,8%	2,1%	16,4%	4,6%
	General Science	70,3%	5,5%	13,0%	4,3%
North-East	Mathematics	44,6%	1,6%	23,7%	15,2%
	General Science	44,2%	1,6%	23,8%	15,0%
North	Mathematics	54,2%	0,8%	12,8%	14,8%
	General Science	51,0%	1,3%	14,8%	15,1%
Southeast	Mathematics	66,7%	2,0%	22,6%	2,0%
	General Science	83,4%	2,4%	5,4%	1,8%
South	Mathematics	69,2%	1,0%	15,4%	3,1%
	General Science	78,2%	1,8%	6,1%	2,4%

Suitability of teacher education for secondary education – Biology, Physics, Chemistry and Mathematics

Table 22 presents the distribution of the subjects by the training suitability groups. Chemistry and Physics show the worst indicators, with 33.9% of Physics teaching provided by graduates in another subject. The best result is in Biology, in which almost eight out of ten teachers are in the most suitable training group (Group 1).

Table 22: Distribution of teacher functions by training suitability group and subject for secondary education – 2020[37]

	Group 1	Group 2	Group 3	Group 4
Biology	76,3%	2,9%	8,0%	1,8%
Physics	44,0%	1,8%	33,9%	3,0%
Chemistry	57,8%	1,8%	22,0%	2,6%
Mathematics	69,4%	1,8%	16,1%	2,2%

This scenario should consider the sector (public or private)[38].

36
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included .

37
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

38
According to CEB 2020, the federal schools are responsible for 0.25%; State schools 86.2%; municipal schools 0.4%; and private schools 13.2% of the total student population in secondary education.

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

This scenario should consider the sector (public or private) [Table 23][38]. Of each ten students, eight are in State schools, in which the highest suitability of the teacher training is for Biology (75.9%). In Physics, only 40.7% of teacher functions have the desired training (Group 1), and 37% have a degree in another subject. The best situation is the federal institutions, with suitability values above 70%, but these schools only serve 0.25% of the total student population. The private schools, responsible for 13.2% of the students, also show a higher incidence of teachers lacking qualifications in Physics (55.8%), while 22.5% of Physics teachers have a degree in another subject.

Table 23: Distribution of teacher functions by training suitability group, subject and sector for secondary education – 2020[39]

		Group 1	Group 2	Group 3	Group 4
Federal	Biology	79,1%	13,2%	6,7%	0,5%
	Physics	74,1%	14,5%	9,7%	0,9%
	Chemistry	71,1%	13,2%	14,3%	1,0%
	Mathematics	79,9%	9,5%	9,0%	0,9%
State Government	Biology	75,9%	2,4%	8,2%	1,7%
	Physics	40,7%	1,2%	37,0%	2,8%
	Chemistry	56,0%	1,2%	23,4%	2,4%
	Mathematics	69,2%	1,3%	16,7%	1,8%
Municipal	Biology	68,8%	1,6%	8,7%	3,6%
	Physics	51,0%	1,7%	20,8%	2,6%
	Chemistry	51,4%	0,8%	20,4%	3,2%
	Mathematics	58,2%	0,5%	23,6%	4,2%
Private	Biology	78,0%	4,4%	7,0%	2,6%
	Physics	55,8%	2,4%	22,5%	4,5%
	Chemistry	69,0%	2,9%	14,5%	4,2%
	Mathematics	71,9%	3,4%	16,0%	3,7%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

Distribution by gender and colour also deserves a detailed analysis: women are concentrated in Biology (65.4%) and Chemistry (53.2%), while men in Physics (64.2%) and Mathematics (54.8%). As regards colour/race, Black women are half as well represented as white women.

38
According to CEB 2020, the federal schools are responsible for 0.25%; State schools 86.2%; municipal schools 0.4%; and private schools 13.2% of the total student population in secondary education.

39
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

Table 24: Distribution of teacher functions by gender, colour and subject in secondary education – 2020[40]

	White men	Black men	White women	Black women
Biology	21,1%	13,6%	43,8%	21,6%
Physics	37,3%	26,9%	24,6%	11,2%
Chemistry	27,8%	19,0%	35,7%	17,5%
Mathematics	30,6%	24,2%	31,6%	13,6%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.
Note: In producing the information on colour/race in the table, the following categories were no response, yellow (Asian) and indigenous. The black and mixed-race responses were summed into the Black category.

Table 25: Distribution of teacher functions by training suitability group, subject and gender/colour for secondary education – 2020[41]

		Group 1	Group 2	Group 3	Group 4
White men	Biology	68,2%	2,0%	23,0%	1,7%
	Physics	51,6%	1,7%	32,2%	2,2%
	Chemistry	61,6%	1,9%	23,1%	1,8%
	Mathematics	70,0%	1,5%	18,8%	1,5%
Black men	Biology	74,9%	3,3%	8,9%	1,6%
	Physics	51,5%	2,4%	30,2%	2,9%
	Chemistry	63,6%	1,9%	18,5%	2,2%
	Mathematics	75,0%	2,0%	11,9%	2,2%
White women	Biology	83,2%	2,5%	5,1%	0,8%
	Physics	35,4%	1,2%	40,8%	1,8%
	Chemistry	59,2%	1,7%	23,2%	1,5%
	Mathematics	69,9%	1,1%	18,8%	1,1%
Black women	Biology	77,0%	3,5%	8,2%	1,6%
	Physics	38,7%	1,4%	36,1%	2,9%
	Chemistry	62,1%	1,6%	18,3%	2,4%
	Mathematics	72,5%	1,6%	14,0%	1,8%

The data show better training suitability for Black men than white men. In the case of women, with the exception of Biology, the Black women also demonstrate better training suitability than white women. Black men have more suitable training for Mathematics than all the other gender/race/colour categories (75%). These are questions that require new studies if they are to be fully understood.

40
Table reading orientation : Each of the selected subjects sums to 100% by line.

41
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.
Note: In producing the information on colour/race in the table, the following categories were no response, yellow (Asian) and indigenous. The black and mixed-race responses were summed into the Black category.

Table 26: Distribution of teacher functions by training suitability group, subject and geographical region for secondary education – 2020[42]

		Group 1	Group 2	Group 3	Group 4
Centre-West	Biology	64,3%	13,1%	7,5%	2,2%
	Physics	41,6%	7,2%	25,2%	4,3%
	Chemistry	61,9%	3,2%	12,0%	2,6%
	Mathematics	72,5%	2,1%	11,7%	2,7%
North-East	Biology	64,2%	2,3%	14,0%	3,4%
	Physics	36,3%	1,5%	36,0%	4,6%
	Chemistry	46,1%	1,8%	26,2%	4,3%
	Mathematics	63,7%	2,3%	16,1%	3,6%
North	Biology	75,4%	1,8%	8,3%	1,8%
	Physics	52,0%	1,0%	27,4%	2,0%
	Chemistry	65,4%	1,0%	15,0%	2,0%
	Mathematics	77,0%	1,4%	7,5%	1,7%
Southeast	Biology	85,6%	2,0%	5,3%	0,7%
	Physics	46,5%	1,3%	37,9%	1,3%
	Chemistry	61,2%	1,4%	25,5%	1,1%
	Mathematics	69,4%	1,8%	20,9%	1,0%
South	Biology	81,8%	1,6%	3,5%	1,6%
	Physics	47,9%	1,3%	28,9%	4,5%
	Chemistry	62,9%	2,7%	15,5%	3,9%
	Mathematics	72,1%	1,0%	12,6%	2,7%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

42
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

In the analysis by region, the differences observed become more marked. In all regions, the training suitability rate in Physics is below 50%, except for the North, with 52.0%. In the Northeast, only 36.3% are Group 1, a value close to that found for Group 3. The picture is not much better in the South-East. In only 46.5% of Physics teachers have the desired training (Group 1), and 37.9% have a degree in another subject.

One possible reflection is to associate these values with those found in the Higher Education Census (CES), which may indicate an interest in a specific teacher training degree. Although they are different surveys, carried out on different survey populations at different times, the fact that the Physics teacher training degree, of the four selected, is the one which has fewer students, 30,175 (Table 2, enrolment) and only 2,459 (Table 6) graduates, it may reflect on the results found for the suitability of the teaching training. Biology shows the best situation, showing the highest incidence of both enrolments and graduations in the CES survey.

As a final analysis, the tables below show a comparison between the years 2015 and 2020, by teacher training suitability, considering the geographic region (Table 27) and sector (Table 28) for State and private schools (which represent the largest number of students).

In general, analysing the rates per year for Group 1 for all subjects and regions, an improvement in the indicator can be seen. The greatest chance seen is for Physics which presented improvements in the range of 30% (Central-West and Northeast) and 40% in the North, Southeast and South between the 2015 and 2020 census. In the North, the increase is 12%. At the other extreme, Group 4 (without higher education) shows a drop, highlighting the result for Physics in the Northeast, with a reduction from 16.4% (2015) to 4.6% (2020).

When comparing data from Group 3 (graduates with a degree in another subject), also for Physics, unlike in Group 1, the difference between 2015 and 2020 is marginal, except for the North, with a drop of 8.8%, and for the South, with a drop of 5%. As far as Group 3 is concerned, the increase in the Southeast region for Chemistry and Mathematics should be noted, as well as significant drops in the North for all subjects.

Table 27: Distribution of teacher functions by training suitability group, subject and geographical region for secondary education, comparing 2015 and 2020[43]

		Group 1		Group 2		Group 3		Group 4	
		2015	2020	2015	2020	2015	2020	2015	2020
Centre-West	Biology	63,7%	64,3%	7,4%	13,1%	10,8%	7,5%	4,7%	2,2%
	Physics	32,6%	41,6%	5,6%	7,2%	27,8%	25,2%	10,0%	4,3%
	Chemistry	52,1%	61,9%	1,3%	3,2%	16,8%	12,0%	7,2%	2,6%
	Mathematics	66,4%	72,5%	1,8%	2,1%	11,3%	11,7%	7,1%	2,7%
North-East	Biology	62,0%	64,2%	1,5%	2,3%	14,9%	14,0%	9,2%	3,4%
	Physics	28,4%	36,3%	0,8%	1,5%	36,3%	36,0%	16,4%	4,6%
	Chemistry	39,7%	46,1%	1,3%	1,8%	27,5%	26,2%	13,8%	4,3%
	Mathematics	58,0%	63,7%	1,3%	2,3%	16,7%	16,1%	11,4%	3,6%
North	Biology	65,2%	75,4%	0,9%	1,8%	18,1%	8,3%	2,9%	1,8%
	Physics	39,6%	52,0%	0,5%	1,0%	36,2%	27,4%	5,0%	2,0%
	Chemistry	54,0%	65,4%	0,6%	1,0%	24,7%	15,0%	3,8%	2,0%
	Mathematics	70,4%	77,0%	0,7%	1,4%	11,6%	7,5%	3,5%	1,7%
Southeast	Biology	80,3%	85,6%	2,0%	2,0%	10,7%	5,3%	2,7%	0,7%
	Physics	39,8%	46,5%	3,7%	1,3%	40,1%	37,9%	5,6%	1,3%
	Chemistry	62,1%	61,2%	6,9%	1,4%	18,3%	25,5%	4,2%	1,1%
	Mathematics	73,5%	69,4%	2,1%	1,8%	24,3%	20,9%	4,1%	1,0%
South	Biology	83,3%	81,8%	1,7%	1,6%	5,3%	3,5%	3,8%	1,6%
	Physics	41,0%	47,9%	0,6%	1,3%	33,9%	28,9%	11,7%	4,5%
	Chemistry	61,7%	62,9%	1,9%	2,7%	17,4%	15,5%	8,7%	3,9%
	Mathematics	68,7%	72,1%	0,8%	1,0%	16,0%	12,6%	6,8%	2,7%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2015 2020.

43
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

Considering the two sectors with the most students, the differences between 2015 and 2020 are more subtle, but the values seen for Physics are of concern. In the State schools, the increase in Physics teachers in Group 1 was 7.5%, but it still has values close to 40%, regardless of the year, for teaching functions with a degree in another subject (Group 3). In private schools, the change is similar, with an improvement of 8% for Physics in Group 1. It is worth noting that, for the four subjects, the percentage of teachers without higher education (Group 4), regardless of the year in question, is higher in private schools than in State schools. One hypothesis is the greater control of the selection of candidates for teaching positions by State education authorities for their own schools via competitive public selection processes.

Table 28: Distribution of teacher functions by training suitability group, subject and sector (State and private) in secondary education, comparing 2015 and 2020[44]

		Group 1		Group 2		Group 3		Group 4	
		2015	2020	2015	2020	2015	2020	2015	2020
State Government	Biology	72,3%	75,9%	2,0%	2,4%	12,0%	8,2%	4,7%	1,7%
	Physics	33,2%	40,7%	1,9%	1,2%	39,7%	37,0%	9,4%	2,8%
	Chemistry	53,0%	56,0%	3,1%	1,2%	22,1%	23,4%	5,4%	2,4%
	Mathematics	67,5%	69,2%	1,3%	1,3%	15,2%	16,7%	6,1%	1,8%
Private	Biology	75,1%	78,0%	2,8%	4,4%	11,0%	7,0%	5,4%	2,6%
	Physics	47,8%	55,8%	4,0%	2,4%	24,7%	22,5%	11,8%	4,5%
	Chemistry	60,0%	69,0%	5,6%	2,9%	16,8%	14,5%	8,3%	4,2%
	Mathematics	67,6%	71,9%	2,2%	3,4%	13,4%	16,0%	8,8%	3,7%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2015 2020.

The provision of science and computing labs for school students

This topic presents an analysis based on data extracted from the CEB regarding the provision of science and computer science laboratories for primary and secondary school students. This section examines the provision of equipment such as science and computer laboratories in schools. The data is organised by sector (public or private) and the geographical location of the school, as well as gender and colour, which allows the teaching force to be classified into four groups for analysis: white women, black women, white men and black men.

With the intent to analyse whether the provision of learning spaces, data on the provision of laboratories in the census years 2010, 2015 and 2020 are shown. The data are limited to information on primary and secondary students by region and sector. The objective is to examine the data and analyse student access to science teaching infrastructure in Brazil. The selection of these data sets is based on the assumption that scientific literacy comes from the opportunity to have access to practical experiences and experimentation in all the science areas taught at school. The possibility of equipping schools with laboratories is an important strategy and is included in various regulatory instruments governing the provision of education.

44
Table reading orientation: the percentages should be read by line for each of the subjects. Cases that could not be classified in the training suitability groups were not included.

Laboratories are spaces where theory is translated into reality, where the abstract becomes real through actions, sounds or images. Laboratory experiments allow students to verify what they have learned in the classroom empirically. However, for this to occur, the laboratories need to be more than a classroom with benches. They need to be environments equipped with devices, instruments to manipulate materials, audio-visual resources and everything necessary to transform a room into an appropriate environment, so that students can learn by experiencing, by verifying. (ABRAMOVAY; CASTRO, 2003, p. 321)

It should be emphasised that what we are examining here is the existence or not of physical laboratory spaces on the basis of data extracted from the CEB, the mere existence of which does not guarantee that it will be used for the purpose intended – teaching science to students. This second aspect would require another study, with verification of the effective use of the space and its quality. An example is what was seen during visits to schools which had projects approved under the Gestão para Equidade: Elas nas Exatas (Managing for Equality: Girls in Science) scheme. During these visits, it was found that teachers had difficulty in using the laboratories, either because of a lack of training and consumables, or because of a school culture that favoured exposition over educational practices focused on active learning.

However, it should be emphasised that educational policies aiming at introducing technology into Brazilian schools have been in place for more than three decades. One of the reference actions, post-LDB, was PROINFO (National Educational Technology Programme), officially launched by Decree No. 522/MEC (BRAZIL, 1997). The objective was to promote the use of Information and Communication Technologies (ICT) in publicly funded schools through partnerships with the States and municipalities, involving the acquisition of computers, setting up educational technology centres and sections, and computer laboratories in publicly funded primary and secondary schools, as well as sufficient training for the use of ICT resources in the classroom and technical support for schools (CARVALHO; MONTEIRO, 2017). Other programmes and actions were developed, among them ProUCA (one computer per student), which was evaluated in partnership with universities and yielded theses and dissertations over the following years (HABOWSKI; CONTE; KOBOLT, 2020). This scenario contributes, in part, to explaining why there are more computer labs in Brazilian public schools than science laboratories.

However, according to the academic literature, the laboratories have been responsible not only for developing technology skills but have demonstrated the limits and challenges faced in making a real impact on implementing the educational policy of digital inclusion. The barriers are various and of different magnitude, as already mentioned in the section on the BNCC and the use of technologies in education: they are not to be found in every school, partly because of a lack of the infrastructure required, such as internet access, but also basic requirements such as a stable electrical supply; the maintenance and updating of equipment; security of school premises; the absence of technical staff and the lack of properly trained teaching staff, contributing to the laboratories being abandoned after installation or being used for other purposes.

Tables 29 and 30 show the location of students by geographic region against the provision of science and computer laboratories. First, it should be noted that the increased provision of laboratories consistently matches the school stage reached by the student and is dependent on the region where the school is located. The North and Northeast of Brazil have fewer science and computing laboratories, while the South and the Southeast the most.

More students have access to computing laboratories than to science laboratories, independently of whether they are primary or secondary students or the region they are studying in. In the North and Northeast, less than 10% of students have access to a science laboratory in the early primary school stages but, theoretically, more than 30% of those students have access to computing laboratories at the same stage. The situation is the same in all regions, showing that access to computers is greater than science laboratory equipment. The provision of science and computer laboratories for the first stages of primary education is greatest in the South, where 27.9% of students have access to the former and 68.1% to the latter.

Regional differences are maintained. In the Northeast, 48.9% of the students have access to science laboratories, compared to 73.6% in the South, while 17% fewer students have access to computing laboratories in the Northeast than the South.

Table 29: Distribution of students by selected educational stage and provision of science laboratories in their schools by geographic region in 2020[45]

Stage – Region		Science laboratory	
		No	Yes
Primary education (initial years)	Centre-West	83,9%	16,1%
	North-East	91,1%	8,9%
	North	92,2%	7,8%
	Southeast	80,4%	19,6%
	South	72,1%	27,9%
	Total	84,0%	16,0%
Primary education (final years)	Centre-West	71,9%	28,1%
	North-East	83,4%	16,6%
	North	80,1%	19,9%
	Southeast	58,4%	41,6%
	South	42,3%	57,7%
	Total	67,0%	33,0%

Secondary education	Centre-West	51,3%	48,7%
	North-East	51,1%	48,9%
	North	46,8%	53,2%
	Southeast	46,3%	53,7%
	South	26,4%	73,6%
	Total	45,5%	54,5%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

Table 30: Distribution of students by selected educational stage and provision of computer laboratories in their schools by geographic region in 2020[46]

Stage – Region		Computer laboratory	
		No	Yes
Primary education (initial years)	Centre-West	36,9%	63,1%
	North-East	68,3%	31,7%
	North	62,2%	37,8%
	Southeast	32,1%	67,9%
	South	31,9%	68,1%
	Total	**46,3%**	**53,7%**
Primary education (final years)	Centre-West	30,5%	69,5%
	North-East	54,1%	45,9%
	North	46,3%	53,7%
	Southeast	16,6%	83,4%
	South	17,8%	82,2%
	Total	**32,1%**	**67,9%**
Secondary education	Centre-West	23,6%	76,4%
	North-East	24,1%	75,9%
	North	27,7%	72,3%
	Southeast	10,2%	89,8%
	South	14,1%	85,9%
	Total	**17,5%**	**82,5%**

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

Joaquim José Soares Neto *et al.* (2013) speak of the need for us to reflect on the quality of education by understanding the nature and condition of what is provided, mainly when it concerns school infrastructure, including the provision of laboratories. To support this, they established a four-point scale on the basis of the 2011 School Census: Rudimentary, Basic, Satisfactory, Advanced. It should be noted that one of the differentials observed in the authors' evaluation concerns the funding status of the school, by educational stage and region.

45
Table reading orientation : Each of the selected subjects sums to 100% by line.

46
Table reading orientation : Each of the selected subjects sums to 100% by line.

The article shows that 62.5% of federal schools are in the Satisfactory and Advanced categories of the scale, 51.3% of State schools are in the Basic category, 61.8% of municipal schools are in the Rudimentary category, and 72.3% of private schools are in the Rudimentary and Basic categories. The authors also note that of the 5,496 schools in the range of 20 to 30 in the scale (Basic), 5,036 (99.9%) are municipal schools. (ALMEIDA *et al.*, 2013, p. 93)

Our analysis has already shown that the federal schools are responsible for educating only a small number of the total school students in Brazil – less than 0.5% at every educational stage throughout the country. This information should be taken into account in the analysis of the provision of laboratories, given below. As determined by the Federal Constitution of 1988 and LDB of 1996, most students in the initial years of primary education attend municipal schools, especially in the North and Northeast of the country. On the same basis, the States are responsible for secondary education, providing it to 86.1% of students in the Centre-West and 93.4% of students in the North. The role of the private schools should also be considered, being responsible for 9.2% of students in the initial years of primary education in the North and 21.6% in the Southeast. Private schools in the Southeast also have the highest number of enrolments in the final years of primary school (18.8%) and secondary school (16.2%).

(Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.)

Table 31: Distribution of students by selected stages and provision of science laboratories in schools by sector in 2020

Stage		Science laboratory	
		No	Yes
Primary education (initial years)	Federal	3,0%	97,0%
	State	84,0%	16,0%
	Municipal	92,9%	7,1%
	Private	52,3%	47,7%
	Total	**84,0%**	**16,0%**
Primary education (final years)	Federal	0,4%	99,6%
	State	61,1%	38,9%
	Municipal	84,1%	15,9%
	Private	35,8%	64,2%
	Total	**67,0%**	**33,0%**
Secondary education	Federal	0,6%	99,4%
	State	48,5%	51,5%
	Municipal	52,2%	47,8%
	Private	26,0%	74,0%
	Total	**45,5%**	**54,5%**

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

The provision of computer labs is much more robust, though provision is less for students enrolled in municipal schools. They are available for half of the students in initial years primary education. t is worth highlighting the results observed for students in private schools, which have fewer laboratories available compared to the state network for the three educational stages considered, a 15% difference in favor of state schools for secondary education (Table 32). These results should be considered with some caution as while the public schools say that they have computing laboratories, they are not always available to the students as they are being used for other purposes, in the same way as science laboratories.

Table 32: Distribution of students by selected stages and provision of computer laboratories in their schools attended by sector in 2020[47]

Stages		Computer lab	
		No	Yes
Primary education (initial years)	Federal	2,1%	97,9%
	State	24,4%	75,6%
	Municipal	51,0%	49,0%
	Private	44,2%	55,8%
	Total	**46,3%**	**53,7%**
Primary education (final years)	Federal	0,0%	100,0%
	State	15,6%	84,4%
	Municipal	46,8%	53,2%
	Private	35,5%	64,5%
	Total	**32,1%**	**67,9%**
Secondary education	Federal	0,0%	100,0%
	State	15,5%	84,5%
	Municipal	27,1%	72,9%
	Private	30,7%	69,3%
	Total	**17,5%**	**82,5%**

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2020.

An analysis which is important to gain a better understanding of the provision of science laboratories to students in the selected stages is to include the variation between different periods – in the case chosen for this study, the years 2010, 2015 and 2020 – so that the student access profile across the last decade can be established. However, the reality of the Brazilian educational system requires extra care: if there are laboratories in the schools, a change in the number of schools will also influence their provision to students. Thus, Tables 33 and 34 show the variation in the number of laboratories by the number of schools in Brazil.

Table 33 indicates an increase of 12.0% in the relative provision of science laboratories for the period from 2010 to 2015, it being a little lower, 4%, between 2015 and 2020, while the absolute number of schools shrank by 4.3% in the first period and by 3.7% in the second. That is, while the number of schools has decreased, the percentage of existing schools with laboratories has increased.

47
Table reading orientation : Each of the selected subjects sums to 100% by line.

Table 33: Variation in the number of schools that have science laboratories and total schools in Brazil for the periods 2010 to 2015 and 2015 to 2020[48]

Science laboratories	2010		2015		2020		Variation	Variation
	N	%	N	%	N	%	2010-2015	2015-2020
	18.991	9,7%	21.278	11,4%	22.121	12,3%	12,0%	4,0%
Total Schools Brazil	194.969	100,0%	186.488	100,0%	179.612	100,0%	-4,3%	-3,7%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2010, 2015 2020.

In "Total Schools Brazil", the data refer to the change in the number of schools and in the number of science laboratories. We can see a small increase in the number of laboratories. These values need to be put into perspective for the analysis of the provision.

The same change is not observed in relation to the provision of computing laboratories. While provision increased by 20.8% between 2010 and 2015, it dropped by 25.5% between 2015 and 2020.

Table 34: Variation in the number of schools that have computer laboratories and total schools in Brazil for the periods 2010 to 2015 and 2015 to 2020[49]

Computer laboratory	2010		2015		2020		Variation	Variation
	N	%	N	%	N	%	2010-2015	2015-2020
	68.745	35,3%	83.033	44,5%	61.835	34,4%	20,8%	-25,5%
Total Schools Brazil	194.969	100,0%	186.488	100,0%	179.612	100,0%	-4,3%	-3,7%

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2010, 2015 2020.

48
Orientation for reading the table: Each year shows the number of schools in both absolute numbers and % terms that have science laboratories available. The variations refer to the periods 2010 to 2015 and 2015 to 2020. For example: for the period 2010-2015, the calculation is: 21,278 (N 2015) – 18,991 (N 2010) = 2,287/18,991 = +12.0%

49
Table reading orientation: Each year shows the number of schools in both absolute numbers and % terms that have computing laboratories available. The variations refer to the periods 2010 to 2015 and 2015 to 2020. For example: for the period 2010-2015, the calculation is: 83,033 (N 2015) – 68,745 (N 2010) = 14,288/68,745 = +20.8%

Tables 35 and 36 describe the variation in the number of students who had access to a science laboratory between 2010 and 2015 and 2015 and 2020 by educational stage. The last column in the two tables shows the variation of student numbers in each of the stages, regardless of whether or not they have access to the science laboratory. It should be noted that while there is an increase in access to science laboratories in the initial years of primary school (7.7%), due to the drop in the number of students at the same stage, the same is not observed for the final years of primary education and secondary education. The negative variations of -11.7% and -4.8% respectively are in line with the overall decrease in the number of students. In general, between 2010 and 2015, the number of students in the three stages declined by -9.2% The numbers are low for all stages. In the best scenario, half of secondary students have access to a science laboratory.

Table 35: Variation in the number of students who have science laboratories available by stage, between 2010 and 2015[50]

Science laboratories	2010		2015		Variation 2010-2015	Variation in student numbers by stage
	N	%	N	%		
Primary education (initial years)	2.244.733	13,3%	2.418.371	15,5%	7,7%	-7,9%
Primary education (final years)	4.639.445	32,5%	4.093.775	33,1%	-11,7%	-13,2%
Secondary education	4.449.550	55,9%	4.236.797	55,8%	-4,8%	-4,6%
Total	**39.108.544**	**100,0%**	**35.521.675**	**100,0%**	**-9,2%**	

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2010 2015.

The same change is not observed for the period 2015 to 2020, in which access to science laboratories declines for the three stages. Considering the decade 2010 to 2020, there are no representative changes in access to science laboratories for the students considered.

50
Table reading orientation: Each cell represents the variation of students who have access to science laboratories for the selected stages in 2015 compared to 2010. For example, for the 2015-2010 variation in initial years, the calculation is: 2,418,371 (N 2015) - 2,244,733 (N 2010) = 173,638 / 2,244,733 = 7.7%.

Table 36: Variation in the number of students who have access to science laboratories by stage, between 2015 and 2020[51]

Science laboratories	2015		2020		Variation 2015-2020	Variation in student numbers by stage
	N	%	N	%		
Primary education (initial years)	2.418.371	15,5%	2.368.048	16,0%	-2,1%	-4,9%
Primary education (final years)	4.093.775	33,1%	3.934.350	33,0%	-3,9%	-3,5%
Secondary education	4.236.797	55,8%	3.742.881	54,5%	-11,7%	-9,6%
Total	**35.521.675**	**100,0%**	**33.580.894**	**100,0%**		**-5,5%**

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2015 2020.

The reality for access to computer laboratories is a little better. Table 37 shows the variation between 2010 and 2015, and it can be seen that there was an increase of 9% only for the initial years of primary school. Of this group, 71.6% of the students had access to laboratory spaces. For secondary education, the laboratory access rate was close to 90% for both periods.

Table 37: Variation in the number of students who have access to computer labs by stage, between 2010 and 2015[52]

Computer laboratory	2010		2015		Variation 2010-2015	Variation in student numbers by stage
	N	%	N	%		
Primary education (initial years)	10.218.401	60,5%	11.137.897	71,6%	9,0%	-7,9%
Primary education (final years)	11.836.061	83,0%	10.453.074	84,5%	-11,7%	-13,2%
Secondary education	7.432.650	93,4%	6.969.300	91,8%	-6,2%	-4,6%
Total	**39.108.544**	**100,0%**	**35.521.675**	**100,0%**		**-9,2%**

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2010 2015.

51
Table reading orientation: each cell represents the variation in the number of students in the chosen stages who had access to a science laboratory between 2010 and 2015. For example, for the initial 2020-2015-year variation, the calculation is: 2,368,048 (N 2020) - 2,418,371 (N 2015) = -50,323 / 2,418,371 = -2.1%.

52
Each cell represents the variation in the number of students in the chosen stages who had access to a science laboratory between 2010 and 2015. For example, for the initial 2010-2015-year variation, the calculation is: 11,137,897 (N 2015) – 10,218,401 (N 2010) = 919,496/10,218,401 = +9.0%

Table 38: Variation in the number of students who have access to computer labs by stage, between 2015 and 2020[53]

Computer laboratory	2015		2020		Variation 2015-2020	Variation in student numbers by stage
	N	%	N	%		
Primary education (initial years)	11.137.897	71,6%	7.947.326	53,7%	-28,6%	-4,9%
Primary education (final years)	10.453.074	84,5%	8.103.066	67,9%	-22,5%	-3,5%
Secondary education	6.969.300	91,8%	5.659.197	82,5%	-18,8%	-9,6%
Total	**35.521.675**	**100,0%**	**33.580.894**	**100,0%**		**-5,4%**

Source: Prepared by the authors based on the microdata of the Synopses of the School Census of 2015 2020.

There was a significant drop in the provision of laboratories by the end of the five-year period, being -28.6% for the initial years of primary education, in which coverage decreased to 53.7% of students. Comparing the last two columns, the provision of laboratories drops more sharply than the number of students, indicating a real decline in provision. The economic crisis and the impossibility of increasing education spending may be an explanation of this situation.

The very large data set presented aims to provide a reliable picture of the teacher profile and access to laboratories, especially for the final years of primary education and secondary education, where specialist science teachers are to be found. There are many different readings of the data, opening up the possibility of additional analysis. We chose to produce a cross-data analysis by social marker (gender and colour/race) and the sector and geographical region of the school. Some of this information is new and deserves in-depth analysis to support the construction and verification of the hypotheses.

53
Each cell represents the variation in the number of students in the chosen stages who had access to a science laboratory between 2015 and 2020. For example, for the period 2015-2020 in the first years of primary education, the calculation is: 7,947,326 (N 2020) – 11,137,897 (N 2015) = -3,190,571/11,137,897 = -28.6%

The information that immediately catches the eye, however, is the situation of secondary school students studying physics. The suitability of teacher training falls short when compared with the other subjects taught at that level. This indicates that it is not only the operating conditions of the school or the salaries on offer for the teaching profession, along with the other challenges facing education, that need to be addressed. It seems that there is a more specific situation discouraging people from training as physics teachers. See the analysis of the data from the Higher Education Census, in which the enrolment and graduation rates of potential physics teachers are significantly lower than those of other subjects.

This indicates that it is not only the operating conditions of the school or the salaries on offer for the teaching profession, along with the other challenges facing education, that need to be addressed.

This being the case, both the training of physics teachers (CES) and their subsequent teaching practice (CEB) deserve individual studies. Such studies have distinct objectives and methodologies and cannot be compared. However, the data show a trend – a lower initial interest in studying for a teaching degree in physics but an increase in the proportion of graduates and suitability of the training of teachers when they are actually exercising their profession, but they are still far from the level experienced for the other subjects reviewed. Some studies in the literature are concerned with teaching degree graduates; for example, Patrick Vizzotto (2021), who presents information from the 2018 Higher Education Census for physics teaching degrees. The author's results are in line with what is shown here, in addition it examines some other issues more deeply, using the INEP quality indicators, such as Course Concept (CC), Preliminary Course Concept (CPC), the National Student Performance Survey (ENADE) and the Difference Indicator between Observed and Expected Performance (IDD). In the conclusions, the author points out that:

> **Most of the courses are classified as Level 3 under the Course Concept quality indicators. It may be possible that there is an association between quality indices and the performance of course graduates. (VIZZOTTO, 2021, p. 9)**

When presenting the profile of physics teachers in state public schools, another author, Nascimento (2020), examines the microdata of the 2018 Census of School Education, which identified 44,706 physics teachers, of which only 9,000 have a physics teaching degree. The result is different in the analysis presented here because the parameter teacher function was used rather than teachers, since it was considered important to know whether the teacher in the classroom, even if teaching several classes, is qualified to teach the assigned subject. When it comes to the suitability of the training (Table 5), regarding the categories of suitability of teacher training in relation to the discipline they teach, the table includes both teachers with a teaching degree and those with a B.Sc. and a PGCE-equivalent qualification. These different views make it impossible to compare the studies but indicate that there are several possible paths and views available in the analysis of the educational indicators. The data on each of the subject and courses selected for analysis can be explored separately, linked to the evidence of research already carried out, for example. This approach, however, is not within the scope of this panoramic survey.

If the data show an improvement in teaching between 2015 and 2020, the fact that there are significant numbers of teaching functions in categories 3 and 4 is concerning. INSET programmes in their various forms may be a route for unqualified teachers to become better prepared for the challenges of dealing with a subject in the classroom.

It was not possible to assess teaching quality and student learning by individual subject. There remain some unanswered questions, such as: would a more appropriately trained teacher (Group 1 – teachers with a teaching degree in the same discipline they teach or a B.Sc. in the same subject with a PGCE) lead to an improvement in student learning? Also, what are the teacher absenteeism figures by subject?

6

Science teaching in the academic literature

2010 to 2020

One of the considerations when mapping the teaching of the natural sciences and their technologies in Brazilian school education was to examine what the academic literature has to say about the field over the last decade, on the basis of research studies. As already mentioned in the chapter on methodological procedures, for this research, the SciELO platform was chosen as the source of data on research, as it covers an important spectrum of the journals in the area of education. The main descriptor used for the survey was science teaching, resulting in a group of 281 articles when the platform was accessed in March 2020. It should be noted that these articles were published in 22 journals, most of them produced in the Southeast and South of Brazil, and 55% were published in the journal *Ciência & Educação*, which is produced by the Post-Graduation Programme in Education for Science of the Faculty of Sciences of UNESP, Bauru, SP, which is specifically concerned with the area.

After the results were examined through a critical reading process, five themes emerged: Teacher training; teaching methodologies and practices; curriculum; scientific literacy; inequality, rights and inclusion, which match the scope of the research. Those articles categorised as State of the Art, related to reviews of literature, were included under some of the chosen themes, when relevant. A number of articles were studied which focused on primary education, which is the area emphasised in this document.

Teacher training for primary education: in favour of a collaborative, critical, reflective and a questioning approach to the teaching of social reality

It is of interest that the articles speak of the focus of teacher training being a critical and reflective approach to theory and methodology, as well as developing teacher autonomy. The articles addressing this theme generally reference the same authors, who are authorities in the field of education, to support their research[54].Teacher training is identified as a challenge for public policies and for renewing the approach adopted by teacher training institutions, something pointed out by Bernadete Gatti (2009) and others. It is recognised that teacher training has been subject to a variety of changes in educational theory and methodologies over time, and transforming these into practical pedagogy remains a challenge, which is not always successfully overcome.

Maura Ventura Chinelli, Marcus Vinícius da Silva Ferreira and Luiz Edmundo Vargas de Aguiar (2010), in "Epistemology in the classroom: the nature of science and scientific activity in the professional practice of science teachers" present the results of research that sought to identify the different epistemological concepts incorporated into the professional practice of science teachers. The authors argue that the coexistence of different concepts may underlie some of the difficulties experienced in the teaching and learning of the sciences, including the lack of interest of young people in this field. They advocate the inclusion of studies of epistemology and the history of science in teacher training courses, as well as sociological studies of the curriculum.

54
Among the authors cited are Freire (1977, 2005), Zeichner (1993), Pimenta (2005), Maldaner (2006), Nóvoa (2007), Ibiapina (2008), Tardif (2010).

In all the articles concerned with teacher training, there is a recurrent argument based on scientific literature: that, in the light of the impact of scientific and technological development on society, there is a need to develop a moral and ethical awareness of the impact of scientific activity on society. Such an approach would mean overcoming a traditional distinction between the natural sciences and the social sciences.

The authors consider that space should be opened for a discussion on the democratisation of knowledge and ethical issues related to the production and distribution of scientific and technological products.

In this sense, teacher training would not be restricted exclusively to academic activities and teaching practice but would also be influenced by the teacher's own personal path (CHINELLI; FERREIRA; AGUIAR, 2010). Non-formal learning also contributes to generating concepts about science, scientists, scientific activity, and helps to give meaning to teaching. It is no coincidence that studies about teachers' views about the nature of science and scientific activity stand out. They express concerns about possible preconceptions that may influence the way science is taught and thought about. The authors consider that space should be opened for a discussion on the democratisation of knowledge and ethical issues related to the production and distribution of scientific and technological products (2010, p. 33). They understand that the rupture of the barriers represented by current paradigms would imply experimenting with, or rather experiencing, other formative spaces, such as science centres and museums, in order to encourage a perception of the social and historical character of the knowledge being imparted. These same concerns can be found in more recent articles, corroborating the arguments about the importance of considering teacher professional development as part of a *continuum*, favouring in this process a change to the ingrained mentalities and practices of current teaching.

In this sense, Flavia Rezende, Gloria Queiroz and Gleice Ferraz, in their article "Teaching objectives from the perspective of natural science teachers" (2011), show results of a study of the discourse of science teachers (physics, chemistry, biology and mathematics) regarding the purposes of education. It should be noted that less than half of the 27 teachers participating in the study said their objectives included social reality issues. The researchers advocate that initial teacher education addresses the social and thematic problems related to core living conditions such as health, education, and food security, as well as environmental problems, and that they be included in the science teaching curriculum, given that these are issues faced by all humanity in the 21st century. Following the same line, the article "The science concepts of a group of graduate teachers and their relationship with the training process" by Ana Lucia Santos Souza and Daisi Teresinha Chapani (2015) analysed the science concepts of teaching degree graduates and their relationship with the concepts as set out in course documentation and by the teacher of the subject Content and Methodology of Primary School Science Teaching. According to the authors, the results showed that the critical approach underlying the course was not reflected in the construction or review of the science concepts of future teachers, who generally had a positive view. The authors identify "three factors that influence the formation and perpetuation of these concepts: (i) the interference of teachers throughout school life; (ii) the way the media presents science and technology; (iii) distorted views of science and technology in textbooks, among others" (SOUZA; CHAPANI, 2015, p. 955).

A common aspect to the articles analysed is a recognition that the social transformations resulting from advances in science and technology are subject to the forces that govern society – economic, political, social, moral and ethical

A common aspect to the articles analysed is a recognition that the social transformations resulting from advances in science and technology are subject to the forces that govern society – economic, political, social, moral and ethical interests have stimulated research whose focus is science teacher training that contributes to the emancipation of the trainee teachers, which promotes a critical and reflective vision supporting a questioning view of social reality. Galvao, Reis and Freire (2011) consider that an understanding of the nature of science implies that students understand scientific knowledge from the direct impact on their life and therefore recommend the discussion of controversial social and scientific issues in school as a way of bringing science closer to reality. Their research aimed to understand how a group of 29 graduate teachers studying for a master's degree in education assessed the potential of this methodology.

With the same interest in addressing controversial themes in science classes, Silva and Krasilchik (2013) consider them to be a rich methodological tool for the teaching of science with a view to educating individuals who will be capable of making decisions about real problems – bioethics, for example. The research examined how 32 teacher trainees identified and handled ethical dilemmas, which could potentially be discussed with future students. The content concerned themes such as the environment and the use of new biotechnologies, among others. To be successful in this task, they emphasise the need for the scientific aspect to be predominant, maturity of judgement, and the analytical ability to deal with ethical dilemmas in a constructive manner. They make us aware, however, of studies that have shown that science teachers are uncomfortable about exposing themselves to controversial subjects, often opting to maintain a neutral position, to avoid facing the situation. In this sense, the inclusion of bioethics in initial teacher training could be favourable, helping students overcome a certain attachment to the purely biological dimension of their subject and contribute to the development of analytical reasoning and ethical perception, based on themes very close to the reality of future teachers.

The educational perspective of Paulo Freire is a central reference in research whose objective is to encourage reflections on contextualised practices in the initial training of teachers and in the teaching of science. Taking as their starting point his work Extensão ou comunicação? (1977), Carolina dos Santos Fernandes, Carlos Alberto Marques and Demetrio Delizoicov (2016), in the article "Contextualisation in the initial training of science teachers and the educational perspective of Paulo Freire", signal the importance of a contextualised and problem-focussed approach to teacher training and science teaching, in order not to reduce the formative processes to the mere application of techniques, but to show the effective importance of communication in the educational act. Their proposal is that teachers may bring the context of the reality of students to their teaching practice, where previous knowledge is heard so as to lead to problem-posing and to the introduction of scientific knowledge.

The training of a teacher does not finish when they graduate as a teacher, as has already been pointed out. It is in the classroom experience that the teacher experiences and formulates hypotheses, plans, executes and reviews their lesson plans and continues to build their professional identity. There is an understanding that it is not only the teaching activity that needs to be continually improved, but also the development of a critical perspective of reading reality and teaching science, as shown in the articles reviewed so far.

However, the proposal advocated by Paulo Freire (1996 and 2005) requires, according to the authors, a collective work involving an interdisciplinary team focused on research and the transformation of reality, intrinsic to a process of permanent in-service teacher training and development (INSET). This collaborative perspective is also explored by Fabiana Cardoso Urzetta and Ana Maria de Oliveira Cunha (2013), in the article "Analysis of a collaborative proposal for the continuous training of science teachers from the perspective of professional teacher development". The authors sought to understand the opportunities for professional development by analysing a collective proposal for science teacher INSET, viewed as a partnership between universities and schools. According to them, the analysis of the experience showed that the involvement of university researchers favoured the interest of schoolteachers by investing in their professional development through specialist diploma and master's courses.

However, the proposal advocated by Paulo Freire (1996 and 2005) requires, according to the authors, a collective work involving an interdisciplinary team focused on research and the transformation of reality, intrinsic to a process of permanent in-service teacher training and development (INSET).

The perspective of collaboration also appears related to the training itself, as pointed out by Armando Santos, Gloria Regina Pessoa Campello Queiroz, Patrícia Domingos and Giselle Faur de Castro Catarino (2019), who used a case study to investigate various aspects that enhance co-teaching in teacher training and the possibilities for developing an interdisciplinary approach, concentrating on the importance of floating to life on the planet. The objective was to analyse how co-teaching based on a didactic sequence entitled "The Floating of Bodies and Life", could contribute to the learning of teacher trainers and trained teachers through interdisciplinary dialogue. The proposal was to show teachers in training the possibilities of integrated work on relevant themes and to reflect on the potentiality and obstacles of their own practices, developing co-learnings in the process.

Patrícia de Oliveira Rosa-Silva, Alvaro Lorencini Júnior and Carlos Eduardo Laburú (2010), in "Analysis of the reflections of the science teacher on their relationship with the students and implications for their educational practice", they analyse the reflections on the interpersonal relationships between teachers and students and their influence on the educational practice. As a procedure they also used a video recording of a lesson as a resource for analysis and self-evaluation by the teacher themselves. The reflections of one of the teachers revealed a distance between herself and her students in the teaching and learning process:

> **We do not know when the prejudices began, as well as the time they would last, because we revealed data collected from the process of continuing education in the medium term (a school year). The fact that the teacher describes her conduct; answering her own questions; analysing the confrontation between what she read and she actually did in the classroom; planning actions, aiming to remove the prejudices she created against the students, leads us to consider the reflection on the action, with the help of the self-examination mediated by the dialogues between the teacher and the researcher, a strategy that enables the self-criticism of the professional in question. (ROSA-SILVA; LORENCINI JÚNIOR; LABURÚ, 2010, p. 80)**

The researchers point out that, in this experience, the ability to solve practical problems depends on a "reflective conversation" with the practice and problem situation presented by the participating teacher. The idea is to get the teacher to question their own work and practice on the basis of the educational situations they experience.

With a slightly different perspective, Fabiane de Andrade Leite and Lenir Basso Zanon (2018) present, in "Styles of thought of teachers of natural sciences and the process of shared autonomy", a study that reflects on the development of a collective of thought of teachers in the field of nature sciences in a training programme. The research focussed on an INSET project for natural science teachers during 2015, a continuation of a project that had been running for five years. The training methodology adopts an approach based on action research, from an emancipatory perspective. In this sense, the objective was to analyse the meanings expressed by teachers and teacher trainees on the concept of autonomy. They identified both the presence of both conservative and transformative thinking emanating from an emancipatory perspective. The authors advocate the development of thought collectives (as conceived by Ludwig Fleck) in the natural sciences as a more powerful educational approach. For that to occur:

[...] there is a need for those training science teachers to demonstrate interest in the process of collective interaction in a collaborative way, that moments of shared learning are encouraged, that the processes are continuous and permanent, with regular meetings held systematically from the perspective of action research, that the individual sub-disciplines in the subject area are represented and that a favourable environment is built to generate complexities and transform the conservative thinking style. (LEITE; ZANON, 2018, p. 975)

Overall, the articles identify gaps in the initial training that need to be addressed by INSET courses, mainly for teachers of the first stages of primary education. Some authors observe a strong concern with the foundations of education and the epistemological base of teaching in initial teacher training. They identify weaknesses in the approach to specific content indispensable for teaching in the first years of primary education, mainly concerned with the specificities of the natural sciences.

From the perspective of Thaís Augusto and Ivan Amaral (2015), the topics that most require additional training, either during the initial training or through INSET courses, are those that relate to other curricular components (multi or interdisciplinary) and those related to sustainability. Considering primary education, especially the first years, the authors warn, in the article "The training of teachers for teaching science in the initial years of primary school: analysis of the effects of an innovative proposal" , of the importance of integration between the main subject areas and specific topics and association between theory and practice in these two dimensions as essential. The objective of the study was to analyse the effects of an innovative proposal for INSET regarding the concepts and practices of science teaching for the initial years of primary school as reported by 13 multi-subject teachers who teach science to these classes. The results show that while most of them may have understood the key ideas of the subject area, they had gaps in their prior knowledge of specific science content which, when added to the limited class time available, were the main factors that made it difficult to learn and understand some of the ideas which the subject area was concerned with. The study concludes that there is a general lack of integrated training of science teachers, given that the supervised stages, which are the only practical activity, contribute to the generation of a wide range of possibilities and knowledge necessary for an effective approach to addressing specific themes. This fragility requires INSET programmes that includes the exchange of views, research and additional experiences.

The images taken by the students were able to awaken the trainee teachers to the possibility of moving away from strict adherence to the curricula and books, enabling them to develop their teaching practice more freely.

In "Reflections on experiences of continuing teacher education in a science centre: Trajectory, conceptions and formative practices", Fernanda Bassoli, José Guilherme S. Lopes and Eloi Teixeira César (2017) analyse reports sent to research agencies that examined records of teachers on an INSET course at the Science Centre of the Federal University of Juiz de Fora (2007 to 2015). They specifically examined the INSET experiences of teachers of the natural sciences and chemistry. Their intention was to find elements that reflected changes in the conceptualisation of INSET courses for science teachers from the classical approach of technical rationality to the later practical-reflective and emancipatory-political approach. The analysis of the research into these training experiences, combined with the views of the INSET course lecturers on the pedagogical practices supported by theoretical references, played a central role in the changes implemented in the courses offered by that institution.

Another study – "Introduction to research with teaching sequences in the online INSET of science teachers" (MASSI; GIORDAN, 2014) – produced in the context of a specialist diploma course in science teaching – REDEFOR, an initiative of the Secretary of Education of the State of São Paulo (SEESP), in partnership with the University of São Paulo (USP), the State University of Campinas (UNICAMP) and the São Paulo State University (UNESP) –, the objective of this study was to focus on the proposal for a study aimed at the production of research based on didactic sequences. Aimed at teachers who work in the state education system, whether in schools or other educational bodies, the authors describe the proposal for a directed study aimed at articulating research issues about educational practice through didactic sequences. They argue that this experience, by articulating the teaching activity and research on its practices, involving teachers in service, contributes to the creation of a production community, and if validated collectively, generates a common tool for teacher planning, and can be maintained after the completion of the diploma course.

A common criticism of some of the research presented here, not only among those who discuss teacher education, but also in studies on pedagogical practices, is the tendency to separate the academic world from the world of practice. In the article "The importance of shared reflection in the process of conceptual evolution of science teachers on their role in the mediation of knowledge in the school context" , published in 2013, the authors Lenice Heloísa de Arruda Silva and Fernando Cesar Ferreira (p. 427) suggest that the curricula for teacher training courses offer:

[...] first, a solid knowledge of the relevant scientific principles, that is, knowledge of the basic sciences relevant to their area of expertise; then they build knowledge of the applied sciences or techniques, in order, at the end of the day, to employ that knowledge in their professional practice. In relation to training courses for teachers of biology, physics, chemistry and other areas, this separation is realized in the theory-practice dichotomy and is manifested in the separation between scientific knowledge and professional teaching knowledge and between academic knowledge and school reality.

It is not uncommon for teaching training to be based on the teaching process through the use of tools in addition to textbooks. The article "Scenes and scenarios of the socio-environmental issues: mediations through photography" analyses a proposal for a socio-environmental activity involving a group of students training as teachers of Biology and Physics at the Federal University of Pará (UFPA), which made photography the trigger for research beyond the traditional possibilities used by schoolteachers (SANTOS et al., 2014). Serving as a provocation, the images taken by the students were able to awaken the trainee teachers to the possibility of moving away from strict adherence to the curricula and books, enabling them to develop their teaching practice more freely. Through photographs, field journals, readings and text production, action research enabled the trainee teachers to build a critical view of the local reality about environmental issues.

In our understanding, photography is a fundamental tool for teaching science, because it makes it possible not only to see the central issue of a given image or situation, but also to incorporate the multidimensional aspects of complex issues being studied, such as socio-environmental issues. We consider that by using photography we are able to build spaces of possibilities, subjectivities, authorship, autonomy, knowledge, wisdom and sensitivities when reading the world. Without a doubt, such spaces enrichen the teaching and learning process. (2014, p. 62)

As highlighted by the authors above, the issues regarding the teaching of science presented so far, when it comes to the training of science teachers, demonstrate the complexity of pedagogical practice and the process of building knowledge in the school environment. Training is fundamental for good teaching practice, and studies signal the importance of a teacher who collaborates with their peers on planning or assessment and who leads students through the same process of a collective approach to building knowledge.

Patrícia Albieri Almeida, Gisela Tartuce, Bernardete Gatti and Liliana B. Souza analysed theses, dissertations and articles published between 2008 and 2018, aiming to identify specific pedagogical practices relevant to the initial and continuous training of schoolteachers. One of the questions that guided this research was to discover "What inspires so many works that are concerned to shed light on pedagogical practices in everyday school at their different levels and modalities?" The researchers perceived that:

When examining theses and articles that are deeply based, even in various epistemic strands, on a theoretical approach that underpins the construction of educational practices, or those that when studying educational practices reveal their supporting referents, it can be seen that the motivation and interest in seeking cultural means and forms are there to improve the actions aimed at forming new generations of small children to young adults in all subjects, from mathematics to the arts, through the passing on of the knowledge that makes up the school curriculum. (ALMEIDA et al., 2021, p. 144)

This perception can also be found in the articles that will be reported below. The greatest number of articles in the survey carried out in the SciELO platform under the descriptor "teaching science" are concerned with teaching practices, pedagogical practices and didactic sequences. There were 91 references out of a total of 279, of which 55 referred to the period 2010 to 2020, and of these 28 were included in this review, as identified in **Chart 4**. This group of articles was organised by the themes identified in the reading of the abstracts and generated two subcategories: use of the arts and other forms of discourse; teaching practices and didactic sequences.

The number of articles in this theme is not surprising, since research on teaching requires thinking about the means of realising learning, considering the development of the cognitive, affective, relational and social dimensions. If, in the literature on teacher training, studies on the processes are highlighted to better prepare a science teacher capable of recognising the meaning and nature of science, who adopts a critical and reflective attitude to the social reality, who establishes a dialogue with their students while stimulating them to learn scientific knowledge, the research then focuses on how to realise this view. Following the example of what was identified in the above-mentioned study, case studies predominate, experiences with teachers in state schools or in initial or continuing education, whose reports are usually limited to a particular reality and whose strategies are not detailed (ALMEIDA *et al.*, 2021). Nevertheless, the research is inspiring and reveals the strength of a field of knowledge that continues to be dedicated to the improvement of the teaching-learning processes of the sciences.

Teaching methodologies and practices

The studies on initial and continuing education point to a profile of a primary school science teacher who can, ideally, be characterised as[55] attentive to their own conception of scientific knowledge, to its constant improvement, collaborative with their peers and their students; capable of critical reading of the social reality, identifying the main social and environmental issues in order to awaken interest in their students and valuing their previous knowledge through an investigative and questioning process, and

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Max Weber (1999).

who is capable of articulating scientific knowledge with them. This profile is a simplification, a generalisation of the real situation, which is open in this case to the complexity of the teaching profession, but also to the expectations for performance in practice. The following articles are concerned with the practices and approaches available to the teacher wishing to perform well. Some of the challenges identified in the research on training help to identify what is required to achieve that, as several studies are carried out with the participation of teachers and activities in schools or make use of tools such as video recording, diaries and other means to record them, as well as questionnaires.

Fernanda Bassoli (2014), in the article "Practical activities and the teaching and learning of science: myths, trends and distortions", for having acted as a supervisor of practical placements and having followed the difficulties faced by the teacher trainees, highlights the importance of practical classes in school life:

During the period I acted as a supervisor of practical placements in science and biology teaching courses, I encountered this reality every school term through the narratives of my trainee students – scattered across a range of state, municipal and private schools – about the near absence of practical sessions in the classes they were observing. When present, the practical activities aimed at demonstrating theoretical content and proving theories. (p. 584)

Her perception is shared by other authors, who observe the absence of practical activities, supported by the same reasons she identified in her article: insecurity, lack of support, excessive workload, poor school infrastructure, among others. The author draws attention to the lack of works that address the lack of preparation or motivation of the teachers themselves as a cause of indiscipline and lack of motivation amongst the students in the face of dull and essentially expository teaching. It defends the importance of discussions that consider practical activities in real contexts, taking into account possible weaknesses in training, the lack of the necessary infrastructure in both the schools and the teachers, students and their families themselves, but also as part of the intrinsic difficulties of work involving social interaction. This view of the teacher's work can be found, although with different nuances, in some of the articles presented here.

Teaching science and research practices, problem solving and argumentation

A group of articles explores approaches such as investigative pedagogy, problem solving, and argumentation. The article "The construction of arguments in science classes: The role of data, evidence and variables in establishing justifications" , by Sasseron and Carvalho (2014), presents a bibliographic review that examines this diversity of approaches, and, despite some specificities, it articulates them to some extent. According to these authors, in the context of a problem-focused approach, there are teaching approaches that have been gaining space in both higher education and school education. They cite as an example the approaches defined as: themes based on the work of Paulo Freire, investigative teaching and the Science, Technology and Society-based approach (STS)[56]. In relation to the latter, it has been supported by different scholars, and its epistemological and pedagogical bases may vary, depending on the theoretical perspective adopted. We now examine the work of some of the authors who interact with these approaches.

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Interestingly, the STS and Science, Technology, Society and Environment (CTSA) approaches are strongly represented in articles dealing with scientific literacy, as we will see below.

In the article “Research activities in science teaching: historical aspects and different approaches”, Andréia Freitas Zômpero and Carlos Eduardo Laburú (2011) identify a consensus amongst researchers regarding the development of skills inherent to scientific activity, such as raising hypotheses around a problem, collecting and analysing data, arguing and constructing explanatory models. But they propose different nomenclature for investigative activities in science teaching, such as “inquiry-based learning,” “project-based learning,” “discovery-based learning,” “problem solving,” – all stemming from the inquiry-based educational theories of the educationalist and philosopher John Dewey. They are in agreement, however, that this inquiry-based approach to science teaching makes it possible to improve the students’ thinking and cognitive skills, as well as cooperative efforts amongst themselves, in addition to building an understanding of the nature of scientific work. The article seeks to identify in the literature the characteristics of teaching activities that can be considered investigative. They identified different ways of developing these activities with the students and a lack of consensus amongst the researchers of this approach to teaching. The polisemy of the descriptions of the concept, however, reveals a point of greater convergence regarding the use of activities based on problem resolution, favouring the engagement of students and an involvement with investigative procedures.

In another article on the theme, the same researchers – Zômpero, Gonçalves and Laburú (2017) – discuss and analyse how investigative activities favour the development of cognitive skills for scientific research and activate executive functions, in light of studies of neuropsychology. They note that the methodological application of investigative activities in science teaching improves cognitive skills for scientific research, as well as executive planning functions, proactive action, and monitoring. Cognitive abilities for scientific research involve the ability to observe, record, analyse data, compare, perceive evidence, make inferences, reach conclusions, improve reasoning and argue. Some of these skills were assessed on the basis of the performance of the students who participated in 2015 in the Programme for International Student Assessment (PISA) test, developed and coordinated worldwide by the Organization for Economic Cooperation and Development (OECD), and by the Anísio Teixeira National Institute for Educational Studies and Research (INEP) in Brazil. The authors analysed the questions of the test and described the cognitive processes involved in their resolution which the students should demonstrate by solving some of the questions, such as identifying questions and evidence, elaborating, evaluating and communicating conclusions. In the authors’ view, the development of these cognitive abilities, if developed, can contribute to cognitive instrumentalisation of young people to deal with and solve problems in the material, intellectual and cultural environments of their lives. They conclude that the methodological application of research activities in science teaching can contribute to improving these skills and the use of executive functions, generating structural changes in the central nervous system and behaviour, given the inseparability of neuro-biological development and physical and mental actions.

From the perspective that investigative and problematising activities can stimulate interest and learning in science, Marcelo Leandro Feitosa de Andrade and Vânia Galindo Massabni (2011) carried out research aiming at "understanding how primary school science teachers perceive these activities, as well as knowing whether they are used by them and the reasons for their use or non-use in the classroom". The researchers interviewed 12 science teachers, who said that they rarely used practical activities and had difficulties in carrying them out. The idea was to explore the meaning of practical classes and activities and the motivation for their use (or not) in the classroom, as well as the reasons that support them. The results confirm the limited use of practical activities, even among more experienced teachers. Among the arguments identified are the lack of time to prepare the activities and the frequent change of schools, which does not favour integrative and collaborative work with colleagues. However, considering an understanding of the nature of science is a fundamental precept for forming students and teachers with a more critical view of the world and reality, the researchers were concerned with the arguments raised by some of the teachers interviewed for not using practical activities, such as the possibility of inappropriate behaviour by students, especially in activities involving experiments, alleging safety issues.

Thinking about the specificities of science teaching at each stage of schooling has been an important challenge in the debate on both the school curriculum, learning and pedagogical practices. In the article "Physics for children: Addressing physical concepts based on problem solving", by Beliato Santana Campos, Naiara Fonseca de Souza and Simone Aparecida Fernandes (2012), the low relevance of physics and natural phenomena in the first years of education. They argue that at this stage contact with specific phenomena may awaken children's interest in science. For this reason, the article proposes to address the use of problem-solving involving experiments already in the initial years of schooling. The work was developed in a 4th year primary class in a municipal school in Gandu (BA). The children carried out a number of activities, recorded them in drawings and then discussed them as a group. There was no intervention by the teacher during the activities, only later, when the content was systematised in writing. The process started from the children's interest in understanding natural phenomena, surprising the teachers by their engagement in the activity. The intervention and its results show the importance of teacher training focused on scientific literacy and practices that can stimulate work involving scientific concepts in the initial years of primary education.

the development of these cognitive abilities, if developed, can contribute to cognitive instrumentalisation of young people to deal with and solve problems in the material, intellectual and cultural environments of their lives.

Still in the field of physics teaching in the initial years of primary education, the researchers Ana Paula Solino and Simoni Tormölhen Gehlen (2015), in the article "The role of Freirean problem-posing in science and physics classes: Articulations between the Freirean thematic approach and the inquiry-based approach to the teaching of science", analyse the role of problem-posing in the context of a didactic-pedagogical proposal based on the relationship between the thematic approach of Paulo Freira and inquiry-based teaching of science. To do so, they used the theme "Rio Cachoeira: What water is this?", which arose from a local problem experienced by the school community in Itabuna (Bahia). The activities carried out showed that the water "of the river discussed in the activities is not a simple water, as is commonly discussed in science textbooks. This water is culturally marked by a history that has been and will continue to be written by the individuals immersed in this context" (SOLINO; GEHLEN, 2015, p. 925). The authors argue that the Freirean problem-posing approach can contribute to structure the problems of the scientific/physical activities of the inquiry-based approach, besides allowing students to reflect on problematic situations in their reality, while at the same time exercising an investigative attitude to the practical problems of science.

In this sense, the themes that emerge from the students' experiences are considered starting points to structure the whole didactic-pedagogical process, but also the starting point for planning the entire sequence of activities. By assuming this function, the conceptual problems typical of the inquiry-based approach may become more significant for students, involving themes related to the real problems they experience.

Renata Batista and Cibelle Silva (2018), in their article "The historical-investigative approach to science teaching", discuss the contributions of inquiry-based science teaching in stimulating those attitudes required in scientific practice, such as inquiry, reflection, discussion, observation, exchange of ideas, argument, explanation, and reporting of discoveries. In addition, it favours the active participation of students. According to these authors,

[...] the curricular reforms of the 1990s began to consider aspects of the nature of science, in order to emphasise the non-neutrality and complexity of scientific practice. The objectives were for students to understand better what science is and develop a broader view of the relationship between science, technology and society, without losing sight of the need to learn scientific concepts. (BATISTA; SILVA, 2018, p. 99)

The researchers argue that content involving the history of science, but also sociology and philosophy, can contribute to "humanising" science as an inspiring source for learning the concepts and procedures of scientific activity and as a way of engaging students. The historical-investigative approach (HI) would aim, in this sense, to motivate and teach scientific concepts in a more critical way, explaining difficulties and achievements and contextualizing the content taught in the classroom.

However, they also said that an historical-investigative approach is not a simple process, since it involves creating the conditions for involving students in the whole investigative process, leading them to study historical episodes related to experimental practices which, in turn, require the teachers to have the desire and ability to mediate and generate an environment conducive to reflection. The research they carried out involved testing lesson plans using the historical-investigative approach with teachers from state schools in São Carlos (SP). The lesson plans included physics kits from the Experiment Collection of the Centre for Scientific and Cultural Information of the University of São Paulo (CDCC-USP).

Inquiry-based teaching was also the subject of a study by Ana Paula Solino and Lucia Helena Sasseron (2019). The authors are members of the Physics Research and Teaching Laboratory (LaPEF), of the University of São Paulo (USP), which since the 1990s has had an interest in research in the problem-solving approach. The question they sought to answer was: How do teachers and students attribute meaning and sense to a didactic problem in an investigative lesson? Qualitative research made use of data extracted from videos of third-year primary school inquiry-based classes in a state school. They used the significant elements of the problem-solving theories of Vygotsky as a means to analyse the data.

The inquiry-based class started with the following challenge: Three men want to cross a river. The boat can support a maximum of 130 kg. The three men weigh 60, 65 and 80 kg, respectively. How can they cross the river without sinking the boat? (2019, p. 275). In their article "The significance of the didactic problem based on potential significant problems: analysis of an investigative class", they discuss the second part of the activity, when potential significant problems (PSP) were revealed. A teacher-mediated process which relates daily thinking processes to the scientific approach and meaning is initiated, generating an opportunity to introduce knowledge. An important learning point identified by the authors is the importance of a well-formulated didactic problem capable of generating questioning by the students. Or, as the authors point out, "a problem that generates cognitive and collaborative needs arising from contradictions, as well as establishes the imaginative and creative processes required to solve them." And they consider the need to "expand the discussions of these elements beyond the context of classroom interactions, investigating both their limitations and their potential in the curricular approach to didactic and pedagogic science activities within the humanising approach of Vygotsky" (SOLINO; SASSERON, 2019, p. 584).

The argumentation approach used as a teaching resource can be found in the article "Argumentation in science teaching: the Brazilian context", by Luciana Passos Sá and Salete Linhares Queiroz (2011). The authors analysed Brazilian academic production on the use of argumentation in science teaching presented at National Meetings on Science Education Research and in Brazilian journals concerned with education and science education. They analysed aspects such as the year of publication, geographic region and HEI of origin, educational stage for which it is intended and thematic focus. The literature reviewed by the authors shows that studies on argumentation began in the 1950s, based on the works of Perelman, Olbrechts Tyteca and Toulmin, and the development of critical approaches to thought and language. Their choice of the annals of the National Meetings on Science Education Research covering the period 1997 to 2009 is due to the fact that it is the most significant meeting in the area; they also considered articles published in Brazilian journals included in the CAPES Qualis Programme. They also included journals from the area of education that relate to the teaching of science and mathematics. According to the authors, research in the area of physics is reported with more frequency in the literature when compared to the other areas, favouring secondary education. The research focused mainly on teacher training and the development of strategies promoting the concept of argumentation. They highlight the lack of studies that deal with the elaboration of models for analysis and mechanisms for teaching argumentation.

Lucia Helena Sasseron and Anna Maria Pessoa de Carvalho (2014) write about activities in science classes that contribute to the construction of arguments, especially working with data, evidence and variables in order to construct rationales. They studied the verbal interactions that occurred in the classroom, analysing how argumentation is established in science classes. In order to do this, they recorded two 4th-year primary school science classes. The initial analysis provided them with evidence of the arguments collectively constructed in these classes. They base themselves on the Toulmin's Argument Pattern (TAP), but also carry out a supplementary analysis with the objective of understanding how information and data are worked on the construction of the argument. The authors supported their argument in "works of the area that mention the possible inadequacy of this reference when used to analyse the interactions that occurred in the classroom". However, they concluded that for science classes, TAP is not appropriate, because interactions must, in essence, occur through dialogue. Previous studies on scientific literacy and the use of the argument have already questioned this limitation:

The argument model proposed by Toulmin was used in these studies and allowed us to analyse the coherence and cohesion of an argument with its structure as its focus; however, we are faced with situations in which, although internally coherent and cohesive, the argument was misleading, signalling to us the poverty of its quality in relation to the theme of Natural Sciences addressed at the time it was expressed. This has prompted us to look for alternative ways of analysing the construction of arguments in such a way that we could find ways to point the way forward for this development throughout the process. (SASSERON, CARVALHO, 2013, p. 173-74).

In the case analysed, they observed that the teacher follows a path that begins by working with available empirical data, which are evaluated in other situations and lead to the construction of hypotheses by the students and the gathering of evidence used in the investigation. Similar results have already been observed by them in other studies they have carried out.

What draws attention to this analysis is that the order in which the argument is constructed is counter intuitive: the teacher is not part of the construction of the claim that would satisfy the condition of stability, but this claim is a consequence of the analysis of several situations; providing us with evidence that the process it uses is a process of investigation into empirical data. (SASSERON, CARVALHO, 2014, p. 408).

In the article "The construction of argument data in an investigative didactic sequence in ecology," by Sofia Valeriano Silva Ratz and Marcelo Tadeu Motokane (2016), the analysis of the argument and its relationship with the teaching of science is based on data provided by the teaching material. The authors use the TAP methodology to identify the argument constructed in an investigative didactic sequence in ecology applied to teachers in a short INSET course.

The research is the result of a partnership between the research group and a local education authority in the state of São Paulo in 2012. This education authority intended to train science and biology teachers so that they could provide innovative experiences in science teaching. The application of the investigative didactic sequence to 25 general science and biology teachers lasted approximately two hours. The workshop was recorded and transcribed. On the basis of the results obtained, the authors emphasise the importance of good leadership of the investigative didactic sequence, as well as attention to the quality of the data provided by the didactic material and the previous knowledge of the learners. In addition, they recommend a collective approach to INSET, such as permanent spaces for reflection and acceptance by teachers of their role as important agents in the development of argumentative and transformative reasoning of reality, accompanied by critical reflection.

As in Ratz and Motokane's Article (2016) , other articles included in the survey also made use of the didactic sequence as an instrument for their research on teaching practices. The expression "didactic sequence" gained visibility in Brazil in the 1990s upon the publication of the Curriculum Parameters in 1992, due to the study of texts by means of discursive genera. The concept of a didactic sequence is associated with the theory of socio-discursive interactionism. Its epistemological origins are the work of Mikhail Bakhtin and Jean-Paul Bronckart, which is based on a methodology that integrates studies of cognitive psychology with the theory of speech genres. For these scholars, the student-student and teacher-student social interactions are fundamental to the development of learning and, in this case, the appropriation of reading, writing and formal orality at school.

In the study of academic literature on science teaching described here, some studies present examples of didactic sequences based on specific thematic content, such as that seen in "Conceptual profiling and the concept of death in the teaching of science", by Aline Andréia Nicolli and Eduardo Fleury Mortimer (2012). Death is a topic that is rarely included in classes, but it allows us to explore the concept of the life cycle. This research consisted of creating a conceptual model of death and identifying the characteristics of the life cycle. Another topic that gave rise to a didactic sequence was the annual seasons, described by Camila Linhares Taxini et al. (2012), with the intention of presenting an overview of the contents involved and the relationships between scientific knowledge and daily life. The starting point for the construction of this didactic sequence were the prior conceptions of those involved, and the work of the teacher was to introduce concepts of astronomy during the process.

Maria Raquel M. Morelatti *et al.* (2014) analysed sequences of activities or didactic sequences described by teachers of mathematics and the natural sciences in primary and secondary schools. The objective was to identify patterns implicit in these sequences that could reveal the teaching concepts of these teachers. The research showed a tendency towards the activity being predominantly teacher-led throughout the process, with the student executing the actual activity. Finally, researchers Erivanildo Lopes Silva and Edson José Wartha (2018) discuss epistemological and pedagogical aspects of the design of didactic sequences and learning in the field of science teaching.

In general, the results of the studies reported in the articles show that a direct approach involving teachers delivering real activity in the classroom can contribute to an improvement in teaching practice. In the majority of cases, gaps in the performance of the teachers are noted and highlighted. The research methodologies that involve the direct participation of teachers in the classroom tend to contribute more strongly to the self-evaluation and reflective process of these professionals, a process that could be continuous in the formation and improvement of pedagogical practice, as well as fundamental in updating scientific concepts and their application.

Teaching science using the arts and other subjects

An important subgroup in the Teaching Methodologies and Practices category are articles that use other subjects and approaches to stimulate the interest of children and adolescents to learn the sciences and to broaden their relationship with cultural, social and historical reality. The subgroup includes research on the use of music in the teaching of science (BARROS; ZANELLA; ARAUJO-JORGE, 2013); theatre (OLIVEIRA, 2012; FREITAS; GONCALVES, 2018); literature such as poetry, science fiction, comics/cartoons, scientific journals (PASSI, 2013; PALCHA; OLIVEIRA, 2014; KAWAMOTO; CAMPOS, 2014; GROTO; MARTINS, 2015; GIORDAN; MASSI, 2019; LIMA; RAMOS; PIPASSI, 2020); images and drawings (WOLF; MARTINS, 2014; SILVA; AGUIAR JR.; BELMIRO, 2015; SANTOS; PUGLIESE; SANTOS, 2019); games (SANTOS; AQUINO, 2018; DINIZ; SANTOS, 2019); films and documentaries (SOUSA, 2020), among other creative ways to expand learning possibilities and means of bringing students closer to science.

The magazine Ciência Hoje das Crianças (Children and Science Today) has been used and studied as a teaching resource for science classes and interdisciplinary activities. The researchers Marcelo Giordan and Luciana Massi (2019) analysed the section "Eu li, eu leio" (I read, I read) of the magazine from the perspective of Bakhtin's concepts of speech genres and chronotopes. They recorded 22 stories from current and past readers published in 2016, in a special edition commemorating 30 years of publication. The analysis supported a criticism by the authors that the publication favoured a stereotypical view of the scientist, in which they are characterised by curiosity, enjoyment of studying and a knowledge of nature and animals. According to them, this view is corroborated by other authors. They warn of the importance of taking greater epistemological and pedagogical care with the use of other science education materials, so as not to reproduce stereotypes and limit the meaning of science.

Marcelo Diniz Monteiro de Barros, Priscilla Guimarães Zanella and Tania Cremonini de Araújo-Jorge (2013), in their article "Can music be a strategy for the teaching of the natural sciences? Analysing approaches by schoolteachers, they discuss the possible use of Brazilian popular music by teachers of the natural sciences and biology. Data from a questionnaire indicates that most teachers do not work with Brazilian popular music as a strategy for teaching these subjects. Among the reasons given is a lack of time and an excessive workload. The opinions of the teachers on the main factors that could contribute to these results were discussed, as well as the reasons that lead them to use or not this pedagogical strategy. On the other hand, in the reflexive process about the results, those who said they would use music justified it by a desire to enrich and diversify their classes and the need to innovate the methodology used in class, among other aspects.

Based on theoretical-methodological contributions proposed by Vygotsky, the researchers Guilherme da Silva Lima, João Eduardo Fernandes Ramos and Luís Paulo de Carvalho Piassi (2020) analysed poetry produced by students from the 9th year of primary school in science classes resulting from a didactic sequence. The study involved analysing the poetry produced by the students and used the following question as the starting point: *Do you know who you are talking to?*

From this question, the science teacher questions the micro and macroscopic reality, seeking to question the place of the human being in the Universe. The methods used by the teacher during the classes were diverse, including reading texts, videos, panels,

discussions and individual and group work. In order to produce these, the teacher explained the nature of the activity to the students and introduced them to some poetry, including "Portuguese Sea", by Fernando Pessoa (2002), and two other poems written by students in the previous year [2013]. (LIMA; RAMOS; PIASSI, 2020, p. 10

The poems presented different orientations for reality, using concepts worked on in the classroom to support the students' positions. The focus of the activities was questioning of scientific, ethical and philosophical issues, favouring an interdisciplinary approach.

In an article on the use of drama in the teaching of science, Nívia M. S. Freitas and Terezinha V. O. Gonçalves (2018) seek to establish a dialogue between science and art, primarily mediated by drama. The research question was: *In what manner do formative experiences mediated by drama practices contribute to the learning of socially relevant knowledge and critical and reflective understanding of reality?* In the article, they explore the discursive textual analysis of the TV news programme entitled Diálogo noturno (Night Talk). The theatre-news programme experience with students involving the restaging of classroom scenes, allowed them to express with creativity and criticism information relevant to the reality experienced in their daily life, especially regarding their socio-environmental reality.

Luís Paulo Piassi (2013) presents, in his article "Science fiction and cognitive estrangement in science teaching: critical studies and classroom proposals", reflections on the inclusion of science fiction in the science classroom. He argues that the characteristics of this genre favour a specific way of reasoning about the natural world. According to him, the mechanisms used in science fiction are based on conjectures that promote the so-called "cognitive estrangement" capable of helping students to question things, which may be the starting point for a critical approach, not only of concepts and laws, but also of its epistemological and sociocultural implications and motivations. He based his work on Craig Freudenrich's use of the 1984 film 2010: The Year We Make Contact in the classroom, where he worked with a group of 7th to 9th grade elementary students in the USA for three weeks exploring topics such as Newton's Laws of Motion, momentum, forces, and other physics topics.

However, he considers the importance of choosing works that include innovative and transformative themes, supporting some interpretative effort on the part of the students. The article, based on the literature on the theme, lists a number of good reasons for the use of science fiction in science classes: to encourage students to pursue their own interests in this literary genre; to confront world visions and narrative techniques in their relationship with scientific knowledge; and to identify, appreciate and analyse the works more critically.

With the intention of reflecting on the perception of teachers regarding the canonical iconography of evolution and how biological evolution is seen as synonymous with the progress of living beings toward a presumed ideal of organic perfection (Homo sapiens), Patrícia da S. Santos, Adriana Pugliese and Charles Morphy D. Santos (2019) published "The linear iconography of evolution from the perspective of school teachers", a result of qualitative research involving primary and secondary school teachers of science and of other non-related areas. They investigated how the teachers perceived the iconography of evolution and how it influences the understanding of the fundamentals of evolutionary theory in the classroom. The results demonstrated that the teachers did not address the historical and social condition and did not mention issues such as the exploitation of the environment and human beings, human racial hierarchy and colonialism, content that would allow us to reflect on racism and stereotypes. According to the authors, these results corroborate the initial hypothesis that the iconography of evolution – the progressive march of progress of the hominids – remains present in the school reality and is rarely de-constructed in the discourse of teachers (2019, p. 19).

There are many ways of stimulating the interest of children and adolescents in the sciences. Most of the research taking place involves a very restricted universe of teachers, students and schools. It is important that these results be expanded. Academic articles tend to circulate among researchers and their peers, generally far from the reach of the school.

The science curriculum and contextualized science

In a search for articles on the theme "curriculum" in the SciELO platform under the descriptor "science teaching", only a few hits were obtained. This intriguing situation has led us to consult the Research Groups Directory and the result, shown in the table below, may help to explain the low presence of the theme in the collected articles. It is possible, however, that a different result would be obtained in a search taking as the principal descriptor the term "curriculum" and associating it with "science teaching" as a secondary descriptor. In any case, what has been discovered is that few research groups are concerned with research into the science curriculum in school education.

Chart 8 –- Number of research groups focusing on curriculum + science teaching

Descriptors used	Filters applied	Research Groups
Curriculum	Group name and research focus	592
Curriculum	Group name	123
Science curriculum	Group name and research focus	**021**
Science teaching	Group name and research focus	555
Science teaching	Group name	190
Science teaching in schools	Group name and research focus	**006**
Science teaching in schools	Group name	**002** (one in education and one in mathematics)

Source: Research Group Directory – CNPq. Accessed in January 2022.

One of the articles analysed: "An analysis of science curricula in the light of Bernstein's theory". by Franciele Braz de Oliveira Coelho (2017), presents a bibliographic review of three journals concerned with the area of education (2010-2014), identified in the SciELO platform, which published articles analysing natural science curricula on the basis of the sociological presuppositions of Basil Bernstein. This research line has a special emphasis on journals published in Portugal. In the case of articles referring to Brazil, the work of Claudia Galian (2012) should be highlighted, as it informs of an unfavourable context for the development of complex thinking, due to the compartmentalisation of knowledge in curricular components, without seeking to interrelate the different areas of knowledge.

The author highlights a very present issue in educational debates about the need to develop interdisciplinary practices in schools, where knowledge can be built by students in a non-fragmented way. It suggests that INSET courses and more time for teachers to plan their lessons is an appropriate approach to handling this challenge.

The Common Curriculum (BNCC) and its relationship with a contextualised approach to the teaching of the natural sciences

The science curriculum has been changing according to the teaching practices to suit the new needs of the interaction of the sciences with other components to generate meaning in the reality of the students, their culture and the environment in which they live (CARDOSO; ARAUJO, 2012). "The science curriculum: rural teachers and schools", by Lívia de Rezende Cardoso and Maria Inez de Oliveira Araújo, analysed the selection of content by science teachers working in rural schools. They point out that the curriculum is guided by the selection of content from the textbook. The local context and the practices of the surrounding community do not arise naturally as a learning resource.

The curricula, unlike legislation-based documents, should take into account that proposals developed in the school environment are, in addition to being guidance for the school community, also trigger the production of curricular policies (CARDOSO; ARAUJO, 2012). It is a flow that promotes the distribution of ideas in both directions for knowledge dissemination, taking into account the community in which that curriculum is being implemented and has meaning, expanding opportunities for access to contextualized content, as the BNCC recommends. The document does not intend to standardise what schools should teach, since it is the responsibility of the schools themselves to define the application of the curriculum in their pedagogical policies. The text stresses that

> **[...] the curricula have complementary roles in ensuring that the essential learnings defined for each stage of school education are achieved, since such learnings only materialise through the set of decisions that characterise the curriculum in action. It is these decisions that will adapt the BNCC proposals to local reality, bearing in mind the autonomy of the different education authorities and schools, as well as the characteristics of students and their context. (BRASIL, 2018, p. 16)**

The principles that guided the production of the core curriculum guidance for the natural sciences are supported by four axes: conceptual knowledge, social and historical contextualisation of knowledge, processes and practices of research, and means of communication in the natural sciences. This set of axes can be interpreted both in general, considering the relations between themselves and each specifically, and individually, as Maria Eunice R. Marcondes states in "The Natural Sciences in the 1st and 2nd editions of the Common National Curriculum " (2018). Defining a context to explore a topic is necessary when considering an integral approach to scientific literacy.

Some studies focus on exploring paths to education through the perspective of traditional knowledge, bringing cultural themes to the fore. This is the case in a study presented by Cardoso and Araújo (2012) on the science curriculum in a rural school, where the teachers interviewed by the authors make it clear that the curriculum is not adapted to the local reality, indicating a lack of cultural integration in the proposed curriculum, in addition to demonstrating how the textbook was mistakenly used as the curriculum itself. While providing guidance to the teacher on the organisation, development and assessment of their classroom work, the textbook ends up becoming the instrument that sets the content to be taught. Thus, considerable expectations are placed on the supporting material for the teacher and little on the school's political and pedagogical mission.

Questioning the construction of Brazilian scientific knowledge based on knowledge and customs that do not belong to the country's geographical environment and are unrelated to local or national reality, an article highlights the alternative knowledge related to indigenous traditions, as an opportunity to redirect the curricular structure of science teaching by relating it to nature and its resources (CAVALLO, 2018). The text argues that traditions carry in themselves the traditional knowledge of local cultures which have been side-lined but which should be recovered

[...] especially in terms of biodiversity conservation and sustainable use of natural resources, it can become an alternative knowledge system, equally valuable to achieve the intrinsic objectives that translate into sustainable development. (CAVALLO, 2018, p. 382)

Considering local experiences and stories when developing a BNCC-supported curriculum as a starting point would be fundamental to characterise the core curriculum as an instrument of democracy (MARCONDES, 2018) that can, in addition to providing the student with greater meaning, give value to teachers' knowledge of the communities in which they work.

When constructing science curriculum proposals, care also needs to be taken to ensure that they are truly interdisciplinary. According to Santos and Valeiras (2014), interdisciplinary approaches are based on "strategies to integrate subject knowledge in the most profound form possible," but most of the proposals identified in surveys are limited to inserting several subject areas into the same context, without articulating them in an integrated and collaborative manner. This frequently creates a sense of disconnection amongst the students, and an obligation to carry out tasks that do not make sense. Therefore, curricular initiatives to reform the science component of the curriculum need to be multiple in nature: at universities, in INSET courses and in the school itself, from the perspective of a science that considers itself a cultural production, maintaining a dialogue with other cultural systems, while still taking into account the prior knowledge of teachers and students (CARDOSO; ARAUJO, 2012). These critical approaches to interdisciplinarity point to the challenges involved in implementing the BNCC, which presupposes a connection between knowledge about common phenomena and objects.

A concern to apply a local context to the science curriculum takes into account cultural aspects that come loaded with the traditions and customs of the population to which it is being applied and the daily life of the community (CARDOSO and ARAÚJO, 2012). Considered as an agent of the educational process, the teacher is responsible for bringing contemporary discussions based on practice beyond the walls of the institution to the classroom and that they are relevant to the students. Teachers are expected to select content which takes into account the skills covered by the BNCC without disconnecting the teaching from the local reality of their students, using educational resources as supplementary material and not a framework to be followed, but recognising them as multiple and diverse in their usefulness.

This elaboration – which connects scientific knowledge to local and prior knowledge – required the participation of questioning teachers who are involved with the different realities of their schools and students, so that they can encompass relevant aspects of their students' lives in meaningful teaching proposals. Achieving this goal implies a collaborative, continuous and reflective approach to the entire school community when building the curriculum for teaching science, both at school and for INSET projects.

Next, a selection of articles from the SciELO database survey that explore scientific literacy will be examined from the perspective of changes related to the use of the terms for the democratisation of science and understanding of its employment, it also focuses on arguments concerning a critical perspective of science teaching, as seen so far, in the literature on teacher training and teaching methodologies and practices.

Science alphabetisation and science literacy

Published articles tend to include both terms. Although they originated from the same term in English: "scientific literacy", they are dissociated processes, although often interrelated. The use of the two terms has been the subject of a linguistic debate, and when it comes to the teaching of science it has been accompanied by the learning expectations of scientific education, as Francimar Martins Teixeira illustrates in "Scientific alphabetisation: questions for reflection" (2013). According to Leda Tfouni, the two terms started to be differentiated in Brazil in the 1990s. In her book *Literacy and Alphabetisation*, she explains that

> **[...] while alphabetisation is concerned with the acquisition of reading and writing skills by an individual, or groups of individuals, literacy focuses on the social and historical aspects of the acquisition of a writing system by a society. (TFOUNI, 1995, p. 20[57], *apud* SOARES, 2002, p. 144)**

Succinctly, being scientifically alphabetised would imply reading and writing science, and this meaning opens up an important discussion about functional literacy. Reading and expressing yourself scientifically does not guarantee that anyone understands what is written, nor the social impact of that text or information. From the articles analysed, one of them cites the term "scientific alphabetisation" only to justify that this would be a first step in a linear view of science teaching, which culminates in the second, "scientific literacy", where the student is able to participate in the decision-making processes because they have acquired an adequate repertoire in the "scientific literacy" stage (FURTADO; BRITO; ALMEIDA, 2021). The authors make it clear, in this way, that science teaching should not only present science through its terms and concepts but prepare the citizen in different ways to apply this knowledge intentionally in their decision-making.

57 TFOUNI, Lêda. Literacy and Alphabetisation. São Paulo: Cortez, 1995.

Addressing precisely this aspect, Santos and Mortimer (2001), in "Decision-making for responsible social action in science teaching", refer to scientific alphabetisation to say that scientific information on the subject involved is essential but not sufficient if the expectation is to go beyond mere alphabetisation in regard to scientific facts, thus justifying the use of the term "scientific literacy" and explaining its objective as preparing for a change of personal attitudes and for questioning the direction of scientific and technological development.

Considering levels of development for scientific literacy, a parallel with the BNCC can be drawn and the development of the skills with the curricular scheme of revisiting the same theme at ever deeper levels according to the year of schooling, as well as identifying situations and their impact on society and the environment, and then recognising technological issues that are arising to be explored, assessing the possibilities for a solution to then make a conscious decision, as an interesting approach to the integral development of the student and an exercise of citizenship, as argued in the article "Dimensions of the contents mobilised by biology students when discussing antibiotics and health" (CONRADO; NUNES-NETO; EL-HANI, 2020).

The general competence established in the BNCC closest to scientific literacy is:

To argue on the basis of reliable facts, data and information, to formulate, negotiate and defend common ideas, views and decisions that respect and promote human rights, socio-environmental awareness and responsible consumption at the local, regional and global level, with ethical positioning in relation to the care of yourself, others and the planet. (BRASIL, 2017).

It is possible that the absence of discussions on scientific alphabetisation is the result of the time period adopted for the survey of articles carried out for this research (2010-2020), a period in which the discussions on guidance documents were already more focused on scientific literacy. The more recent the article, the greater the emphasis on forming fully equipped citizens, the more linked to the BNCC.

Scientific literacy considers that, in education for citizenship, the student needs to collectively analyse and discuss possible solutions to a problem so that the decision taken is that which meets the interests of the majority. For this to happen, schools need to pursue a model of democratic participation, aligned with awareness and responsibility. It is important to bear in mind that in education, teaching for behavioural change is a complex process. The difference between the intention of the class and the actual attitude of the students in their actions requires attention and a mismatch can arise from the lack of applicability of the topics addressed in the classroom. Recognising the scientific principles that support the topic under discussion, for example, is as relevant as understanding how they relate to the social experiences they spend every day. This is the questioning of their rational bases, taking into consideration other views to combine logic and empathy in the construction of values (SANTOS; MORTIMER, 2001).

The insertion of themes involving social issues related to science and technology into the curricula remains the starting point for perpetuating the ideas of scientific literacy in school, but needs to be accompanied by a significant change in the approach and posture of the teachers,

[...] in order to incorporate discussions on social issues into their classes, including the environmental, cultural, economic, political and ethical aspects of STEM; student social engagement activity through concrete actions; and discussion of the values involved. (SANTOS; MORTIMER, 2001, p. 107)

As a way of making science part of society, not something segregated and exclusive to scientists, the STS movement has emerged, recognising the limits and responsibilities of this group, thinking of science and technology as social processes (SANTOS; MORTIMER, 2001), as already addressed in this document. As a result, STS has developed, mainly including the fields of sociology and public policies, so as not to be subject to a reductionist view of the already established technological system (SANTOS, 2007).

In the curricular framework for science there is a clarification of the employment of the terms in the sense of the form of participation in society: science as a natural environment, technology as an artificial medium and society as a social medium, all related to each other. For Santos (2007), STS education is the intersection between science education, technology education, and citizenship education.

From this perspective, science would influence several areas of society: politics, the environment, culture, the economy, among others, and it should, therefore, be part of the training of the citizen who modifies it. However, science practices were very focused on forming scientists who had little regard for the implications of science and technology on society (SANTOS, 2007). Thus, scientific literacy aims to clarify to students how these two broad areas (science and technology) relate to support the decisions citizens make in their lives.

The articles found in the SciELO platform with the term "science teaching", which explore scientific alphabetisation and scientific literacy from the perspective of changes related to the use of the terms "STS" and "Science, Technology, Society & Environment" (STSE) for the democratisation of science and understanding of its use indicate that there is no consensus on the understanding of the assumptions and characteristics of the STSE perspective in comparison to STS (LUZ; QUEIROZ; PRUDENTIUS, 2019). Education based on environmental issues, or environmental education is more clearly socially reflective in classroom practice and has been strengthened by global environmental discussions. The author's survey indicates that much research ends up encompassing the environmental theme in STS issues and consider that science education, characteristic of the STS approach, should already encompass environmental education, and a new nomenclature is not necessary.

It is possible to find articles that use the terms as synonyms, as complementary, without differentiation, and also STSE as an evolution of STS. The justification for using the two terms may be the interpretation of element S (society), which, for some authors, already implicitly incorporates E (environment) as being part of society.

In this debate, there is a perspective that argues that just as STS should not minimize environmental discussions because it does not highlight the environment, the term STSE should not limit them to the area of the environment, avoiding the other three fundamental axes. It proposes the use of social-scientific issues as a way of achieving educational objectives aiming at an integrated approach to education in science, technology, society and environment (STSE) through actions to promote a more environmentally and economically sustainable society (CONRADO; NUNES-NETO; EL-HANI, 2020). These proposals support reflection on situations in which scientific, technological and social development and the way in which they influence the sustainable use of the environment should be open to a critical perspective, thus spreading the precepts of scientific literacy.

Santos and Mortimer (2001) reinforce the view that the underlying purpose of teaching science in the curricula should be "decision making for responsible social action". These authors present different decision-making models that can guide activities to present the similarity of this process with the scientific method since, in both, there should be no single path to follow. They question, therefore, the rationalist approach to solving problems of a complex nature.

[...] the curricular approach to the development of decision-making abilities should not be reduced to following these steps, since the decision will also involve the discussion of the value, cultural and ethical aspects. (SANTOS; MORTIMER, 2001, p. 101)

The current curricular guidelines in the BNCC make reference to the STS perspective, aiming to support a meaningful education for citizenship, without setting aside the learning of concepts in the various subject areas. In the first decade of this century, before the BNCC came into force, educational policies included learning objectives based on the applicability of production techniques and were, therefore, less reflective in nature and more focussed on work. The science curricula ended up being drafted with the objective of supporting entrance into higher education and the labour market, leaving the quality of the teaching and learning in the background (SANTOS, 2012).

Brazil lacks curricula that promote the conceptual, procedural and attitudinal dimensions of a broad scientific education that recognises the importance of science and technology in solving problems in everyday life. As it currently stands, the BNCC proposes the intentional construction of educational processes for learning in line with the needs, possibilities and interests of students and also with the challenges of society. It is worth noting that the STS or STSE approach provides for multidisciplinary discussions as essential and that they require the insertion of several activities in the school curriculum that involve more than scientific education for citizenship. The classroom practice would need to promote understanding of the present challenges facing humanity from the social and technical aspects of science in society (SANTOS, 2012).

Recognising science in the context of transformation of society requires a repertoire of knowledge and experiences, which may be considered just scientific alphabetisation, but by using this knowledge to effectively transform reality, along with an implicit sound knowledge of the theoretical aspects and the ability to transpose them into the practical aspect, demonstrates scientific literacy. Reading a scientific text requires the interpretation, evaluation and inference of meaning, which is not restricted to the bounds of scientific alphabetisation. These capacities are required for the reader to position themselves in relation to the information contained in that text and to develop intellectual autonomy (TEIXEIRA, 2013).

Themes related to inequality, rights and inclusion

Science teaching cannot fail to recognise the implications of the different social groups that shape society. In the topic on scientific literacy and alphabetisation (6.4), the survey identified authors intent on focusing on science in everyday life, on seeking solutions to social problems, as well as on research on teacher training. From the start, the mapping of science teaching has aimed to identify how it has been addressing gender relations, ethnic and racial issues and other human rights-related issues essential for the construction of scientific literacy strategies. This perspective contributes to the strengthening of the debate on the social and political function of the school, by broadening and adding a level of complexity to the world view of children and adolescents. In this sense, the survey reported only 23 articles (12%). This section will examine three articles concerned with gender and sexuality, four with ethnic-racial issues and five concerned with inclusion.

These articles have in common the need to teach science using broader references, taking into account the experiences of teachers and students and, consequently, the exchanges between these subjects for educational purposes as well as for scientific practice.

Gender and sexuality

Attention has been drawn to the sparseness of the gender theme in discussions about science teaching, which is the curricular component that, because it deals with the human body and reproduction, tends to be a focus when sexuality is being discussed. Used as a form of expression and part of the subject, the body needs to be understood and studied as a social organism, in addition to its biological functions. The school should be a space for discussion of differences in gender-related social behaviours that are limiting when we talk about social education.

Although Brazil is a diverse country, most schools do not reflect what the 1988 Federal Constitution tried to emphasise in their teaching: how social differences need to be considered and explored in education. In Article 3, it defines the promotion “of the good of all, without concern for origin, race, sex, colour, age and any other forms of discrimination” and Article 5 states that “everyone is equal before the law, without distinction of any nature”, reinforcing that “men and women are equal in rights and obligations under this Constitution” (BRAZIL, 1988). In denial of these founding principles, we still find unequal school environments, marked by discrimination and violence in the areas of gender and sexual orientation.

Some elements of the school routine, loaded with prejudice, can perpetuate representations of gender relations and sexuality defined in the first half of the 20th century. Influenced by political discussions and conservative governments, textbooks do not appear to have been updated to disseminate ideas about the individual construction of sexuality influenced by social and historical factors, as Leandro Coelho and Luciana Campos (2015) argue in "Sexual diversity and science teaching: seeking sense." Because teachers are seen as the only source of guidance in the learning process, textbooks which do not address these themes mean that important discussions are silenced when heteronormative historical constructions based on sexism and androcentrism are presented, a theme addressed in the article "The textbook as a cultural artifact: Possibilities and limitations for approaches to gender relationships and sexuality in Teaching Sciences" (BANDEIRA; VELOZO, 2019). The BNCC itself was influenced by conservative policies and in its text and the 2018 version (final) and the terms "sexual orientation" and "gender identity" were excluded.

See the comparison between the two texts and, in particular, the deleted words.

Chart 9 – Comparison between the texts of the 2017 and 2018 versions of the BNCC

Version 2017	Version 2018
Select arguments that highlight the multiple dimensions of **human sexuality** (biological, sociocultural, **affective** and ethical) and the need to respect, value and welcome **the diversity** of individuals, without prejudice based on **gender differences**. (BRAZIL, 2017a, p. 301)	Build arguments based on reliable data, evidence and information, and negotiate and defend ideas and views that promote socio-environmental awareness and respect for oneself and the other, welcoming and valuing the diversity of individuals and social groups, without prejudice of any nature. (BRAZIL, 2018, p. 322)

Since the school is a place that privileges socialisation, discussion and problem-posing of meanings associated with complex social construct understandings such as gender identity, science teachers often become the only channel of information about sexuality and, therefore, it is important to understand how these teachers build an understanding of these themes, since they may become mediators of these conversations (COELHO; CAMPOS, 2015).

The possibility of discussing concepts in the light of their realities should be the basis of the enchantment and motivation for the learning of science, but the textbook, being a physical, printed object with little dynamic content, appears in school institutions as a regulator of teaching and learning. Active teaching methodologies may be erroneously reduced to the insertion of technological resources in the classroom environment. However, re-purposing the textbook as a trigger for research and a textual resource for consultation, for example, presents the student with a new role and the textbook with a different purpose, including the possibility of consulting different books. Books, if used properly, are no longer a static symbol and are transformed into cultural artifacts that bring with them a diversity of concepts and possibilities for updating knowledge.

Books, if used properly, are no longer a static symbol and are transformed into cultural artifacts that bring with them a diversity of concepts and possibilities for updating knowledge.

Bandeira and Velozo (2019) highlight the role of the book beyond the didactic. They take the view that the book is a source of political power and ideology in addition to the teaching of science. Schoolbooks may often be the only books read by many Brazilians throughout their lives. They include books that ignore women scientists or even represent the human body exclusively as a male body (except for the study of the female reproductive system); others include illustrations in which women are placed in a social condition always inferior to men, reproducing socially oppressive stigmas that should be widely questioned and debated.

Furthermore, it is necessary to be attentive to the training of teachers who are often unaware that this topic deals, even if less explicitly, with democracy and the struggle for human rights, and now with recent advances in sexuality and gender such as the possibility of formally changing one's name in the civil register, as stated by Zilene Soares and Simone Monteiro (2019) in their article "Training the teacher in gender and sexuality: Possibilities and challenges". Although official documents such as the PNE and BNCC have had the terms removed from their texts, teachers can (and should) address the issues in their classes, since the students themselves demand it.

Thinking in this context, in 2007, a partnership between the Special Secretariat for Women's Policies (SPM), the British Council, the Ministry of Education, the Special Secretariat for Policies to Promote Racial Equality (SEPPIR) and the Latin American Centre for Sexuality and Human Rights (CLAM) of the Institute of Medicine of the State University of Rio de Janeiro (UERJ), resulted in an important initiative: the development and introduction of the Gender and Diversity at School (GDE) INSET course and the publication of the guidance *Gender and Diversity at school: the training of teachers in gender, sexuality, sexual orientation and ethnic-racial relations*[58]. The chapter on educational policy "Building a gender and diversity education policy" highlights the importance of educational actions aimed at teacher education:

58 Available at: https://www.gov.br/mdh/pt-br/navegue-por-temas/politicas-para-mulheres/arquivo/arquivos-diversos/publicacoes/publicacoes/gde-2007.pdf. Accessed on 17 June 2021.

Laws will not suffice if mentalities and practices are not transformed, hence the structuring role that actions that promote the discussion of these themes acquires, motivating individual and collective reflection and contributing to overcoming and eliminating any prejudiced treatment. (PEREIRA; ROHDEN, 2007, p. 15)

Questioning behavioural patterns and values in the field of sexuality is an important step toward critical biological determinism and may be favoured by the connection that students have with their science teachers. By using this channel of communication to insert themes that have gained greater visibility, such as the rights of the LGBTQIA+ population[59], educators and students favour dialogue from the perspective of social construction of human sexuality (SOARES; MONTEIRO, 2019). This group, made up of historically rejected individuals, is growing and is represented by members of the school community itself, making the relevance of conversations about sexual diversity even more necessary to avoid the classification of individuals as "normal".

Widely diffused meanings that define what is deviation and what is normal reinforce difficulties in recognizing sexual diversity as legitimate. To discuss sexual diversity is to defend the recognition of different possibilities of sexuality in life, especially with regard to sexual orientation and gender identities that diverge from the heterosexual pattern of today's society. (COELHO; CAMPOS, 2015, p. 897)

Science teachers end up being the only sources of information about sexuality, which is why it is important to understand how these professionals build their understanding of these topics, as they can be mediators of these conversations.

Despite the importance of an integral educational process which supports an understanding of and respect for the different forms of gender expression, teachers report difficulties in implementing activities on sexuality, not only with regard to the school itself but also with regard to the families of the students, as reported by the authors Soares and Monteiro (2019) in research carried out with teachers who took the GDE course. There are situations in which families place restrictions on certain subjects, teachers refuse to use the student's social name, the school administration does not approve projects on sexuality, and the students themselves demonstrate a conservative attitude when discussing issues such as homosexuality.

The training of educators and the education of learners should not be based on the false impression that science teaching offers an opportunity to explore biological concepts about sexuality and gender and that this alone is sufficient to understand the equality of civil rights independent of sexual orientation. Another challenge in the gender field is to be able to insert debates in the classroom that promote the deconstruction of gender stereotypes, such as the association of colour with sex, over-valuation of male achievements, the linking

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People who identify themselves as lesbian, gay, bisexual, transexual, transvestite, ransgender, queer, intersex, asexual and more.

of women's identity with the home environment, among others. The lack of distinction between the professional and private world of educators can be an obstacle to the inclusion of activities that question entrenched behaviours such as those mentioned here.

Initiatives aimed at addressing sexual diversity in the context of the public education pose a challenge to the different moral, cultural, religious and family values and norms that permeate gender and sexuality issues, as illustrated by the advances and setbacks still prevalent in the second decade of the 21st century. (SOARES; MONTEIRO, 2019, p. 300)

The differences need to be seen as a pedagogical tool, a starting point for the development of competences for life in a democratic society like the one we want to build. The representations of masculinity and femininity in our culture no longer account for the historical moment in which we find ourselves. The construction of identity is a complex process that involves several aspects and should be fostered by the school with information and knowledge.

Ethnic-racial issues and science

With the intention of discussing the potential contribution of science teaching to education on ethnic-racial relations, seven articles on the subject were reviewed. Of these, two deal with the issue more broadly within science education, presenting challenges and possible contributions to anti-racist education and the debate on ethnic-social relations and citizenship. These studies highlight excerpts from the official documents that provide guidance to educators on this theme. The other articles take a more applied approach, presenting practical projects for educators and students which value popular knowledge (local culture) through ethno-botany and ethno-biology, in order to promote interculturality in the classroom.

The school has a key role in building positive social relations and has a responsibility to inform and engage students in the effort to eliminate discrimination and social inequality (VERRANGIA; SILVA, 2010). However, today we see schools that consolidate inequalities in society by denying racism, not recognizing discriminatory acts and perpetuating silent behaviour (FRANCISCO JÚNIOR, 2008). In primary education, the PCNs provide guidance that students should be able to appreciate the social and cultural diversity of Brazil, as well as other peoples and nations. without discrimination on the basis of cultural differences, social class, beliefs, sex, gender, ethnicity or other individual and social characteristics (BRAZIL, 1998).

There are many forms in which different groups are distinguished in Brazil, however the most common are those related to marginalisation for physical genetic or biological reasons. In this sense, it is worth differentiating between the terms 'racism', 'discrimination' and 'prejudice', the latter being an idea that precedes the relationship itself, being a prejudgement rooted in stigmas and stereotypes (FRANCISCO JÚNIOR, 2008). Racism is a more comprehensive concept, being an historical, social and cultural construction that is charged with a cause-and-effect relationship between the physical characteristics of an individual and their personality traits, social condition, intelligence or culture, leading to an erroneous notion of superior and inferior individuals. Discrimination is, indeed, an action that prevents equal access to opportunities – it is the manifestation of prejudice.

Francisco Júnior (2008), author of the article "Anti-racist Education: Reflections and possible contributions from the teaching of science and some thinkers," states that, when the topic involves race, the differences end up becoming synonymous with inferiority, as is the case with indigenous peoples. When no attempt is made to understand the difference, it is disregarded and represents a major historical distortion of human development. Used as a pretext to justify white hegemony, classification by phenotype emerges, loaded with associations between biological status and limitations in cultural development. There is different approach to labelling of the human being called "alterity", which is used to refer to the set of representations and the construction of the identity profile of other people, naming them. It is important in terms of determining respect for the 'other' that is different from 'me', but it has negative connotations when used to diminish the identity symbols of one group in relation to another, as discussed by Juanma Sánchez-Arteaga et al. (2015) in "Alterity, human biology and biomedicine".

It should be noted that the discussion of science is impoverished when we have teachers who lack knowledge of indigenous and African peoples, for example, or textbooks that do not include the knowledge that is specific to these groups, failing to appreciate the history of the construction of populations. We must not deprive learners of a knowledge what is present in our society. We need to rescue and value it through education.

In an attempt to contribute to an understanding of the reality in schools of knowledge of the indigenous peoples, extending beyond the exotic, folkloric vision, researchers Juarez Melgaço Valadares and Célio da Silveira Júnior (2016) conducted research with indigenous educators in an intercultural training course. The proposal was to engage them with the tensions resulting from the encounter of different cultures and the plurality of knowledge in the classroom. Some of the situations experienced by indigenous teacher trainees in the classroom were analysed under the metaphor of the text seen as a flame or crystal. This experience supported a better understanding of the reality of school education of indigenous peoples.

In order to make it possible for students to know the specificities of our culture and their relationship with the ethnic composition of Brazil, it is necessary that non-hegemonic knowledge be included. In considering the knowledge of the peoples who form society as a form of knowledge, teacher training and textbooks need to be supported by material on their cultures that demonstrate the wealth of the resources available when working with the students. Through the teaching of science, there are numerous ways in which this local knowledge can be brought to bear, knowledge of the cultures that has been erased from Brazilian culture that is fundamental to the contextualisation of teaching and learning.

In the article "Citizenship, ethnic-racial relations and education: the challenges and potential of science teaching", the authors Douglas Verrangia and Petronilha B. G. e Silva (2010) identified five possible themes in science teaching from theoretical-methodological references and the empirical data from two studies which could support an ethical approach to promoting ethnic and racial relations by educators. They are a) the impact of the natural sciences on social life and racism; b) overcoming stereotypes, valuing diversity and natural sciences; c) Africa and its descendants and world scientific development; d) science, media and ethnic-racial relations; e) traditional knowledge from the African and Afro-Brazilian context and science.

Inclusion

The third and last sub-group considers eight articles focused on the theme of inclusion, organised on the basis of the discussion of the specificities and limits of special education and science teaching. Inclusion in school education is guaranteed by a number of statutory documents and is understood as the right of children and adolescents to access, stay and participate in school according to their capacities and the responsibility of the State and society in guaranteeing this right.

Even with this apparent legal consensus, the application of this right leads us to consider several factors and, in the case of science teaching, they revolve around the required accessibility to be considered and provided for both students and teachers with disabilities. This is the case with the work of Ivani Cristina Voos and Fábio Peres Gonçalves (2019), "The professional development of teachers of special education and the teaching of the natural sciences to blind and visually-impaired students", in which they reflect on the strategies used for teaching science to blind and visually impaired students. The strategy used was a training course for sighted teachers and for blind teachers. The text highlights the potential of them working together to extend and improve science teaching for all students.

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The same can be said with regard to the need to adapt science teaching to the needs of the deaf population by adopting a bilingual approach. Walkyria Dutra de Oliveira and Anna Maria Canavarro Benite (2015) in their article "Science lessons for the deaf: studies on the production of the speech of sign language interpreters and science teachers" discusses the importance of teachers having a basic understanding of sign language as a means of supporting the learning of deaf students. However, there is a caveat on the part of the authors because this awareness on the part of the teacher does not remove the need for an interpreter, for example, but it requires that they work together in order to ensure a more accessible language that enhances the learning of these students. In addition, making schools accessible implies acquiring mechanisms to adapt the means used and transpose the content in an appropriate manner (VILELA-RIBEIRO; BENITE, 2013). Investment in teacher training and physical infrastructure are both good approaches towards a more inclusive school.

Generally, there is a concern in the texts with the training of science teachers – initial and continuing – that it should be done in a reflective manner taking into account the guidelines for inclusive education. Once again, the perspective of the right to education is a catalyst for the work of the teacher.

However, this need cannot be detached from a broader reality that permeates teacher training in Brazil as, in the case of science teaching, we are still faced with two major obstacles: the difficulty of translating the scientific language into school language accessible to the reality of the students, and the lack of trained science teachers. Although in recent years the number of places in science teacher training courses on offer has increased, there is little interest from candidates to enrol in them, since the devaluation of the teaching career does not make the courses attractive. These challenges end up damaging the effective implementation of inclusive education, as pointed out by Lidiane Pereira and colleagues in the article "Paths for training science teachers for inclusive education in Goiás, Brazil, from the perspective of participants in a collaborative network" (PEREIRA *et al.*, 2015, p. 488).

A further consensus found in the articles is the need for special education specialists to support teachers from different areas of education. These professionals are trained in various areas of education and have completed specialist training or undertaken postgraduate studies related to special education. The LDB, in Article 59 (revised in 2013), establishes that professionals providing education to students with special needs should be

[...] teachers with sufficient expertise at the secondary education or higher education level to provide specialised care, as well as regular teachers qualified for the inclusion of these students in the standard classes. (BRAZIL, 1996)

Vilela-Ribeiro and Benite (2013) suggest that specialists in special education should follow teacher training courses which ensure that their initial training already offers possibilities for implementing solutions related to the topic. There is an important point that Voos and Goncalves (2019) make regarding specific pedagogical training and initial training, which is the difficulty of training and developing special educators in the natural sciences. Special education teachers who are involved in the teaching of the natural sciences, but who are not directly involved in the classroom (they may be responsible for producing accessible materials, for example), are part of the wider circle supporting natural science teachers, since, despite being specialists in special education, they are not trained in the specific area of knowledge. Therefore, it is necessary to understand how knowledge can circulate among the different areas involving the curriculum, assessment and pedagogical practices.

As a professional responsible for learning, the teacher needs to ensure that different learning opportunities are available for all students, considering the individual differences of each one and enabling the inclusion of students with special educational needs. The initial specific training in science does not currently include extensive experience of inclusion. Therefore, a strategy that has been shown to be a good alternative is to identify alternative ways of supporting teachers. The Goiana Network for Research in Special/Inclusive Education (RPEI), described by Pereira *et al.* (2015), is an example of a diverse collaborative network of teacher support that encourages discussions of concepts within the framework of teacher training. Formed of lectures, undergraduates and postgraduate students at the Federal University of Goiás (UFG), members of the Goiás State Department of Education (Special Education Unit) and the Goiânia Deaf Association), the network provides a space for reflecting on practice and on promoting change in teaching methods, mediated by researchers. Recognising the gaps shows the urgency of the need to change education management and practice so as to involve the entire school community, with an initial focus on access to information about the different special needs groups and then on participation in the transformation of educational practices.

Finally, an article by Luís Paulo Piassi (2011) – "Scientific Education in Primary Education: the limits of the concepts of citizenship and inclusion in the PCN" –, published more than a decade ago, includes concerns that have yet to be overcome. Arguing that science education is one of the fundamental bases for an education that is inclusive and focused on forming citizens, Piassi challenges educationalists and others, saying that we need to move beyond a change in knowledge content and teaching methods. He believes that those concerned are cautious when it comes proposing more extensive steps are taken than those initially proposed by the NPCs. The rights of people with disabilities have advanced, however the objective conditions for the full exercise of citizenship require more effective progress. In the field of education, for example, issues relating to accessibility, infrastructure, the availability of specialised human resources, where applicable, and adapted spaces are not fully guaranteed by the state.

Considerations and recommendations

...there is no such thing as teaching without research and research without teaching. One inhabits the body of the other. As I teach, I continue to search and re-search. I teach because I search, because I question, and because I submit myself to questioning. I research because I notice things, take cognizance of them. And in so doing, I intervene. And intervening, I educate and educate myself. I do research so as to know what I do not yet know and to communicate and proclaim what I discover. (FREIRE, 1996, p. 32) [p. 15, English edition published by Rowman & Littlefield Publishers (2000)

The Industrial Revolution, which began in the second half of the 18th century, is considered by history as a milestone in technological development, promoting great transformations in people's lives, in their mobility, through the railways, and supporting unprecedented geographical expansion, with its consequent impact on nature and different ethnic groups. From then to now, there seems to be no limit to technological and scientific development and they are present in every aspect of our lives. In the 20th century, technological evolution, known as the Third Industrial Revolution, led to radical change in different areas: industrial automation, the health sciences, large-scale agriculture and livestock production, space technology and telecommunications, among others. So many advances, however, did not necessarily lead to the well-being and safety of all living beings. The climate crisis and hunger are challenging examples. All the scientific and technological knowledge produced by humanity is, in fact, a capital asset, access to and control of which is disputed by and restricted to specific groups. Several authors, researchers in the field of science teaching, draw attention to the rise of movements critical of scientific and technological development, especially after World War II. Science and technology have become the subject of political debate, as shown by Décio Auler and Walter Antonio Bazzo (2001, p. 1):

After initial euphoria with the results of scientific and technological advancement in the 1960s and 1970s, environmental degradation, as well as the linking of scientific and technological development to war (atomic bombs, the Vietnam war with its defoliant napalm) made science and technology (S&T) the target of a more critical view. In addition, the publication of the works *The Structure of Scientific Revolutions*, by the physicist and science historian Thomas Kuhn, and *Silent Spring*, by the marine biologist and conservationist Rachel Carsons, both in 1962, gave impetus to discussions on the interaction between science, technology and society (STS).

It is true that in critical movements, among which STS and CTSA stand out, there are different perspectives or focuses, as we have seen, but it is possible to identify some important convergences, including: the recognition of an unequal appropriation of science and technology harming less developed countries; the recognition of a science whose application considers social relevance and local specificities; approaches that consider the social and ethical implications of the application of science and technology and, above all, a spreading of scientific knowledge to all people through scientific education, such as that underlying the Citizen Science movement, which is not restricted to the school.

These perspectives can be found in the literature examined in this research and, to a certain extent, can be found in the assumptions that guide the main educational regulations that affect the teaching of science, such as the BNCC. However, this awareness, registered in the academic field and reflected in educational policies, is to some extent confronted by a number of challenges, ranging from the effectiveness and applicability of a critical and transforming perspective of the science curriculum (nature and its technologies) in school education, to the initial pedagogical training of teachers in teacher training courses and continuing training, INSET, aimed at the continuous improvement of teaching professionals, as well as objective conditions for quality education. These conditions include well-equipped and functioning physical spaces for science and computer laboratories; INSET programmes focused on teaching practices for practising teachers; time available for planning; out-of-school programmes and activities (visits to museums, laboratories and research centres in higher education institutions, and to natural spaces for scientific exploration and experiments; participation in science fairs and scientific competitions, etc.).

In the contemporary world, scientific and technological advancement has not prevented a surprising wave of negation of science emerging. A recent and vivid example visible world-wide has been the spread of disinformation about medical science, the high point involving the avoidance of health Covid-19 sanitary protocols during the 2019-2021 pandemic and rejection of vaccines, this negation including highly educated people, many of whom are active in the scientific field. Although political and ideological factors can have an impact on people's actions and reactions, the division between science and society in general is noticeable. Identifying an opportunity to "dissect disinformation" about Covid-19, a chemistry lecturer at a Brazilian public university adapted their continuing education project by adding a practical chemistry teaching activity involving undergraduates – potential future schoolteachers – and secondary school students in a critical reflection based on mistaken information dressed up as scientific knowledge:

They made use of a media production that brought together elements that supported the development of the project. It is a video released on social media presented by a male, middle-aged layman narrator in the kitchen of his home; it show simple preventive procedures for Covid-19; includes explanations making incorrect use of scientific terms found in the content of school science courses, being very similar to alternative concepts reported in the literature (about pH levels, bicarbonate, alkali substances, viruses, etc. The narrator adopts several roles in the six minutes of his talk, that of teacher, friend, specialist and healer. The material was analysed in the undergraduate course in order to identify the roots of the arguments presented in the video in the teaching and learning problems discussed in previous elements of the course, especially alternative views and criticism of the gaps in traditional teaching. (MARSON et al., 2021, p. 42)

The echoes of the voices behind the proposition prepared for the natural sciences area of the BNCC reverberate in theoretical and critical evidence and reflections for teaching practices that are socially engaged, that are concerned with themes of local and global relevance, that recognise the various environmental, climate, health, energy and food security issues. This perspective combines the knowledge and role of technology, both in thinking about advances in scientific knowledge and the benefit they bring to society in general, and the disturbance they bring to life on the planet.

The production of knowledge as a social practice is sometimes influenced by biases that need to be taken into account when preparing the meanings in the teaching of the sciences in schools and the ways they are taught, as shown by the teacher training project followed by the chemistry teacher mentioned above. This perspective is present here, where the purpose is to contribute to both a critical debate on educational policies focused on the teaching of the natural sciences and their technologies and to the putting forward of proposals, at a time when the BNCC is being implemented throughout Brazil. Initiatives related to INSET, the production of teaching material and other teaching-learning resources are in progress.

Expectations of change in Brazilian education have been high since the debates on the new Common National Curriculum guidelines for Brazil started, as well as a fundamental reform to secondary education and the introduction of a comprehensive, well-rounded education. In 2020, the Covid-19 pandemic led to in-person classes being suspended, the effect of which on these educational reforms cannot be ignored. In addition, the introduction of the BNCC and of related INSET programmes are in progress. While taking into account that the education system is currently concerned with dealing with the effects of the pandemic on the learning of children and adolescents, as the result of the suspension of in-person classes and the prevalence of hybrid schooling in 2020 and 2021, it remains essential to find ways of supporting the educational systems during the implementation of the new national BNCC Sciences curriculum and related INSET programmes, as well as other actions supporting those teachers involved in the teaching of science.

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The research cited in this document calls attention to the importance of continuous teacher training which aims at the professional improvement of teaching, as well as updating scientific concepts and their application. In the SciELO survey of academic articles on science teaching that deal with teacher training and on teaching methodologies, the perspective of reflective teaching based on dialogue stands out, where science teachers collaborate with their peers in other subject areas – enabling interdisciplinary actions such as planning or assessing learning – or with the students themselves, favouring practical activities, connected with the reality of their lives but focused on scientific knowledge. If, on the one hand, they identify the influence of different theoretical-methodological concepts on teacher education as an aspect to be questioned, on the other hand they value the confrontation of different ideas and viewpoints, as well as the contact with different ways of dealing with challenging situations in the classroom, as a possible and necessary strategy for teaching practice in science education.

This panoramic survey reflects the gaps that have emerged in the process of its preparation. Considering the teaching of science in school education as a multidisciplinary field, we need to consider the specificities of each area of knowledge that it involves (principally biology, chemistry, physics, but also mathematics and computing) and its presence in each stage and modality of teaching – which opens up a range of possibilities to suggest actions, research, and training, which can lead to an agenda that involves school systems, managers, schoolteachers, and researchers. There is an accumulation of experience and knowledge not only in academics active in research and teaching in higher education institutions, but also in those professionals working in school education, whose projects and initiatives were not in the scope contemplated in this panoramic survey. When moving towards new steps in support of a research and action agenda, however, we need to consider the diversity of contexts, complexities, the organisation of the state and municipal educational systems in Brazil, as well as the level of autonomy they have in implementing their educational policies.

A recognition that scientific knowledge does not reach everyone and that specific groups are under-represented in certain areas has, over the past two decades, stimulated actions and the production of documents with evidence that supports attempts to raise awareness and promote changes in this scenario. Internationally, especially in the United States, a movement to improve STEM education has been gaining strength over the last two decades in the face of the low performance of students in these fields of knowledge and the need to improve the international competitiveness of the country in question. One of the strategies implemented has been to increase the number of students who belong to groups under-represented in STEM undergraduate courses. School education has also been a focus, under the argument that there is no specific stimulus for these areas of knowledge, making it less common for young people from low-income families and historically discriminated groups, such as women and black people, to pursue careers in the STEM field.

Another factor supporting the call for new policies and actions is the realisation that school curricula need to be updated to meet the needs of the job market and the requirements of scientific and technological development. This approach has been the focus of criticism because it favours an economic perspective rather than one that is concerned with social justice benefiting the under-represented groups. This criticism has been particularly supported by feminist gender and race studies, which have promoted the point of view that equity in these areas cannot be limited to access, but to a broader policy that considers effective participation in different decision-making spaces, as well as employment relations (PUGLIESE, 2020; SÍGOLO; GAVA; UNBEHAUM, 2021; REZNIK, 2022).

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The perspective adopted in this research supports a scientific and technological education that pro-actively aims for inclusion, equity and diversity in school education, either through the areas covered in science education or through specific projects. Among the many learning points, some key aspects may be highlighted not only when thinking about, for example, the implementation of the BNCC science curriculum or initial and continuing teacher training, but also when considering the need for broader actions and programmes that extend beyond the school space, as a creative and necessary way to contribute to advancing and strengthening science education in schools, such as the implementation of science clubs, Bancas de Ciências (a programme for the popularisation of science) and other initiatives that foster the dissemination of science through activities involving school students and teachers.

In this panoramic survey, we highlight some important points to be considered if the British Council in Brazil wishes to adopt a strategy in the area of scientific and technological education that is focused on a well-rounded and emancipating educational process which is clearly connected to recent research, and on national and international debates and existing educational policies for the area.

Initial and continued teacher training from an inclusive and equitable perspective

Despite the long path towards the transformation of teacher training for science teachers being followed, the significant development of the science curriculum and the improvement of legal frameworks, political actions are also needed to improve the teacher training curriculum and INSET training of science and technology teachers. A possible strategy is the promotion of dialogue between managers and education professionals working in the specialist departments of Education authorities, aiming to improve teaching and, consequently, to align classroom practices with the core BNCC curriculum.

As regards developing strategies to support the professional development of science teachers, there is a clear need to support the training of educator scientists, that is, teachers interested not only in teaching, but in providing students and students with immersive experiences in science. This can be made possible both by restructuring the curricula of both general teacher training and field-specific (biology, physics and chemistry) teacher training degrees, and by offering INSET programmes that consider local contexts, especially in environmental education, such as recognising and appreciating the knowledge of traditional quilombola, indigenous and riparian communities.

The way in which the curriculum for science is expressed, and how it will be implemented in schools, can demonstrate the direction in which science education will go in the coming years, especially after the BNCC has been fully implemented.

It is important to observe through studies and discussions, how and if diversity and differences related to gender, race/colour, ethnicity, deficiencies (including in education), social conditions and special needs are being included in educational policies and the curricula.

This overview demonstrates that there are few studies on science teaching that are concerned with racial and gender issues. Incentives to decolonialise knowledge and deconstruct white superiority in education need to apply across the board, including science textbooks, which rarely depict black bodies in their pages. In higher education institutions, especially in the teacher training degree courses for science teachers, equal treatment and valuing all cultures are means of empowering knowledge during the course and encouraging students to be critical and aware. It is essential to train teachers who give voice to the cultural participation of blacks and indigenous peoples as subjects who were enslaved, without ignoring their ancestral intellectual, cultural, philosophical, technological and scientific contributions to all components of the curriculum.

The teaching degree courses should be updated with the historical and political context of the legal frameworks that establish policies for reparation, recognition and valuation, focusing on an approach to institutional racism and the role of the state and black movements in transforming the reality of racial inequality into dialogue with other countries. The National Curriculum Guidelines for Education of Ethnic-Racial Relations and Teaching of African-Brazilian and African History and Culture – DCNNERER (BRAZIL, 2004) respond to the need for affirmative action policies and strengthen the amendment of the LDB proposed by Law No. 10.639 (BRAZIL, 2003). It includes in the official school curriculum the mandatory presence of the theme "African-Brazilian and African History and Culture". Now Education and Ethnic-Racial Relations is to be found in HEIs, especially in the social and applied science areas. While diversity in education has now become the subject of public policies, specific actions tend not to be sustained in practice, because they require investment and political interest, such as hiring education professionals qualified to teach the area in pedagogy and teacher training courses. The pedagogy course is the principle means of training teachers of primary and middle-school teachers. Based on the scenario presented by Resolution CNE/CP No. 2/2015 (BRAZIL, 2015d), it establishes teaching as an emancipatory and permanent process connected to a common national curriculum that guides national education and determines the information and skills to be covered in initial teacher training courses and INSET programmes. With this, it is expected that graduates from teacher training courses are capable of working in the area of Education and Ethnic-Racial Relations.

If the curriculum for ethnic-racial relations is still seen to be fragile in pedagogy as mandatory content in initial teacher training, the situation tends to be more challenging in undergraduate teacher training courses, especially those related to the natural and exact sciences. Teacher training strategies arise from isolated efforts by activist teachers to address racial and gender inequalities through optional courses or continuing education projects. The challenge is to recognise the need for a paradigm shift in the training of both scientists working in the natural and exact sciences, as well as teachers on teacher training courses and schoolteachers themselves.

Professor and astrophysicist Alan Alves-Brito ponders:

Much more than including content in the curricula of the exact sciences, it is necessary to shape historical, social and cultural awareness so that future science teachers and graduates not only understand the assumptions and consequences of the colonial wound and self-declare as non-racist in everything they do but, above all, promote, as critical professionals, anti-racist and anti-sex policies and actions wherever they may be. We need to develop a new pedagogy in science, strongly linked to sex and gender education and ethnic-racial relations in a brutally unequal country, in which a large part of the population is not included in the process of building science and technology. (ALVES-BRITO, 2020, p. 836)

For this author, science is a human construction, the greatest innovation of which is diversity itself, the greatest of all innovations. In this sense, it advocates scientific education and a programme of anti-racist, anti-sex, critical, anti-discrimination, emancipatory and diverse scientific dissemination, that consider those individuals and "black bodies" historically excluded from the processes of construction of science and technology. It needs to unfold within all the components of the curriculum including, for instance, the inclusion of ethno-mathematics in degree courses for mathematics teachers.

In the case of gender inequalities and discrimination, although they are being confronted in field of education, gaining space in pedagogy curricula and other disciplines linked to the human sciences, even without specific curricular guidelines that could strengthen pressure for their mandatory inclusion in teacher teaching curricula and school curricula, the theme has been the subject of political disputes regarding historical and cultural narratives, such as those that led to the withdrawal of the term "gender" from the final text of the National Education Plan. In the approved version, the mention of the eradication of racial, regional, gender, and sexual orientation inequality was replaced by something more general, such as the eradication of all forms of discrimination, challenging of inequalities, and the appreciation of diversity[60]. Gender inequalities are, as are racial inequalities, an important indicator for education, but the same is not true of the relevant curriculum content, signalling the fragile status of the theme as a social issue, including in the area of education.

The final version of the BNCC curriculum guidelines for pre-school and primary education, approved in 2017, deleted the terms "gender" and "sexual orientation", as recommended by the Ministry of Education, and agreed by the National Council of Education (CNE), unable to oppose it, possibly because of the difficulty of reaching a consensus between the academic sphere and social movements. Although it does not spell out the terms, the document cites the themes of diversity and human rights when dealing with the general competences that underpin the pedagogical foundations of the BNCC. Once again, the

60 More information on National Education Plan in action, available at: http://pne.mec.gov.br/. Accessed on 1 December 2021.

suppression of the terms is evidence of setbacks in the conquest of space for issues related to the fight against discrimination and gender inequalities, subsuming them within education for human rights.

The challenge of making the teaching of science in schools attractive

In the chapter of this panoramic survey that presents the data from the Higher Education Census (CES) and the School Education Census (CEB) regarding the profile of the courses that train teachers for school education, some gaps have been identified where specific studies are required. The teaching of natural sciences in primary education, and the teaching of natural sciences and their technologies in secondary education, require teachers with specific knowledge, since the disciplinary content covers biology, physics, and chemistry. In the study, we included mathematics because trained mathematics teachers tend to teach physics and chemistry as well, while the opposite may also occur.

Although the number of science teacher training degrees in areas such as physics has grown (especially in EAD form), the impact has yet to be seen in the classroom. This is because it is not necessarily qualified physics teachers who teach the subject in schools. The attractiveness of the teaching career is an important point to be explored, not only in the specific areas, but also in pedagogy in general. There is a tendency for many students in higher education to look for other professions than schoolteacher, as it is not seen as a "profession of the future". Attracting talent to the teaching career has been a global challenge, where countries are faced with a shortage of these professionals, and is related to a number of factors, from salaries to the under-valuing of this profession by society, as well as the complex nature of the profession. A study carried out by the Carlos Chagas Foundation (FCC) in 2008-2009 showed that the teaching profession is not being sought by young people, a phenomenon that needs to be studied "because social and economic development depends on the quality of school education, even more so as the so-called knowledge society emerges" (ALMEIDA; TARTUCE; NUNES, 2014, p. 13)

Not to mention the fact that today there are a number of more motivating professions or activities available at the time when professions are chosen. In other words, teaching may not be attractive not only because of factors related to the career itself, but also because of the possibilities opened by countless other occupation.

The study showed that there was a change in the profile of young people seeking education and teacher training courses: difficulties with reading, writing and understanding texts, as well as the lack of mastery of the basic knowledge of the area in which they will teach. Teachers are trained through general education courses, mainly aimed at pre-school and primary education, which are delivered by private HEIs through EAD. The courses, often with only a broad approach to science, are largely focused on the Portuguese language and mathematics, the teaching of science being secondary. A broad approach is followed, which does not function as scientific investigation, including a review of hypotheses, research, experimentation, discussion, revision of the premises and closure of the activity.

The information from this panoramic survey that immediately comes to our attention, however, is the situation of secondary school students studying physics. The level of the teacher training falls short when compared with the other subjects taught at that level. This shows that it is not just school conditions, or the financial aspects, among other challenges for improving education, that need to be addressed. Continuous or specific INSET courses can be a way for those not qualified in physics to be better prepared for the challenges of delivering the subject in a classroom, helping to overcome the lack of trained physics teachers.

On the other hand, it is important to analyse the academic path of the teacher graduates in the teaching of science to verify not only the quality of the training offered, but the need for policies that effectively ensure that students training to become teachers remain in the profession when they graduate. All the variables involved in this process cannot be analysed separately, but together, in order to enrich and expand the research that has already been carried out on this theme and contribute to continued development of the history, diagnosis and challenges of teacher training in Brazil.

Despite the limitations of this study, we believe that it adds relevant data, analyses and discussions to existing research on teacher education. The data presented, together with other studies discussing education in general and teacher training in particular, may provide consistent elements to aid an understanding of the complex scenario of teacher training and the exercise of the profession and thus support the establishment of policies aimed at improving the situation.

Although higher education in Brazil is predominantly private (75.8% of total enrolment in HEIs), most of the students in teacher training degree courses for the natural sciences and their technologies are enrolled in classroom-based courses in federal HEIs, at 61.2%. The first period analysed – 2010 to 2015 – presents two distinct scenarios: an increase of 25.8% in the total number of enrolments in Brazil, with emphasis on the EAD modality, with an increase of 49.8%. Enrolment has declined in most of the teaching degrees selected for analysis: enrolments in three courses (General Science, Biology and Physics) decreased, Mathematics remained stable while Computing saw a significant increase (30.2%) and Chemistry enrolments increased by 4.8%.

In private HEIs, the change is due to a reduction in the offer of classroom-based courses and a transfer to the EAD modality, with the exception of Biology and General Science courses. The data show that the majority of the students in the selected teacher training courses study in classroom-based courses in federal institutions.

The intention is to examine the data and critically analyse the adequacy of teacher training. To this end, we used the adequacy indicator of the education teacher training developed by INEP, according to Technical Note 020/2014. As the intention is to characterise those teachers who are working in school classrooms, it seems more pertinent to consider all the individual classes, schools and sector in which each teacher works. Therefore, we examine the teaching function, which gives us a more accurate view of school science teaching in Brazil. If we look specifically at the State-funded schools, responsible for educating a significant number of students, eight out of ten science teachers are considered to be properly trained, 10% more than Mathematics teachers. In private schools, the reality does not match what is expected either. Almost 20% of Mathematics teachers do not have training in the subject they teach.

The literature reports that the teaching profession in the initial years of school education is largely exercised by women (ROSEMBERG;

MADSEN, 2011; CARVALHO, 2001). Above all, this applies to primary education. White women predominate in General Science (43.8%) and Mathematics (35.3%) for the final years of primary education. White men are to be found in Mathematics, but less so in General Science, where the presence of black women and men is to be found. General Science is taught by more women of all races (72.6%) than men (27.4%).

Thus, the North and Northeast regions, with a predominantly black population, would also have the worst indicators for fully trained teachers. Less than half of those occupying teaching functions of the Northeast region are fully trained, with the same situation applying to Mathematics and General Science.

Thus, the differences in the suitability of training for men and women, black and white, necessarily involve recognising that the conditions of schooling and careers are socially and racially distinct in the different regions of the country. It can be said that this condition already begins at school, in schools with poorer infrastructure (in the case of science and computer laboratories), as will be presented below.

Women are concentrated in Biology (65.4%) and Chemistry (53.2%), while men in Physics (64.2%) and Mathematics (54.8%). As regards colour/race, Black women are half as well represented as white women.

Although they are different surveys, carried out on different survey populations at different times, the fact that the Physics teacher training degree, of the four selected, is the one which has the fewest number of students enrolled (30,175) while only 2,459 finished the course, it may reflect on the results found for the suitability of the teaching training.

The analysis of INEP information (CEB and CES) indicates important changes between 2010 and 2020/2019. It is necessary to look specifically at the training of physics teachers. In the search for articles on the specific theme for this discipline, some studies were located (VIZZOTTO, 2021; NASCIMENTO, 2020). For each degree/course, a specific study can inspire new studies. Another research question is whether the increase in the number of students in the selected teacher training courses, especially at the beginning of this decade and in federal HEIs, is reflected in the appropriate training of teachers working in the profession in the schools themselves. For this, a study is needed that can actually verify the training of teachers actually working in the classroom. In this sense, it is important to study the relationship between properly trained teachers and student performance. Do teachers with initial training appropriate to their teaching role contribute to better student performance?

Another analytical approach is to explore the results of the ENADE assessment cycles for teacher training degrees (2008, 2011, 2014, 2017 and 2021). The student questionnaire includes a set of questions about profile and career intentions, among them: *What do you plan to be doing in five years' time? During your course, did you have pedagogical experiences that you would like to replicate for your future students?* which can offer prospective information on a possible professional career in teaching.

Science Curriculum – the challenge of multi and inter-disciplinarity

During the survey of recent articles dealing with BNCC, we found that few groups were working directly on the science curriculum. We believe that the survey is not about the state of art, but about the state of knowledge. Here we would like to highlight some points that we think are important to revisit in this conclusion.

The approach of the BNCC to the thematic units addressed when teaching science may generate erroneous interpretations as to the extent that the themes should be explored and their relationship with other concepts, as can be seen in one of the first themes proposed: "The Human Being and Health" (BLIKSTEIN; HOCHGREB-HAEGELE, 2017). It can be thought that this thematic unit is concerned with learning about the limits of the human body, focusing only on studying its systems and organs and relating them to health and well-being, while the possibility of identifying functional parallels with other animals is lost. Concepts that can be transposed are not investigated, or are explored only in the anthropocentric context, not encouraging comparison with other living beings and systems.

The isolated presentation of concepts in an arbitrary sequence, which does not favour spiral learning, leads to lost learning opportunities because students often have yet to achieve a sufficient grasp of primary concepts to understand more complex situations. These aspects are aggravated by a lack of examples to support the proposed themes or very specific examples, which make it impossible to extend the repertoire to other situations. In the current version of the BNCC, the spiral approach appears more clearly, even if it is not evident how it will be put into practice. The critical readers of the BNCC, Paulo Blikstein and Tatiana Hochgreb-Haegele (2017, p. 13), point out that BNCC-C "does not signal to those responsible for formulating curricula what the collective and inter-disciplinary themes are".

Some organisations, such as the Brazilian Association of Biology Teaching (SBEnBIO) and the Brazilian Association of Research in Science Education (Abrapec) have expressed their concerns in open letters regarding the treatment of the themes proposed in the learning programmes for the new Secondary Education syllabus. They fear that there is a lack of professionals skilled and specialised in the themes, as well as a lack of the infrastructure required to deliver the five proposed learning programmes and encourage the autonomy of the students. Other points are highlighted, such as the promotion of equality, where specialists have seen discussions about ethnicity, race, gender and sexual orientation being diluted, with the use of generic and universal terms and phrases.

Brazil has a robust history of teaching science as part of a strategy to educate for citizenship, as already mentioned. The implementation of educational policies frequently appears to founder on structural limitations, as is the case with the lack of science-friendly environments in schools, as well as the need to adapt and stimulate teacher training, with reference to the ideal of a critical approach to teacher training.

A possible area of analysis appearing from this panoramic survey is the figure of the teacher and their ability to articulate the different aspects involved in science teaching. If, on the one hand, there is a constant requirement which starts from the initial teacher training and culminates in actions and projects

A possible area of analysis appearing from this panoramic survey is the figure of the teacher and their ability to articulate the different aspects involved in science teaching.

that encompass INSET science teaching programmes, on the other, it is not possible to reflect on this without analysing the macro situation of teacher education in Brazil. This is because the discussions on INSET programmes focused on science teaching should be included in a broader context, with discussions about a Common National Curriculum for INSET programmes for schoolteachers (BRAZIL, 2020) being part of the introduction of the Common National School Curriculum. These documents propose a link between initial training and practical support to teaching. Specifically in the field of science, this means involving students directly in a dynamic universe consistent with the requirements of teachers trained in scientific discussions in a social context, assuming a physical and temporal structure not guaranteed in these milestones related to teacher training.

At 85 points, Brazil's classification in the 2018 PISA survey was below the average for OECD countries. The 2020/21 Covid-19 pandemic aggravated this picture further. The pandemic also showed that the way in which fundamental science is being taught is not sufficient to challenge movements in society that deny science vehemently, showing that, according to Catarino and Reis (2021), there is a need for reflection about these social phenomena, in order to understand their implications for the work of educators and for society. This framework also proposes a careful analysis of the curricular proposals, focusing mainly on the adequacy and contextualisation of the teaching. Proposals that suggest the specialisation of regional curricula make sense when the proposals for practical activities are directly linked to the environment around the school community, welcoming different audiences with different needs. This is a way to tailor the curriculum to reality, valuing the traditional knowledge of the community each school serves and incorporating it into teaching.

Although the BNCC establishes that it is for educational authorities and schools to define the specific details of the curricula to be delivered, different socio-cultural contexts require different approaches (specific regional curricula), discovering potential themes that are sufficiently plural to offer specific approaches to different audiences and regions.

To make use of science, scientific and technological productions applied to society require profound discussions about constructing the values of society and their possible reforms, a reflective process that not all educators are able and willing to undertake, even more so when considering the current demands of the profession. Although there are documents that guide the BCN Teacher Training Curriculum, there is a lack of action to transform and adapt the disciplines and topics of courses given by HEIs, as well as a lack of open dialogue between schools and universities.

Another point to be considered refers to school practices, often based on textbooks which give a feeling of security to the teacher, being restricted to a conceptual and less practical, investigative approach to knowledge. For a teacher to teach the investigative nature of science, they need to have experienced it themselves in school and during their teaching degree course. The science education curriculum does not favour articulation with other subject areas, making it difficult to link content. The academic literature shows that there is a significant consensus that we need to rethink the methodologies employed, as well as the way to understand teaching and learning, breaking with the binomial "explain-listen". The experiments carried out should not only serve to demonstrate the contents. Students should be encouraged to discuss their ideas, make use of their previous knowledge, investigate, question, compare knowledge and recognise in this process the connection between scientific knowledge and their daily lives.

Currently, the teaching of science in Brazil is a reflection of its history and of the country's political, social and economic contexts. Currently, efforts are being made to ensure that new curricular proposals include the necessary changes for their practical and effective implementation in schools. The intention is for Brazil to have a scientifically literate population which is able to understand the transformations of nature, the effects of human action on the preservation and sustainability of the planet, to understand that while technological and scientific discoveries can be a solution, they can also be dangerous. Hence the importance of democratising science teaching from pre-school on, strengthening scientific culture.

Scientific knowledge, however, is not restricted to schools, but is also present in non-formal educational spaces such as science museums, botanical gardens, science clubs, planetariums, observatories, as well as non-institutionalised spaces. To appropriate scientific knowledge is to dominate the technology that has been expanding its presence in everyday life and creating new frontiers of inequality. Associated with scientific literacy, we are living through the challenge of technological literacy.

Technologies in science teaching – generating possibilities to experience the scientific process

Scientific literacy involves the possibility of including experiments and experiences in the different areas of knowledge that are part of the educational process. Equipping schools with laboratories is an important strategy. It should be emphasised that the data given here shows whether or not there are physical laboratory spaces available, on the basis of data extracted from the School Education Census, the mere existence of such spaces not guaranteeing that they will be used for the purpose intended – teaching science to students. It is public knowledge that the provision of libraries in many schools is inadequate and that there is a lack of qualified librarians, as well as computer labs, despite over three decades of educational policies which aim to introduce technologies in Brazilian schools. One of the most important actions, post-LDB, was the National Educational Technology Programme (Proinfo), officially launched by Ordinance No. 522/MEC (BRAZIL, 1997).

As we have seen, the barriers are, above all, a lack of basic infrastructure and regular and constant maintenance. The use of technologies in education does not reach across the school systems, because not all have access to the internet, or have poor access, and equipment is not maintained or updates, a lack of security in schools, the absence of technical staff and appropriate training for teachers in their use. Considering the constitutional right to quality education for all, the uneven regional distribution of equipment and material for science and computer laboratories is notable. While the North and Northeast have the lowest proportion of students with access to schools with science and computer laboratories, the highest proportion is to be found in the South and Southeast. More students have access to computer laboratories than to science labs during primary and secondary education. In the North and Northeast less than 10% of students have access to science laboratories in the initial years of primary school while more than 30% hypothetically have access to computer laboratories at the same stage of their education.

The general competencies established in the BNCC are defined as the "mobilisation of knowledge (concepts and procedures), skills (practices, cognitive and socio-emotional), attitudes and values to meet the complex demands of daily life, of fully exercising citizenship and of the world of work" (BRAZIL, 2017a). They provide guidelines on what students should expect in terms of technology-related learning, with a view to providing an education based on an integrated curriculum delivered using a socio-critical and/or constructivist approach. During the drafting of the BNCC, the text describing General Competence 5, also known as Digital Competence was changed. In the published version aspects related to the creation of technology were now included, ensuring that the student was no longer just a user.

To understand, use and create digital information and communication technologies in a critical, meaningful, reflective and ethical manner in the various social areas (including school children), enabling them to communicate, access and disseminate information, produce knowledge, solve problems and play a leading role and authorship in personal and collective life. (BRAZIL, 2017a, p. 9)

Despite this competence, the integration of technology into the specific competences of the areas of knowledge is not specified, thus making it difficult to construct curricula that objectively include the theme. Another relevant point is that the production of a prescriptive curriculum does not guarantee its effective presence in schools and the teaching-learning process. The PCNs themselves had already established a minimum curriculum, thinking about knowledge for the new century, but they also did not include ways of doing this.

[...] the new communication and information technologies permeate daily life, independent of physical space, and create life and coexistence needs that need to be analysed in the school space. Television, radio, IT and so on have brought people closer to the images and sounds of previously unimaginable worlds. (BRAZIL, 1997, p. 24)

Establishing the connection between science, technology, society and the environment through open dialogue on current problems is fundamental for teaching to have meaning and is covered by the BNCC through digital teaching. The Centre for Innovation for Brazilian Education (Cieb), in order to facilitate the production of proposals aligned with the BNCC and being concerned with scientific digital literacy, makes available the Reference Curriculum for Technology and Computing (2018), in which concepts and skills focused exclusively on the development of skills in the exploration and use of technologies in schools are presented and organised in the form of infographics[61], suggesting themes to be worked by learning stage. A reading of the specific subjects of the BNCC shows that the most common contexts of integrated studies are computing, communication, astronomy and matter transformation processes.

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Technology and Computing Curriculum – Cieb. Available at: https://curriculo.cieb.net.br/profissional. Accessed on: September 2021.

Although technology is one of the pillars in the restructuring proposed in the BNCC (including the names of the areas of knowledge), there are different emphases in each stage of education and also in each subject matter. There are no specific skills defined for the education of young children (pre-primary). In the BNCC, learning and development objectives are presented by age group and field of experience. It is worth pointing out that within the five fields of experience ("the me, the other and the us", "body, gestures and movements", "traits, sounds, colours and shapes", "listening, speaking, thinking and imagination" and "spaces, times, quantities, relationships and transformations", only the latter presents a single objective that makes mention, as a possibility, of using a technological resource in the reading and telling stories activity for the younger age group. The National Curriculum Guidelines for the Education of Young Children (2010) refer to the possibility of working with nature, mixtures, transformations, sensory, expressive, and bodily experiences, mathematical concepts and relationships in young children, but for this the teacher required a training that includes science teaching and scientific literacy.

From the start of primary education, specific skills are divided into areas of knowledge. In the area of natural sciences, it is noticeable how technology appears more often in the specific competencies, but in a general way, without definitions of applications and knowledge constructions, such as:

To analyse, understand and explain characteristics, phenomena and processes related to the natural, social and technological world (including digital), as well as the relationships that are established among them, exercising curiosity to ask questions, seek answers and create solutions (including technological) based on the knowledge of natural sciences. (BRAZIL, 2018, p. 324)

In secondary education, all areas of knowledge mention technology in the title, but none of the competencies presented show what is expected of the student specifically regarding technology in subjective terms. As regards the natural sciences and their technologies, one of the specific competencies does not specify how and why technology should be used:

Investigate problem-situations and evaluate applications of scientific and technological knowledge and its implications in the world, using procedures and languages proper to the natural sciences, to propose solutions that consider local, regional and/or global needs, and communicate their findings and conclusions to varied audiences, in various contexts and through different media and digital information and communication technologies (TDIC). (BRAZIL, 2018, p. 553)

Rufino and Souza Neto (2016) consider that the BNCC does not at any time demonstrate how it should be articulated in the political sphere responsible for its application in educational systems, indicating a gap between the proposal and its implementation. It is for the educational systems and their schools to draft detailed curricula as part of pedagogical projects.

During the Covid-19 pandemic the use of technologies to support education was more pronounced, but the lack of preparation of the Brazilian educational system and, consequently, the marked signs of inequalities of access, such as a lack of structure and knowledge, was evident. With the suspension of classroom-based activities in schools and the adoption of remote education driven by the crises, most students began to socialise and interact with each other exclusively through digital means, albeit in a forced and precarious manner. Teachers and students faced the challenge of sharing ideas and reflections while at the same time getting used to digital tools, making their own choices about the best strategies for adapting the school curriculum to remote learning. Moreira (2020) points out that:

> **In fact, with the sudden arrival of the virus, educational institutions and teachers were forced to adopt distance learning practices, emergency remote education practices, very different from those used in high-quality digital education (MOREIRA, HENRIQUES, BARROS, 2020, p.31.1).**

Considering that access to education during this period was conditional on access to the Internet and digital devices, the difference in the quality of education made available to students in the state and private educational systems in the different regions of the country has become clear from research. It is known that access to technologies is defined by the economic circumstances of the family and its geographical location, since adequate digital access is not available across the whole country[62]. According to the National Sample Household Survey (PNAD, 2019), only 64.8% of the students in the Brazilian state school system have access to the means to participate in remote education, despite it being the case that the mobile phone is the main form of internet access. However, the use of digital technology for education is not just about accessing and using a mobile phone. Despite it having many advantages, being connected via the Internet does not mean that its use for education will bring an improvement in the process of learning natural science content if teachers do not invest in learning how to use it effectively, as well as becoming sufficiently secure to implement a teaching method based on the use of ICT (information and communication technology). A fundamental issue that should be taken into account in discussions about education and technology is its use as both a tool and the object of knowledge, supporting learning in addition to being the subject of study.

There are tools available for use by science teachers to support remote education or classroom-delivered learning. Felipe Fernandes Barbosa (2020) discussed some of these tools, including podcasts:

1. Free simulation tools for remote education

Name	What it does	Link
PhET	Interactive simulations for mathematics and science	https://phet.colorado.edu/pt_BR
Mouse Party	Interactive simulation using lab rats and their relationship with hallucinogenic substances	https://learn.genetics.utah.edu/content/adiction/mouse
Ptable	Interactive periodic table which can be used to explore the properties of elements	https://ptable.com
Célula 3D interativa	Provides information while interacting with a 3D animal cell	http://3d.cl3ver.com/0MKDN
Solar System Scope	Explores the Solar System, including planetary positions, orbit, etc.	https://solarsystemscope.com

Source: Barbosa (2020, p. 36).

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For more information see : https://cetic.br/media/docs/publicacoes/2/20201104182616/painel_tic_covid19_3edicao_livro%20eletr%C3%B4nico.pdf. Accessed on 1 September 2021.

2. Podcasts about science

Name	What it does	Link
Ciência USP	Discussions about news and research in science	https://jornal.usp.br/sinopses-podcast/ciencia-usp
Alô Ciéncia	Science news related to society	https://alociencia.com.br
Ciências e Biologia	Magazine with news, educational material and facts	Available on Spotify
Quimicast	Podcast on chemistry for general audience	https://anchor.fm/quimi-cast
Fisicast	Podcast on physics for general audience	https://anchor.fm/fisicast
Sinapse	Podcase about science for general public	https://anchor.fm/sinapse

Source: Barbosa (2020, p. 37-38).

Many "solutions" intended for educational purposes are based on technological development, but few of these paths consider the impact on the teaching-learning process and also the inequality of access to quality education arising from local specificities. As discussed, the Covid-19 pandemic has made these aspects even more evident.

The influence of social relations on the process of technological development is neglected, and the latter is seen as the main factor of social improvement. This view suggests that if there is technological development, the world will certainly progress, changing people's social conditions for the better (ANTUNES JÚNIOR; CAVALCANTI; OSTERMANN, 2021, p. 1344).

There should be a significant debate about how scientific knowledge should reach the population through technology, covering topics such as the democratisation of access (families with only one device connected to the Internet), control of use and user security/safety (the example of the social media) and media education (digital and ethical behaviour). These topics were not addressed in depth in the research on the subject, indicating an important gap and potential area to explore in more depth in the face of the challenges of hybrid education.

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A powerful theme for the significant inclusion of technology studies in school education is computer and data science. In the twenty-first century, understanding the new language of machine-to-machine communication can ensure that students are better placed in the job market and adapted to the essential individual and social processes. Data science allows situations in various areas of education to be modelled and simulated through the organisation and interpretation of past situations that ensure a certain predictability of future situations. The inclusion of this theme alongside economic, ecological and social studies would impact on the need for changes in the curricula of the HEIs, as well as schools.

Another important deeper investigation that needs to be based on new research is the hybrid teaching model, both for school education and for higher education, in the initial and INSET training of teachers. Principally in the area of higher education, there is research available on distance learning, but little about the hybrid model (and these are quite recent, dated 2020 and 2021). It is necessary to carefully evaluate its application and impact on social interactions, which are fundamental in the process of socialisation and schooling. There are favourable perspectives, pointing out that the advantage of hybrid models is that they are flexible, allowing "curricular development to be enriched, either by the use of different technological resources or different methodological strategies, [...] in a planned way, aiming at the construction of knowledge" (WEBER; OLGIN, 2020). This methodology, indeed, can meet the need to train teachers using approaches that they themselves will use with their students, but it can also broaden existing educational inequalities.

This survey opens up horizons that need to be investigated and explored in depth, such as school science curricula in both primary and secondary education. According to the platform Movimento pela Base (https://observatorio.movimentopelabase.org.br/), all 27 Brazilian states have approved reference curricula aligned to the BNCC; 78.3% having fully adhered to the reference state curriculum, 19.4% having chosen to make changes, and only 1.2% having produced their own reference curriculum. All the state reference curricula are available on the platform and can be consulted to know how the natural sciences are being covered in primary education, especially for the final years, since this stage introduces the specific science disciplines.

Another dimension of science education not covered by this panoramic survey concerns non-school spaces and projects involved in scientific education. One of the pillars of Brazilian public universities, defined in Article 207 of the Constitution, is the principle of inseparability between teaching, research and continuing education. Continuing education, by establishing a relationship between the university and society socialises the knowledge produced by research, but also by teaching, fulfilling its social function, by offering a range of services, training, art, and education for Brazilian citizens. Education has been an important locus in the development of science projects, including their specific disciplinary areas and related areas: Biology, physics, chemistry, mathematics, but also with actions of scientific diffusion and inclusive scientific education and gender and racial equity. Continuing education, together with initiatives in the Ministry of Education, the Ministry of Science, Technology and Innovation, academic associations and also the private sector, has played a fundamental role in extending scientific literacy to the general population and transformative educational action[63].The need to strengthen scientific literacy in the general population has not been fully recognised in the educational system.

The Brazilian government, through the Ministry of Science, Technology and Innovation (MCTI), has historically developed and implemented programmes and actions aimed at stimulating the interest of school students in science, such as the Programa Ciência na Escola [Science at School Programme][64]. It is a partnership between the Ministries of Education (MEC) and Science, Technology and Innovation (MCTI), the National Council for Scientific and Technological Development (CNPq) and the Coordination for the Improvement of Higher Education Staff (Capes).

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In 2022, UNESCO-Brazil launched a mapping of initiatives related to STEM education. The document records networks, collectives and initiatives from civil society institutions focused on gender equality. Available at: https://pt.unesco.org/https%3A//pt.unesco.org/fieldoffice/brasilia/news/meninas-e-mulheres-em-ciencias-tecnologia-e-matematica. Accessed on 8 March 2022. It is also important to highlight, in this same theme, the British Council's Women and Science programme, such as the Chamada Garotas STEM [Calling All STEM Girls], currently in its second edition. In a partnership with the Museum of Tomorrow, the document Girls at School, Women in Science was launched: Tools for School Teachers.

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Available at: https://www.britishcouncil.org.br/mulheres-na-ciencia/material-didatico. Accessed on: 8 March 2022. Available at: https://www.ciencianaescola.gov.br/app/ciencianaescola/sobreoprograma. Accessed on: 8 March 2022.

The programme stimulates the joint development of projects by researchers and schoolteachers aiming to generate a systematic approach to scientific knowledge about science teaching, proposing applicable solutions through innovative actions, creative and suitable for producing effective change in the reality of science teaching in Brazilian public schools.

Through a Call for Proposals and with the support of CNPq, the Institutional Programme of Scholarships of Scientific Initiation in Secondary Schools (PIBIC-EM) aims to awaken interest in the scientific vocation in secondary school students and develop talents for research, through participation in research projects developed within higher education institutions. The initiative, even with cuts in the area's budget, remains active in many universities. The fact that it is dependent on being offered by a university limits its reach to students from schools located in the city where the project is based.

It is important to point out that over the last two decades, many attempts have been made to introduce programmes to give greater visibility to gender issues in science and technology, as well as promoting actions to boost equality in these areas. The only programme that remained active over a period of years was the CNPq/MCTIC Call for Proposals No. 31, Girls in the Exact Sciences, Engineering and Computing, launched in 2013, the last edition of which was in 2018, which aims to stimulate the participation of women in careers in the exact sciences, engineering and computing. The projects, submitted by a proponent linked to a HEI and/ or research institution, preferably women, were intended to involve students from public schools. In all, 85 proposals were approved, and completed their activities by 2020.

Programmes and actions for scientific education and for scientific literacy that involve schools contribute to filling many of the gaps indicated in this document. A study is required to learn more about the results of these actions for the young people who benefit from them, such as schools, their managers and teachers. As well as giving greater visibility to the Citizen Science Network and Science Clubs, which rely on the International Network of Science Clubs (RICC), an initiative that mobilises, maps and shares experiences in scientific education in these spaces.

Despite an unfavourable scenario for initiatives focusing on gender equality, race, ethnicity and sexual diversity and significant mistrust in science, or perhaps for that reason, the moment is right to expand scientific dissemination beyond the limits of universities – strengthening university-school links through continuing education projects – to strengthen existing initiatives, such as the Citizen Science Networks and Science Clubs. These actions can contribute to concrete strategies for the development of interdisciplinary and alternative curricula to training and learning paths in the face of infrastructure limitations (absence of laboratories and materials) through creative and collaborative methodologies (inspiring sources). Studies of inspiring science teaching cases and follow-up of the process of implementing curricula, support and INSET science training programmes can contribute to addressing the gaps identified in this panoramic survey.

Although there are documents that provide guidance, such as BCN-Training, there is a lack of actions to transform and adapt the disciplines and coverage of undergraduate courses in higher education institutions, as well as a lack of open dialogue between schools and universities. The use of science, scientific and technological productions applied to society requires profound discussions about the very construction of the values of society and its possible reforms, a reflection that not all educators are able and willing to do, even more considering the current demands on the teaching profession.

This panoramic survey has sought to contribute to the effort to generate support for new actions and partnerships aimed at promoting the teaching of science in schools that can collaborate to ensure the right to scientific knowledge produced by humanity and the education of individuals that understand the physical world and society, becoming able to make decisions that can ensure the sustainability of the planet and social justice.

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APPENDICES

A01 - List of articles (2010 to 2020) on science education - SciELO platform related to the categories of Teacher Training; Teaching Methodologies and Practices; Curriculum; Scientific Literacy and Alphabetisation; Inequalities, Rights, and Inclusion.

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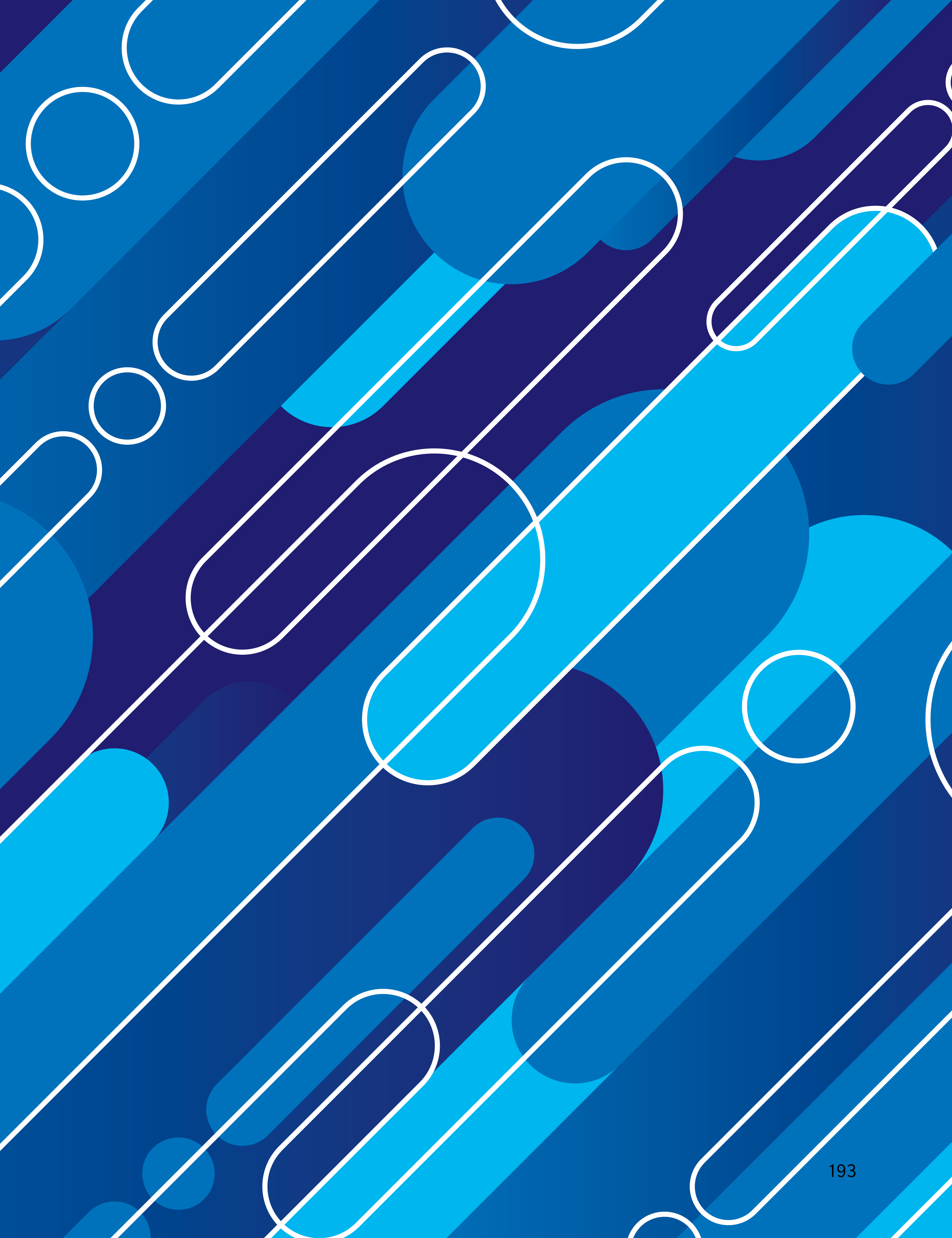
A02 - LIST OF ACRONYMS

WB – World Bank
NGO – Non-Governmental Organisation
BNC Training – Common National Base for the Training of Teachers of Basic Education
BNC Continuing Training – Common National Base of Continuing Education of Teachers
BNCC – Common National Core Curriculum
CEB – Census of School Education
CES – Higher Education Census
Cieb – Innovation Center for Brazilian Education
CNP-CP – National Education Council – Full Council
Crei – Reference Centre for Integral Education
STS – Science, Technology and Society
STSE – Science, Technology, Society and Environment
DCN – National Curricula Guidelines

DCNEM – National Curricula Guidelines for Secondary Education
EaD – Distance Education
EF – Primary Education
EM – Secondary Education
Enade – National Student Performance Test
HEI – Higher Education Institution
ILC – Scientific Literacy Indicator
Inaf – Functional Literacy Indicator
Inep – Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira
LDB – National Education Law
MEC – Ministry of Education
OECD – Organisation for Economic Cooperation and Development
PCN – National Curricular Parameters
PCNEM – National Curricular Parameters for Secondary Education
Pibid – Institutional Programme of Scholarships for New Teachers
PISA – Programme for International Student Assessment
PNAD – National Household Sample Survey
PNE – National Education Plan
Prouca – One Computer per Student Programme
SciELO – Scientific Electronic Library Online
SPSS – Statistical Package for the Social Sciences
DICT – Digital Information and Communication Technologies
ICT – Information and Communication Technologies
UNESCO – United Nations Educational, Scientific and Cultural Organization

A03 - LIST OF CHARTS, TABLES AND GRAPHSTABLES

TABLES



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