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# DEVELOPMENT OF A SCIENCE CURRICULUM PROPOSAL FOR THE FIRST YEARS OF SCHOOLING: FOUNDATIONS, PROCESS AND PRODUCT

## *DESENVOLVIMENTO DE UMA PROPOSTA CURRICULAR DE CIÊNCIAS PARA OS PRIMEIROS ANOS DE ESCOLARIDADE: FUNDAMENTOS, PROCESSO E PRODUTO*

## *ELABORACIÓN DE UNA PROPUESTA CURRICULAR DE CIENCIAS PARA LOS PRIMEROS AÑOS DE ESCOLARIDAD: FUNDAMENTOS, PROCESO Y PRODUCTO*

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**ABSTRACT**: The concerns for promoting scientific literacy for all align with international recommendations from organizations such as the UN and OECD. Guidelines advocate for a contextualized, sequential, and systematic approach to science education from the early years of schooling. In Portugal, the primary school science curriculum (ages 6-10) emphasizes knowledge over skills, attitudes, and values. It reveals the absence of explicit guidance for science education, prompting its reformulation. This article describes developing a curriculum proposal for science education in the early years. The EDR methodology was adopted, and a new curriculum project was outlined through a comparative analysis of the current Portuguese science curriculum for primary education with those of other countries (Singapore, the United States, Australia, England, and Canada). This project aligns with an inquiry-based science education (IBSE) perspective and science, technology, and society (STS) guidance.

**KEYWORDS**: Science Education. Primary Education. Science Curriculum.

***RESUMO****: As preocupações para a promoção da literacia científica para todos estão alinhadas com as recomendações internacionais de organizações como a ONU e OCDE. Diretrizes advogam um ensino das ciências contextualizado, sequencial e sistemático desde os primeiros anos de escolaridade. Em Portugal, o currículo de ciências do ensino primário (6-10 anos de idade) privilegia os conhecimentos em detrimento das capacidades e atitudes e valores e revela a ausência de orientações explícitas para o ensino das ciências o que motivou a sua reformulação. Este artigo descreve o processo de desenvolvimento de uma proposta curricular para o ensino das ciências para os primeiros anos. Adotou-se a metodologia EDR e através da análise comparativa do atual currículo português da área de ciências, para o ensino primário com o de outros países (Singapura, Estados Unidos, Austrália, Inglaterra e Canadá) desenhou-se uma nova proposta de projeto curricular alinhada com uma perspectiva IBSE e orientação CTS.*

***PALAVRAS-CHAVE****: Ensino das Ciências. Ensino Primário. Currículo de Ciências.*

***RESUMEN****: Las preocupaciones por la promoción de la alfabetización científica para todos están alineadas con las recomendaciones internacionales de organizaciones como la ONU y la OCDE. Las directrices abogan por una enseñanza de las ciencias contextualizada, secuencial y sistemática desde los primeros años de la escolaridad. En Portugal, el currículo de ciencias de la enseñanza primaria (6-10 años) privilegia los conocimientos en detrimento de las habilidades y actitudes, y valores, y revela la ausencia de orientaciones explícitas para la enseñanza de las ciencias, lo que motivó su reformulación. Este artículo describe el proceso de desarrollo de una propuesta curricular para la enseñanza de las ciencias en los primeros años. Se adoptó la metodología EDR y, mediante el análisis comparativo del currículo portugués actual del área de ciencias para la enseñanza primaria con el de otros países (Singapur, Estados Unidos, Australia, Inglaterra y Canadá), se diseñó una nueva propuesta de proyecto curricular alineada con una perspectiva IBSE y orientación CTS.*

***PALABRAS CLAVE****: Educación científica. Educación primaria. Currículo científico.*

## Introduction

Science education aims to contribute to the development of scientific literacy for all citizens (AFONSO, 2008; FERNANDES; PIRES, 2019; FERNANDES; PIRES; DELGADO-IGLESIAS, 2016, 2017; ROBERTS; BYBEE, 2014; SALEHJEE; WATTS, 2020) in response to the ongoing transformations resulting from the increasing evolution and, consequently, the influence of science and technology in the daily lives of everyone (GALVÃO *et al*., 2006; SÁ; PAIXÃO, 2016). Therefore, it is necessary for science education to commence from the early years of schooling, as learning from an early age "seems to be a promising path for more and better learning in the future" (MARTINS, 2002, p.18, our translation), with the school serving as a privileged location for this purpose (GALVÃO *et al.*, 2006; PEREIRA, 2002; VIEIRA, 2007).

There are several arguments regarding the relevance of science education in the school curriculum from the early years, within an Inquiry-Based Science Education (IBSE) perspective, acknowledged by various authors, including: it allows children to interpret natural phenomena from everyday life, facilitates more complex future learning; arouses and responds to children's curiosity; promotes an interest in science; fosters a positive image of science; respects the right of children to learn (AKMAN; ÖZGÜL, 2015; FURMAN *et al*., 2019; MARTINS, 2002; PEREIRA, 2002).

In Portugal, the teaching of sciences formally began in primary education in the late 1960s, along with the approval of programs for primary education (Decree No. 23485 of July 16, 1968[3]), with a subject titled "Geographical-Natural Sciences." Its designation was changed a few years later (in 1979) to "Physical and Social Environment," maintaining the program until 1991. In that year, a new curriculum program for the 1st Cycle of Basic Education (CEB) (6-10 years old) was published, accompanied by a change in the name of the subject to "Study of the Environment", a designation that remains unchanged to date. This subject explicitly includes natural sciences (biology, geology, physics, and chemistry) and social sciences (history and geography of Portugal). From 2018 until now, curricular guidelines for science education are realized through the Essential Learnings of "Study of the Environment."

The total minimum weekly hours for these years of schooling is promulgated with Decree-Law n. º 55/2018, defining three hours for "Study of the Environment," seven hours for "Mathematics," and seven hours for "Portuguese." This asymmetrical distribution is

[3]https://www.lexlink.eu/conteudo/geral/ia-serie/3381222/portaria-no-2348568/21893/por-tipo-dedocumentolegal

accentuated by the fact that the subject "Study of the Environment" includes the area of history and geography of Portugal, reducing the weekly time for exploring themes of natural sciences. The need to combat this trend is expressed, for example, by Costa and Martins, who mention the "(...) need to value scientific education in the 1st CEB, giving it equity in terms of hours compared to other areas" (COSTA; MARTINS, 2016 p. 42, our translation).

Regarding Essential Learning, specifically in natural sciences, a comparative analysis of the Portuguese primary school science curriculum with those of countries such as Singapore, England, Australia, and the United States reveals that Portugal is the country (in comparison) where fewer science learning are defined, notably fewer investigative skills and attitudes, and where there is a greater absence of explicit guiding principles for science education (SILVA; RODRIGUES; VICENTE, 2023b), the result of the comparative analysis between the learnings required in the 2019 TIMSS for science (4th-grade students) and the Essential Learnings of science in "Study of the Environment" reveals that more than half of the learnings assessed in this international study are not included in the curricular documents of this educational cycle (SILVA; RODRIGUES; VICENTE, 2021).

All these facts highlight that natural sciences are underrepresented at the primary education curriculum design level in Portugal. In addition to these curricular gaps, primary school teachers' practices focus on methodologies that do little to stimulate active engagement of children and on activities lacking contextualization and connection with everyday life (SILVA; RODRIGUES; VICENTE, 2023a; RODRIGUES *et al.*, 2019). Despite this, other studies (GONÇALVES; VALADAS; FREIRE, 2011) indicate that teachers value science education and recognize the contribution of practical work to the development of children's scientific skills, even though they may hold naive and incomplete ideas about its potential (CORREIA; FREIRE, 2009).

The presented scenario of science education in primary schools in Portugal has led to the development of a Science Experimental Teaching Program (PEEC) for primary education, consisting of three components: i) a curriculum proposal, ii) activities and their respective teaching resources, and iii) activities and learning assessment instruments. This article aims to depict only the first component, specifically the development process and the product of a science curriculum proposal for primary education. This proposal was based on the analysis of science curricula from other countries and principles and emerging reference guidelines from the literature on science education for the early years of schooling.

## Theoretical Framework

The discussion surrounding the reconfiguration of science curricula has been debated for decades (CACHAPUZ, 2022; GUALBERTO; RODRIGUES, 2021; VIECHENESKI; SILVEIRA; CARLETTO; 2016; SANTOS; MORTIMER, 2000; SCHWAN; AYRES DOS SANTOS, 2020; TENREIRO-VIEIRA; VIEIRA, 2019; VIEIRA, 2007) due to their influence on the quality of science education (MARTINS, 2002). For instance, Reis (2021) identified eight challenges toward a better and more utilitarian science education. Challenge number four precisely emphasizes the need to adopt a new curriculum approach as opposed to the traditionally conceptualized one. This author highlights the necessity for the curriculum to include a "set of learnings (...) considered important in a specific historical and social context, marked by certain specific demands" (REIS, 2021, p. 4, our translation) aligned with the guiding principles of science education in pursuit of realizing a democratic society where everyone has the right to and equitable access to knowledge (PANSERA-DE-ARAÚJO *et al.,* 2011).

In general, the assumptions of a current, contextualized, guided, practical, and utilitarian science curriculum are not met in the Portuguese basic education curricula (FERNANDES; PIRES; DELGADO-IGLESIAS, 2016; RODRÍGUEZ-MIRANDA; CARRAPIÇO; SOUSA, 2016; VIECHENESKI; SILVEIRA; CARLETTO; 2016). There is an increasing lack of interest among students in science subjects and a disregard for the progression of scientific careers (OCDE, 2006; ROCARD, 2007; INTERNATIONAL SCIENCE COUNCIL, 2021).

This is primarily attributed to a disconnected science curriculum that fails to relate to students' realities, leading them not to understand the relationship and application between what they learn and their role as citizens. Additionally, teachers are reluctant regarding their science teaching methodologies, confined to oral content transmission, contributing to students' disengagement in this area. Furthermore, the continued preference for textbooks as a privileged didactic resource for science education (TEIXEIRA, 2019; RODRIGUES *et al.* 2019) minimally stimulates the development of students' scientific skills (FERREIRA; SARAIVA, 2021).

The contradiction of an education based on the passive accumulation of knowledge is addressed through the adoption of a Science-Technology-Society (STS) oriented curriculum (FERNANDES; PIRES; DELGADO-IGLESIAS, 2017; RIBEIRO *et al*., 2023; VIEIRA; TENREIRO-VIEIRA; MARTINS, 2011). The deliberate contextualization of curriculum content gives meaning to children's learning, contrasting with conventional curricula (FERNANDES; PIRES; DELGADO-IGLESIAS, 2016; SCHWAN; AYRES DOS SANTOS, 2020), capable of inspiring students' enthusiasm for science and technology subjects (VIEIRA; TENREIRO-VIEIRA; MARTINS, 2011). Introducing themes related to the nature of science contributes to changing perceptions of what scientific work entails, the construction of knowledge, and the benefits and limitations of science (SANTOS; MAIA; JUSTI, 2020).

Teaching guided by the STS orientation

> (...) goes beyond mere academic knowledge of Science and Technology, addressing social problems related to scientific and technological issues, as well as a better understanding of the interactions among Science, Technology, and Society (VIEIRA; TENREIRO-VIEIRA; MARTINS, 2011, p. 16, our translation).

The principles underlying an STS-oriented curriculum focus on its potential to contribute to forming active, informed, and conscientious citizens. It promotes an understanding of how and why science is conducted, making all learning relevant to students' daily lives as active members of society (FERNANDES; PIRES; DELGADO-IGLESIAS, 2017; VIEIRA; TENREIRO-VIEIRA; MARTINS, 2011). For this reason, Fernandes, Pires, and Delgado-Iglesias express the need for:

> (...) curricular guidelines expressed in Official Documents to reflect and translate national and international recommendations, providing teachers with explicit guidance that enables them to implement pedagogical practices in the classroom that promote the development of students' scientific literacy (FERNANDES, PIRES E DELGADO-IGLESIAS, 2017, p. 1001-1002, our translation).

Santos (2001) synthesizes that the Science-Technology-Society (STS) orientation as a curricular reform in science education for the early years of schooling tends to challenge the absence of i) non-canonical scientific content permeated with values and principles; ii) a close connection between educational experiences and life experiences; iii) a combination of educational activities and non-formal and informal activities; iv) ways to access different sources of information; v) resources external to the school; and vi) learning contexts extended to technological aspects and their connection with society.

Regarding curricula with this orientation, several authors have delved into the subject and proposed possible curricular approaches (ex. AIKENHEAD, 2009; LÓPEZ-CEREZO, 1998; MEMBIELA, 2001; ZIMAN, 1994). For instance, López-Cerezo (1998) mentions three approaches to STS integration, namely: i) STS as a curricular addition by incorporating an STS area into a traditional science curriculum; ii) STS as content addition by incorporating an STS linkage at the end of themes/content; and iii) science-technology through STS, involving the reconstruction of content from an STS perspective.

Membiela (1997, 2001), in turn, highlights four curricular approaches with an STS orientation: i) inclusion of STS modules or units in materials of disciplinary orientation; ii) infusion of the STS focus into existing modules or units through repeated punctual inclusions throughout the curriculum; iii) inclusion of an STS discipline; iv) complete transformation of an existing theme through STS integration.

There is a growing interest in analyzing science curricula in light of an STS orientation. An example of this is the study conducted by Fernandes, Pires, and Delgado-Iglesias (2017), which analyzes the curricular guidelines for science education in the 2nd Cycle of Basic Education (10-12 years old) in Portugal, in effect in 2000, focusing on the purposes, knowledge, and methodological procedures for science education.

The results of this study reveal a limited integration of the STS orientation in the analyzed curricular documents, with the specification of STS relationships still insufficient to promote scientific literacy among students in this educational cycle (FERNANDES; PIRES; DELGADO-IGLESIAS, 2017). The same authors highlight the scarcity of explicit guidelines in the curricula related to the STS orientation, which "(...) compromises an effective mobilization and application of scientific knowledge since teachers have little training in this area (...)" (FERNANDES; PIRES, 2019, p. 239, our translation).

On the other hand, a curriculum whose exhaustive content primarily comprises a set of canonical knowledge is mainly outdated and ill-suited to the principles and demands of science education (MARTINS, 2002), perpetuating transmissive approaches (SANTOS; MORTIMER, 2000; VIECHENESKI; SILVEIRA; CARLETTO, 2016). As Vieira states, curricula "should include content about the nature of science and scientific processes, and very little pure scientific content" (VIEIRA, 2007, p. 102, our translation).

Therefore, a curriculum is desired that incorporates current competencies, encompassing knowledge, investigative skills, and scientific attitudes, preparing students for scientific and technological issues at both local and global levels (VIEIRA; TENREIRO-VIEIRA; MARTINS, 2011). According to the European reference framework for key competencies for lifelong learning, scientific competence is defined as the "(...) capacity and willingness to draw on the body of knowledge and methodologies used to explain the world of nature, to pose questions and answer them in a reasoned way" (COMISSÃO EUROPEIA, 2007, p. 6, our translation).

According to Afonso, knowledge includes "(...) terms, facts, concepts, and theories that involve, in increasing order, greater complexity, and abstraction" (AFONSO, 2008, p. 68, our translation). Bueno (2003) adds to this definition the science field's laws, principles, and phenomena. It is unrealistic to expect children to memorize and apply scientific terms in their discourse (PEREIRA, 2002) solely through oral content transmission. Instead, according to the author, the progressive construction of the meaning of these terms through multiple practical experiences is expected.

According to Afonso, skills are related to the "(...) set of procedures used, often involving experimental activity, in research in various domains of science" (AFONSO, 2008, p. 75, our translation).

Table 1 brings together a set of scientific skills defined by various authors (ex. AFONSO, 2008; BUENO, 2003; DUARTE *et al*., 2020; PEREIRA, 2002; VILALLONGA, 2002), adopting the organization proposed by Harlen and Qualter (2018).

**Table 1 –** Investigative Skills

| | **Activity Stages** | | | |
|---|---|---|---|---|
| | **Designing an Investigation** | **Data Collection** | **Analysis, Interpretation, and Explanation** | **Communication, Argumentation, and Evaluation** |
| **Capacities** | Formulating problem questions; Predicting; Planning. | Operationalizing the plan; Observing; Recording data; Collecting data; Measuring; Classifying; Describing; Controlling variables. | Interpreting and analyzing data; Formulating conclusions; Responding to problem questions. | Communicating; Evaluating; Reflecting. |

Source: Authors' elaboration.

These skills are not compatible with traditional teaching through the oral exposition of content but rather through creating situations in which the child is required to apply them in a contextualized and concrete manner (PEREIRA, 2002).

As for attitudes and values, Afonso (2008) considers them essential for intellectual and emotional progress and individual and social development. Several authors (AFONSO, 2008; VILALLONGA, 2002; PEREIRA, 2002) list attitudes and values related to science education, such as respect for evidence, critical reflection, inquisitive attitude, creativity, cooperation, and perseverance.

As Pereira (2002) notes, these are not usually highlighted in curricula with the same emphasis as skills and knowledge. In a recent study (SILVA, RODRIGUES; VICENTE, 2023b), it was precisely found that out of five analyzed curricula (Portugal, the United States, Australia, England, and Singapore), only one identified attitudes as an identity space in the curriculum (Singapore).

Although the various dimensions of competence are presented separately, it is noteworthy that, in practice, they should not be mobilized in a dissociated manner. They should be intentionally and gradually promoted from the early years of schooling to ensure the foundations for future, more complex, and abstract learning (PEREIRA, 2002).

The proliferation of comparative studies on science curricula (ex. CIASCAI; MARCHIS, 2009; DERMAN; GURBUZ, 2018; HAVU-NUUTINEN *et al.,* 2022; SWEE CHIN *et al*., 2022; NG *et al.,* 2011; ORHAN, 2018; PAWILEN; SUMIDA, 2005; RODRÍGUEZ-MIRANDA; CARRAPIÇO; SOUSA, 2016; SENTURK; AYDOGMUS, 2017; SOTHAYAPETCH; LAVONEN; JUUTI, 2013) s contributed to expanding and enriching recommendations and aspects to be considered in a science curriculum. These include: i) guidelines/orientations for teaching, such as learning theories, general objectives, teaching methodologies, activity examples, and educational resources; ii) guidelines/orientations for the assessment process; iii) interdisciplinary connections; iv) explicit statements of learning outcomes at the levels of knowledge, skills, attitudes, and values; v) relating content to the culture and reality of the country in question, as well as other current local or global issues and challenges; and vi) framing within international political-educational issues (PISA, TIMSS, OECD...) and theoretical frameworks (CTS, IBSE, nature of science; sustainable development goals).

In this context,

> (...) a curriculum proposal is expected to be concerned with mastering basic science concepts and, above all, with human and civic education. Thus, it is oriented towards the contextualized and critical construction of knowledge, the development of values and attitudes based on ethics, co-responsibility, and conscious and democratic social participation (VIECHENESKI; SILVEIRA; CARLETTO, 2016, p. 1540, our translation).

The development and adoption of curricula of this nature appear promising pathways for fulfilling science education, especially for developing scientific literacy (PANSERA-DE-

ARAÚJO *et al*., 2011; SANTOS; MORTIMER, 2000), There is an urgent need to act in this direction. Therefore, incorporating explicit guidelines into the predominantly practical curriculum is crucial to streamline and support its proper implementation by teachers.

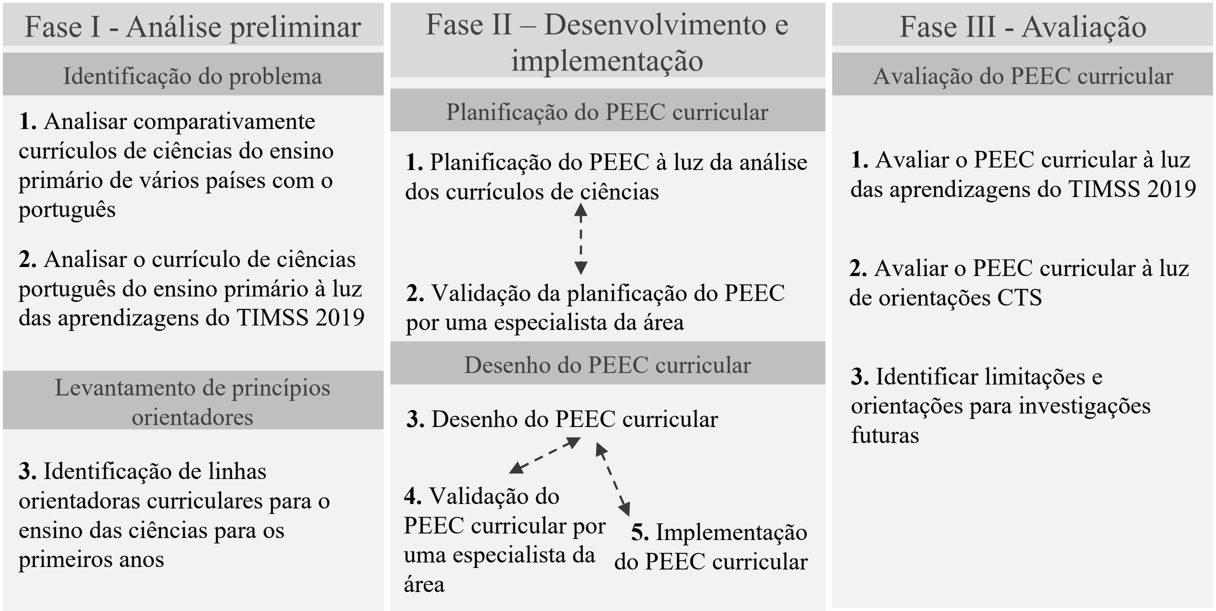
## Methodology

As mentioned earlier, this article is part of a larger research project guided by the research question: "How to promote experimental science teaching systematically, contextualized, with CTS and IBSE orientation in the 1st CEB (1st Cycle of Basic Education)?". The research objective was "to develop (conceive, plan, validate, implement, evaluate) a new curriculum proposal for experimental science teaching with CTS and IBSE orientation."

It is predominantly a qualitative study, and the data collection technique involves documentary compilation. The latent data corpus of the study consists of six curricula (United States, England, Singapore, Australia, Canada, and Portugal). These curricula were chosen based on the results presented in various editions of TIMSS and PISA in science, a process described in greater detail in another article by the authors (SILVA; RODRIGUES; VICENTE, 2023b). As a qualitative study (COUTINHO, 2014), categorical content analysis (BARDIN, 2018) was chosen, supported by the WebQDA software (SOUZA, COSTA; SOUZA, 2015).

The *Educational Design Research* (EDR) approach was employed to develop the curriculum proposal. EDR aims at educational innovation, starting from identified problems, and proposes to develop this curriculum proposal based on iterative cycles (MCKENNEY; REEVES, 2019, 2021). It envisions the effective collaboration of a multidisciplinary team, as exemplified in Figure 1.

**Figure 1 –** Iterative cycle and EDR stages[4]




Source: Authors' elaboration.

The need for change in the science curriculum for the Portuguese 1st Cycle of Basic Education (1º CEB) emerged from previous works, such as the comparative analysis of the Portuguese science curriculum with other curricula (SILVA; RODRIGUES; VICENTE, 2023b) and the insights from the TIMSS 2019 science learning outcomes for primary education (SILVA; RODRIGUES; VICENTE, 2021). Given the identification of this need (Phase I), guiding principles for the development of science curricula were surveyed, as presented in the theoretical framework of this article.

Phase II of development and implementation is characterized by iterative cycles between design/planning, validation, and implementation. In the first phase, the science curricula were analyzed regarding organization, themes, statements of knowledge, skills, attitudes, and values. After completing the first phase, the document underwent analysis by an expert in science education. Based on the feedback received, the document was reorganized, subsequently progressing to developing the Project for the Structuring of Teaching by Competencies (PEEC) curriculum. This process culminated in creating the knowledge analysis tool, categorized by areas and themes (as presented in Table 2).

[4] The figure illustrates the preliminary analysis through identifying a problem; the development and implementation of the curriculum proposal (PEEC) planning, and how the evaluation of the curriculum proposal (PEEC) functions.

**Table 2** – Data Analysis Tool

| Dimension | Category | Category Description |
|---|---|---|
| Physical Sciences | **Materials, objects, and structures** | Knowledge related to: material properties (elasticity, hardness, permeability, buoyancy...), origin of materials, use of objects based on the type of material they are made of, natural and non-natural structures. |
| | **Light** | Knowledge related to: luminous and non-luminous objects, shadows, and mirrors. |
| | **Simple Machines** | Knowledge related to the function, functionality, and use of simple machines in everyday life. |
| | **Magnetism** | Knowledge related to magnet properties, magnetic and non-magnetic materials. |
| | **Air and Sound** | Knowledge related to: properties of air (volume, mass, compression, density) and properties of sound (differences between loud, high-pitched, low, and deep sounds). |
| | **Changes of Physical State** | Knowledge related to: properties of liquids, solids, and gases, effect of temperature on materials, water cycle. |
| | **Energy and Electricity** | Knowledge related to: sources and forms of energy, use of energy in daily life, electrical circuits, electrical insulators and conductors. |
| Biological Sciences | **Diversity** | Knowledge related to: diversity of living beings; classification of living beings; differences between living and non-living beings; causes and consequences of the extinction of living beings. |
| | **External Characteristics** | Knowledge related to: similarities and differences between the visible characteristics of animals and plants, specific functions of the physical parts of animals, visible changes in the human body, constituent parts of plants and their functions, sexual dimorphism, and characteristics that are part of environmental adaptation. |
| | **Internal Characteristics** | Knowledge related to: systems of the human body (digestive, reproductive, respiratory, circulatory, nervous), bones, and their functions. |
| | **Life Cycle** | Knowledge related to: factors that influence seed germination and plant growth; heredity in animals, life cycle of some animals, typical behaviors of some parents that aid in the survival of offspring; importance of reproduction. |
| | **Interaction** | Knowledge related to: animal feeding; the type of relationship that living beings have with each other, and food chains. |
| | **Habitat and Basic Needs** | Knowledge related to: types of habitat and their characteristics; basic needs of different animals and plants; causes, consequences, and solutions of habitat alteration, degradation, and destruction. |
| | **Health and Well-being** | Knowledge related to: symptoms and signs of disease, influence of living beings on the health and well-being of living beings, and healthy habits (diet, rest, physical exercise). |
| Earth Sciences | **Weather and Climate** | Knowledge is related to weather and climate characteristics and is an instrument to characterize weather conditions. |
| | **Solar System** | Knowledge related to: day and night events, moon phases, seasons, planets, and stars. |
| | **Minerals, Rocks, and Soils** | Knowledge related to characteristics of minerals, rocks, and soils, use of minerals, rocks, and soils in daily life. |

| Dimension | Category | Category Description |
|---|---|---|
| | **Sustainable Consumption** | Knowledge related to: practices and attitudes related to responsible consumption. |

Source: Authors' elaboration.

The design of the curricular proposal involved compiling the content from the analyzed curricula and distributing it by themes and grade levels. This process allowed for a preliminary draft of the curricular proposal. A science education specialist with extensive experience in curriculum development and consulting was consulted to ensure validity and fidelity. The development process of the curricular proposal was presented at a national science education meeting and subjected to public analysis by science education experts.

All the feedback obtained facilitated its redesign. During the proposal's concession phase, the natural sciences curriculum for the 2nd cycle of basic education (5th and 6th grades) was considered to avoid repetitions and ensure the foundations for knowledge to be explored in subsequent years. The first version of this curricular proposal enabled its implementation through science activities aligned with the learning objectives stipulated in that curriculum over an academic year. Based on teacher feedback, it underwent redesign and a new implementation in the following academic year. Although the implementation process is not described in this article, throughout the academic years 2020/2021 and 2021/2022, a total of 23 problem-solving questions were implemented in the 1st year, 20 in the 2nd year, 21 in the 3rd year, and 13 in the 4th year, involving the participation of over 200 children.

The third and final phase involved evaluating the curricular proposal in light of the science learning outcomes from TIMSS 2019 and using a CTS (Science, Technology, and Society) curricular analysis tool to position/compare the developed curriculum.

## Analysis of Science Curricula

An initial analysis of reference science curricula was conducted to construct the Curriculum Enrichment Program (CEP), covering Portugal, the United States, England, Singapore, Australia, and Canada for primary education. This analysis addressed the organization, science themes, and learning related to knowledge, skills, attitudes, and values. Subsequently, the analysis of each of these mentioned aspects was systematized.

Regarding organization, the curricula were categorized into three groups: those that structure the expected learning outcomes by themes (Singapore, the United States, and Canada), those that present knowledge organized by science themes, while skills and attitudes are treated transversally across various areas and science themes (Australia and England), and those that do not clearly define knowledge, skills, and attitudes, nor explicitly present science themes (Portugal).

The case of Singapore stands out from the others by initiating science education only in the 3rd year. Subsequently, an examination was conducted to understand which science themes are utilized in these curricula in Biological Sciences, Physical Sciences, and Earth Sciences, based on the analysis tool presented earlier (see Table 2).

Regarding the Physical Sciences area, 26 themes were identified (Table 3). Two themes from the Australian curriculum are repeated over the four years; eight themes from the Canadian curriculum with no repetitions across the years; five from the United States curriculum, also with no repetitions; seven themes from the England curriculum, with no repetition; and four themes from the Singapore curriculum, which, due to its organization, does not anticipate repetitions.

**Table 3 –** Physical Sciences Themes in Curricula by Grade Level

| **Curriculum** | **Physical Sciences Themes per Grade Level** | | | |
|---|---|---|---|---|
| | 1st Year | 2nd Year | 3rd Year | 4th Year |
| Singapore | | | Diversity of materials<br>Cycles in matter and water<br>Interaction of forces<br>Energy forms and uses | |
| Australia | Chemical and pshysical sciences | | | |
| United Kingdom | Everyday material | Uses of everyday materials | Light<br>Force and magnets | States of matter<br>Sound<br>Electricity |
| United States | Waves: light and sound | Structure and properties of matter | Force and interactions | Energy |
| Canada | Materials, Objects, and Everyday Structures<br>Energy in Our Lives | Movement<br>Properties of Liquids and Solids | Strong and Stable Structures<br>Forces Causing Movement | Pulleys and Gears<br>Light and Sound |

Source: Authors' elaboration.

Regarding themes related to the Biological Sciences area, there are 15 themes, nearly half the number counted for Physical Sciences themes (Table 4). The curriculum document for the United States presents three themes, with the repetition of "Interdependent Relationships in Ecosystems" and "Structure, Function, and Information Processing" twice. In the case of

Australia, it was observed that the overarching theme, following the logic of physical sciences, also remained consistent over the four years. In England, three themes were noted, repeating over the years, namely "Plants" in the first three years, "Animals, including humans" in all years, and "Living things and their habitats" twice in the 2nd and 4th years.

In Singapore, four themes are presented (matching the number of themes in Physical Sciences), and whether they repeat over the two years cannot be concluded. Finally, in the case of Canada, four themes were identified (half the number found in Physical Sciences), with no observed repetitions.

**Table 4 –** Biological Sciences Themes in Curricula by Grade Level

| **Curriculum** | **Biological Sciences topics by grade level** | | | |
|---|---|---|---|---|
| | 1st Year | 2nd Year | 3rd Year | 4th Year |
| Singapore | | | Human system<br>Plant system<br>Cycles in plants and animals<br>Diversity of living and non-living things | |
| Australia | Biological sciences | | | |
| United Kingdom | Plants<br>Animals, incluinding humans | Living things and their habitats<br>Plants<br>Animals, incluinding humans | Plants<br>Animals, incluinding humans | Living things and their habitats<br>Animals, incluinding humans |
| United States | Structure, Function, and Information Processing | Interdependent Relationships in Ecosystems | Interdependent Relationships in Ecosystems<br>Inheritance and Variation of Traits: Life Cycles and Traits | Structure, Function, and Information Processing |
| Canada | Needs and Characteristics of Living Things | Growth and Changes in Animals | Growth and Changes in Plants | Habitats and Communities |

Source: Authors' elaboration.

In the field of Earth Sciences, there are a total of 10 themes (almost 1/3 of the Physical Sciences learnings). In the case of the United States, three themes are counted, repeating the theme "Earth's Systems: Processes that Shape the Earth." In Australia, the same theme is repeated over the four years, unlike England, which presents two themes: "Seasonal changes" in the 1st year and "Rocks" in the 3rd year. The Canadian curriculum, like the Australian, gives one theme for each year without repetitions. The curriculum document of Singapore does not encompass Earth Sciences themes.

**Table 5 –** Earth Sciences Themes in Curricula by Grade Level

| **Curriculum** | **Earth Science topics by grade level** | | | |
|---|---|---|---|---|
| | 1st Year | 2nd Year | 3rd Year | 4th Year |
| Singapore | | | - | |
| Australia | Earth and space sciences | | | |
| United Kingdom | Seasonal changes | - | Rocks | - |
| United States | Space Systems: Patterns and Cycles | Earth's Systems: Processes that Shape the Earth | Weather and Climate | Earth's Systems: Processes that Shape the Eart |
| Canada | Daily and Seasonal Changes | Air and Water in the Environment | Soils in the Environment | Rocks and Minerals |

Source: Authors' elaboration.

The repetition or absence of themes was also crucial in the decision-making process in building the PEEC curriculum proposal, where it is observed that in Biological Sciences, repetition is more common, unlike themes in Physical Sciences and Earth Sciences. It was also noted that, in general, curricula are organized by specific science themes, except Australia, which, despite using general areas, still maintains specificity to the sciences. In contrast, being an integrative area, Portugal does not follow this organizational logic.

This consensus was valued and decisive in constructing our curriculum proposal, recognizing the importance of organizing a curriculum around science themes. Regarding knowledge, the United States, Australia, and Canada curricula are specific for linking science and technology with society.

Regarding skills, except for the Portuguese curriculum, all analyzed curriculum documents have a specific and explicit area for them. As mentioned earlier, Singapore, the United States, and Canada curricula integrate skills into science themes. In the case of the Australian and English curricula, they appear detached from themes, becoming cross-cutting. In both cases, a logic of progressive complexity is explicitly presented, contrary to Portugal, where a common statement appears for all years: "Knowing how to ask questions, raise hypotheses, make inferences, verify results, and communicate, recognizing how knowledge is constructed."

Regarding attitudes and values, only the Singapore curriculum has a specific area for them, with statements on curiosity, collaboration, objectivity, integrity, responsibility, integrity, and creativity. In the others, these appear as general objectives or are scattered throughout the curriculum.

## Presentation of the Curricular PEEC

The Curricular PEEC, as mentioned earlier, is a science curriculum proposal for the first four years of primary education in Portugal. This curriculum proposal is based on the assumption that "(...) children do not learn scientific ideas and concepts just because the teacher exposes them (...)" (PEREIRA, 2002, p. 71, our translation).

Varela and Martins (2013, p. 99, our translation) add that the process of learning and teaching is "(...) far from being processes of reproduction and transmission of knowledge." Therefore, it is obsolete to develop and organize a curriculum in an expository approach that calls for memorizing canonical knowledge. In this sense, the socio-constructivist perspective of learning is the one that best fits the developed curriculum proposal.

One of the approaches that is compatible with this teaching vision is IBSE. This approach completely opposes the retrograde position of the teaching and learning process in which experimental rhetoric is supported by the exploration of the textbook, inhibiting the development of multiple student skills. This approach implies changes in how the teacher teaches and students learn (VARELA; MARTINS, 2013).

The emphasis of the learning process shifts to the student, where the teacher's role becomes that of a problematizer and facilitator of more and better learning (VARELA; MARTINS, 2013). This typology is not realized through the implementation of isolated experimental activities (COSTA; DOMINGOS; TEODORO, 2018). The role of a problematized implies that the teacher promotes moments of contextualization, raises and identifies children's prior ideas, formulates the problem question, plans the activity, and operationalizes the plan through observation, measurement, research, formulation of conclusions, and comparison with predictions. It also involves formulating the answer to the problem question, communicating the process, results, limitations, reflection, and evaluation of the entire process (MERCEDES; TEMBLADERA, 2013; NUDELMAN, 2015; UUM; VERHOEFF; PEETERS, 2016; VARELA; MARTINS, 2013).

The development of a curriculum with a Science, Technology, and Society (CTS) orientation was also a concern, considering that "in a CTS science curriculum, canonical scientific content is related and integrated with the everyday world of students in such a way that it mirrors students' natural efforts to make sense of this world" (AIKENHEAD, 2009, our translation).

In this regard, it was ensured that this curriculum proposal was based on the main characteristics of CTS-oriented teaching, namely: i) valuing real situations through contextualized teaching; ii) effective and conscious mobilization of competencies that facilitate, for example, decision-making and resolution of socio-scientific technological problem situations; iii) fostering interest in the connections between science, technology, and society; iv) selecting accurate or realistic and relevant themes involving science and technology; v) active involvement of the child in their learning process; vi) adopting an interdisciplinary approach; and vii) valuing the application of scientific and technological knowledge.

In structuring the curriculum, references from Singapore, Canada, and the United States curricula were adopted. Multiple themes covering Physical, Biological, and Earth Sciences were defined for each school year. Knowledge, skills, attitudes, and values are outlined for each theme. Given the comprehensive nature of the project, which includes practical activities, problem questions were proposed for each theme, resulting in applicable activities to monitor students' learning progress.

The compilation of knowledge from various themes in the curricula (as presented in Tables 3, 4, and 5) led to the selection of the most relevant ones. Decisions were made regarding the distribution of these themes over the years, considering criteria such as the level of complexity and frequency in the analyzed curricula.

In the context of this proposal for restructuring the existing Portuguese curriculum, some modifications were implemented in its organization. This document covers, in addition to the natural sciences, learning in history, geography, and technology, among others. Notably, the proposal focuses exclusively on learning statements related to the natural sciences, structuring itself into four main areas: Biological Sciences, Physical Sciences, Earth and Nature Sciences, and History of Science.

Regarding the themes of Physical Sciences, the analyzed curricula were respected. In the area of Biological Sciences, due to the diversity and nature of the themes, some were retained, and others were created. Similarly to the Biological Sciences area, the Earth Sciences area also underwent some changes, considering that, in some curricula, this theme was not addressed. In addition to these themes, as observed in the Australian curriculum, a specific section was included for each school year, dedicated to knowledge about the Nature and History of Science, giving it appropriate prominence in the curriculum proposal.

In the distribution of themes according to the school years, the analyzed curricula were considered, identifying which school years the exploration of each theme is suggested. Following this logic, the scheme for Physical Sciences was developed (see Table 1).

Similar to what is proposed in the analyzed curricula, the proposal for exploring the themes of Physical Sciences in the Curriculum Enrichment Program (PEEC) is made for only one school year ("Magnetism," "Simple Machines," "Air," "Sound," and "Electricity") or over two school years ("Light" and "Changes in the physical state"). The theme "Materials, Objects, and Structures," given its nature, is distributed over three years, progressing in the complexity of the recommended knowledge.

**Table 1 –** Physical Sciences Themes in the Curriculum Enrichment Program (PEEC) by School Year

| Physical Sciences | | School Year | | | |
|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th |
| Themes | Materials, Objects, and Structures | • | • | • | |
| | Light | • | | • | |
| | Simple Machines | | • | | |
| | Magnetism | | • | | |
| | Air and Sound | | | • | • |
| | Changes in Physical State | | | • | • |
| | Energy and Electricity | | | | • |

Source: Authors' Compilation.

For the 1st year, the introduction of the themes "Materials, Objects, and Structures" and "Light" is planned. In this regard, children are expected to recognize that objects can be made of various materials and that these materials have specific properties, such as hardness, flexibility, and buoyancy, among others. Regarding the theme of light, it is expected, for example, that they recognize that light can be of natural or non-natural origin, that luminous objects have their light, and that illuminated objects do not emit their light but reflect the light from luminous objects. They are also expected to understand that light passes wholly or partially through some materials, not others.

In the 2nd year, the theme "Materials, Objects, and Structures" continues to be explored, and the themes of "Simple Machines" and "Magnetism" are also introduced. These themes aim to develop knowledge related to the origin of materials, properties (e.g., permeability), the functioning of simple machines and their applications in daily life, magnets, and magnetic attractions (e.g., magnetic and non-magnetic materials).

In the 3rd year, the exploration of the theme "Materials, Objects, and Structures" is resumed, revisiting the "Light" theme explored in the 1st year and initiating the themes "Air" and "Changes in physical state." In these themes, the aim is to develop knowledge related to: structures, their resistance, and stability; factors influencing the dissolution time of materials; factors affecting the size of shadows; characteristics of images of objects in various types of mirrors; properties of air (e.g., volume, mass, compressibility); characteristics of liquids, solids, and gases; the effect of temperature changes on materials.

In the 4th year, the exploration of the themes "Sound" and "Energy" begins, continuing the exploration of the theme "Changes in physical state" initiated in the 3rd year. In these themes, the goal is to develop knowledge related to: sound propagation; factors influencing changes in the physical state of materials; changes in the physical state of the water cycle and everyday situations; sources and forms of energy, considering their renewability or not, and their function; electrical circuits (e.g., series and parallel circuits); electrical conductors and insulators.

The concentration of learning in Physical Sciences led to adjustments in the proposed exploration distribution in the Essential Learnings. While the Essential Learnings indicate the exploration of the theme "Changes in physical state" for the 2nd year, the PEEC proposal suggests its initiation in the 3rd year. For example, the exploration of magnets, suggested in the 3rd year, is initiated in the 2nd year in the presented proposal. However, some elements were retained, such as the exploration of materials and their characteristics in the 1st year.

In Biological Sciences, a distribution of knowledge by different themes from the field of Physical Sciences was chosen due to the frequent repetition of these themes throughout the four years of schooling (see Table 2).

**Table 2** – Biological Sciences Themes in the PEEC Curriculum by School Year

| Biological Sciences | | School Year | | | |
|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th |
| Themes | Diversity | • | • | | • |
| | External Characteristics | • | • | • | |
| | Internal Characteristics | • | | • | • |
| | Habitat and Basic Needs | • | • | | |
| | Interaction | • | | • | • |
| | Life Cycle | | • | • | • |
| | Health and Well-being | • | • | | |

Source: Authors' elaboration.

The decision was made to organize the themes progressively over the years, considering the knowledge's complexity level. In the 1st year, the focus is on more elementary knowledge related to the themes "Diversity," "External Characteristics," "Interaction," "Habitat and Basic Needs," and "Health and Well-being." The objective is for the children, during this academic year, to recognize, for example, that there are living beings, dead beings, and non-living beings in nature. Additionally, they are expected to understand that living beings exhibit different external characteristics, performing specific functions that contribute to their survival. They also aim to recognize that living beings inhabit specific environments according to their needs and that animals feed on other living beings, presenting distinct dietary habits.

In the 2nd year, the themes "Diversity," "External Characteristics," "Habitat and Basic Needs," and "Health and Well-being" are continued, and the theme "Life Cycle" is initiated. In this year, knowledge related to the diversity of animal and plant species is selected, as well as the basic needs of living beings (food, water, habitat); symptoms and signs of diseases in animals; factors influencing seed germination; changes in the human body over time; healthy habits to adopt; allergies and food intolerances in humans caused by other living beings.

In the 3rd year, the theme "External Characteristics" and "Health and Well-being" is resumed, the theme "Internal Characteristics" is initiated, and the themes "Interaction" from the 1st year and "Life Cycle" from the 2nd year are revisited. This year, the aim is to address knowledge related to: characteristics that allow or facilitate living beings to survive in certain habitats; sexual dimorphism; types of relationships that living beings have; the need for some animals to build structures to survive; parts and respective functions of plants, factors influencing their growth, how they reproduce, as well as the importance they have in human life in particular; heredity and the role that parents play in the survival of offspring; evolution of living beings.

Finally, in the 4th year, the themes "Diversity," "Internal Characteristics," "Interaction," and "Life Cycle" are continued. In the last year of this educational cycle, exploration related to the following is suggested: classification taxonomies of animals; human body systems, namely digestive, respiratory, cardiovascular, reproductive, and urinary; characteristics and function of bones; types of habitats, characteristics, and dangers of changes in them; food chains; life cycles of some animals; aspects related to the extinction of living beings, including endangered species, causes, consequences, and solutions.

As expected, changes were made to the Essential Learnings of Environmental Studies. For example, there was an anticipation of learnings related to categorizing living beings based on their covering, locomotion, and other characteristics, initially planned for the 2nd year in the Essential Learnings. Some learnings related to "environmental modifications" and "appropriate procedures in situations of burns, hemorrhages..." that were initially planned for the 3rd year were delayed and moved to the 4th year. For instance, the suggestion from Essential Learnings to explore the human body and species on the verge of extinction was maintained in the 4th year of schooling.

Regarding Earth Sciences, as evidenced in Table 3, not all analyzed curricula incorporate it. However, due to the relevance of exploring this area, highlighted, for example, by the Sustainable Development Goals (SDGs), it was decided to include a theme and the respective learnings for each school year.

**Table 3 –** Earth Sciences Themes in the PEEC Curriculum by School Year

| Earth Sciences | | School Year | | | |
|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th |
| Themes | Time and Climate | • | | | |
| | Solar System | | • | | |
| | Minerals, Rocks, and Soils | | | • | |
| | Natural Resources and Sustainable Consumption | | | | • |

Source: Authors' elaboration.

It was decided to initiate this area with the theme "Weather and Climate" in the 1st year of schooling, addressing knowledge related to weather conditions and the distinction between weather and climate. In the 2nd year, the theme "Solar System" was selected, encompassing knowledge about the celestial bodies that comprise the solar system, day and night phenomena, and moon phases. This theme also includes knowledge related to the Nature and History of Science.

In the 3rd year, exploration is focused on the theme "Minerals, Rocks, and Soils," covering the characteristics of minerals, rocks, and soils and their importance and utility in everyday life. In the 4th year, the theme "Natural Resources and Sustainable Consumption" was defined, addressing aspects related to pollution and resource consumption, among others. The decision to include only one theme per year did not allow knowledge retention in the Earth Sciences area in the same years suggested in the Essential Learnings. Thus, regarding issues of minerals, rocks, and soil, initially planned for the 4th year in the Essential Learnings, they were advanced to the 3rd year. The Solar System, for example, indicated for the 3rd year in the presented proposal, is initiated in the 2nd year.

In the case of Nature and the History of Science, although assumed in this proposal as an area with its own identity, possible connections throughout the themes of other areas were highlighted. The theme "Scientists and Their Characteristics" was defined for the 1st year, "Scientific Knowledge and Its Characteristics" for the 2nd year, "Evolution of Scientific Knowledge" for the 3rd year, and "Inventions and Discoveries" for the 4th year (Table 4). These themes are contextualized within the scope of the themes of other areas.

**Table 4**– Nature and History of Science Themes in the PEEC Curriculum by School Year

| | **Nature and History of Science** | **School Year** | | | |
|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th |
| Themes | Scientists and Their Characteristics | • | | | |
| | Scientific Knowledge and Its Characteristics | | • | | |
| | Evolution of Scientific Knowledge | | | • | |
| | Inventions and Discoveries | | | | • |

Source: Authors' elaboration.

In the 1st year of schooling, scientists' work is explored, including with whom they work, where, and their main characteristics. In the 2nd year, within the context of exploring the solar system, the issue of scientific knowledge is investigated, its transformation over time, and the importance of certain scientists in this process. In the 3rd year, while exploring content about species reproduction, the investigation of the theme of evolution is proposed. In the 4th year, when examining the human body, questions about the evolution of Science and technology, specifically in this area, are introduced. Specific connections are also intended to be created in exploring other themes by introducing relevant scientists who have left a mark in the field of Science.

Regarding Science, Technology, and Society (STS) connections, while some curricula allocate a separate area for this knowledge, effective integration of this knowledge is advocated, and for this reason, that logic was not followed.

Concerning skills, examples were followed, such as the curricula of Singapore and the United States, where they were associated with various proposed knowledge themes. Like the Singapore curriculum, the decision was made to detail the skill. These learning statements are suggestions for exploring skills since other skills beyond those indicated in the PEEC curriculum proposal can be mobilized for each activity. However, this indication can facilitate teacher selection. In this sense, they are expected to be understood as suggestions, with an average of four skills attributed per activity.

Like knowledge, skills are also distributed by levels of complexity; for example, in the 1st and 2nd years, children are expected to select the problem question, while in other years, they are expected to define the problem questions of a specific situation/activity. In general, 24 skills were defined and organized across different stages of the activities presented in Table 6.

**Table 6 –** Skills in the PEEC Curriculum

| Activity Stage | Statement | Description |
|---|---|---|
| Designing an investigation | Forecast | Anticipates events related to the problem question. |
| | Formulate problem questions | Formulate/select the question related to the presented theme. |
| | Planning | Identifies and describes the procedures necessary to find answers to the defined problem question. |
| Datac | Operationalize the plan | Executes the planned procedures. |

| Activity Stage | Statement | Description |
|---|---|---|
| | Observing | Observes directly and/or indirectly events, images, and phenomena... relevant to the experience. |
| | Collecting/recording data | Collects and organizes the data in tables, drawings, and/or diagrams. |
| | Measuring | Uses measuring instruments (mass, volume, temperature, length, time, etc.). |
| | Classifying | Groups objects/materials/living beings/non-living beings based on common characteristics/attributes. |
| | Describing | Reports, what was observed, decisions made, and scientific processes. |
| | Controlling variables | Performs procedures that ensure only the effect of the independent variable on the dependent variable is being studied, keeping all other variables (control), thus ensuring the validity of the experiment. |
| | Researching information | Uses various means and sources to seek and access information on a topic (books, internet, encyclopedias, videos, interviews, posters, etc.). |
| | Using equipment | Uses measuring instruments, equipment, and resources according to their purpose. |
| | Comparing | Identifies similarities and differences between objects, materials, processes, living beings, and non-living beings. |
| Analysis, interpretation, and explanation | Organizing and systematizing data | Constructs graphs, mind maps, and schemes to organize the data. |
| | Interpreting and analyzing data | Analyzes the data and makes interpretations based on evidence. |
| | Formulating conclusions | Develops a final argument based on the results obtained. |
| | Formulating answers to questions | Develop answers to the problem question. |
| Communication, argumentation, and evaluation | Communicating | Shared procedures, results, and/or conclusions using drawings, schemes, presentations (among others), concepts, terms, and scientific language related to the theme. |
| | Evaluating/Reflecting | Makes value judgments and analyzes a particular subject carefully and in detail. |

Source: Authors' elaboration.

The same logic as for skills was followed for attitudes and values, except for the suggested number per activity, where a maximum of two attitudes and values are proposed per activity. The defined scientific attitudes are presented in Table 7.

**Table 7 –** Attitudes and Values of the PEEC

| Statement | Description |
|---|---|
| Interest in science | Shows a predisposition to learn sciences through the activities developed. |
| Creativity | Creates feasible solutions for problem-solving in terms of fluency, flexibility, and originality. |
| Objectivity | Reveals assertiveness in experimental procedures. |
| Perseverance | Presents persistence and patience in experimental procedures. |
| Collaboration | Engages in activities and experimental procedures together with other peers. |
| Respect for evidence | Presents flexibility of thought based on the results obtained. |
| Respecting others' ideas | Accepts that colleagues may have different ideas. |
| Intellectual honesty | Recognizes the work of others. |
| Precision and accuracy | Reveal care and precision in experimental procedures (measuring, observing, and controlling variables...). |
| Responsibility | Shows quality in fulfilling obligations. |
| Integrity | Adopts appropriate strategies for knowledge construction in their experiences. |
| Curiosity | Demonstrates a willingness to learn sciences, showing a desire to learn even more through questions, research... |

Source: Authors' elaboration.

## Evaluation of the PEEC

The curricular proposal of the PEEC aims at the

> (...) valorization of daily life for contextualized teaching, as opposed to purely academic knowledge, divorced from the world outside the school (...) in which it appears (...) as a way to foster students' interest and taste for Science and Science learning, improving their attitudes towards Science (VIEIRA; TENREIRO-VIEIRA; MARTINS, 2011, p. 15, our translation).

For this reason, the developed curricular proposal adopted an STS orientation. The analysis tool designed by Fernandes, Pires, and Delgado-Iglesias (2017), to assess whether the curriculum guidelines for basic education are congruent with the Science-Technology-Society-Environment teaching perspective guided the curriculum development process. Its use confirmed that the proposed curriculum is based on an STS orientation in purpose, knowledge, and procedures, as explained below.

Regarding the "Purposes," three parameters were considered: skills development, attitudes and values, education, citizenship, sustainability, and the environment (Table 8). In general, the assumptions are fulfilled.

Concerning the first two parameters, these were explicitly incorporated throughout the curricular proposal, being assumed as learning objectives. The third parameter was included in various knowledge related to habitat protection and actions to preserve animal and plant species, among other proposals within the scope of active citizenship, environmental protection, and sustainability.

**Table 8 –** Evaluation Instrument "Purposes"

| Parameters/Indicators | | | |
|---|---|---|---|
| DIMENSION: PURPOSES | FP1 - Development of skills | | |
| | FP1a | Proposes the development of scientific procedures, problem-solving, and improving critical thinking. | The PEEC curriculum presents, for each theme, a set of expected scientific skills. |
| | FP2 - Development of attitudes and values | | |
| | FP2a | Fosters the development of responsible and conscious principles and norms of conduct, both individual and collective. | The PEEC curriculum presents, for each theme, a set of expected scientific attitudes. |
| | FP3 – Education, citizenship, sustainability, and the environment | | |
| | FP3a | Promotes the development of conscious, informed, and reasoned decisions regarding the consequences of human action on the environment. | The PEEC curriculum presents content relating human action to pollution, habitat destruction, and species on the brink of extinction. |
| | FP3b | Promotes the student's involvement in current problematic issues related to citizenship, sustainability, and environmental protection. | The PEEC curriculum presents habitat protection content, animal and plant species care, and sustainable consumption. |

Source: Authors' elaboration.

For the "Knowledge" dimension, five parameters were analyzed: CP1 - relevance of the thematic focus, CP2 - discussion of controversial issues related to scientific and technological advances, CP3 - reciprocal influence between scientific and technological advances and socio-environmental changes, CP4 - Diversity of CTSA contents/themes, and CP5 - Nature of scientific and technical knowledge systematized in Quadro 9. Considering relevant, accurate, and contextualized themes in daily life materialized as one of the fundamental arguments for the selection of contents to be explored in the PEEC curricular proposal, satisfying parameters CP1 (Relevance of the thematic focus) and CP4 (Diversity of CTSA contents/themes).

On the other hand, topics related to the Nature and History of Sciences were included and given a prominent place. An area was created for content related to scientific and technological advances and their impact on daily life, fulfilling the purposes of the second (CP2) and fifth parameters (CP5). Regarding parameter CP3 (Reciprocal influence between scientific and technological advances and socio-environmental changes), issues related to scientific progress and its implications in daily life are also explored in the section on the Nature and History of Science and Physical and Biological Sciences.

**Table 9 –** Evaluation Instrument "Knowledge"

| Parameters/Indicators | | | |
|---|---|---|---|
| DIMENSION: KNOWLEDGE | CP1 - Relevance of the thematic focus | | |
| | **CP1a** | Suggests the contextualized approach of current themes related to students' prior knowledge and daily lives. | The PEEC curriculum suggests exploring problem-solving questions with an introductory video and assessing children's prior ideas. |
| | **CP1b** | Proposes the discussion of scientific themes based on their social utility. | The PEEC curriculum incorporates scientific themes (energy, simple machines, medicine, etc.) and their utility in daily life. |
| | CP2 - Discussion of controversial topics related to scientific and technological advances | | |
| | **CP2a** | Suggests situations where different social realities lead to new scientific discoveries and technological innovations. | The PEEC curriculum addresses content related to the origin and scientific discoveries (e.g., medicines, vaccines, theories) and technological innovations (e.g., energy, light, etc.). |
| | **CP2b** | Discusses the advantages and limits of scientific and technological knowledge and its impacts on society and the environment. | The PEEC curriculum addresses content related to the advantages, limits, and implications of scientific knowledge (e.g., vaccines, medication, etc.). |
| | CP3 – Reciprocal influence between scientific and technological advances and socio-environmental changes | | |
| | **CP3a** | Highlights the reciprocal relationships between science and technology. | The PEEC curriculum addresses content that relates to science and technology (e.g., medicine, animals, plants, etc.). |
| | **CP3b** | Emphasizes changes in people's living conditions (habits, lifestyle, creation of new resources, etc.) related to technological advances over time. | The PEEC curriculum addresses content on the evolution and construction of scientific knowledge, presenting innovations and scientific discoveries over time. |
| | **CP3c** | Emphasizes the impacts of society and the environment on scientific and technological advances. | The PEEC curriculum addresses how the needs of society influence the advances in science and technology. |
| | CP4 - Diversity of CTSA contents/themes | | |
| | **CP4a** | Privileges the exploration of scientific and technological contents related to other fields of knowledge that require understanding CTSA interactions. | The PEEC curriculum presents connections between the nature of science, science themes (biology, physics, etc.), and their relationships and implications. |
| | CP5 - Nature of scientific and technological knowledge | | |
| | **CP5a** | Presents data related to the nature and history of science and/or different views of scientific knowledge over time. | The PEEC curriculum presents a section on the nature and epistemology of science and connections with other themes (e.g., animals, health, plants, etc.). |
| | **CP5b** | Presents knowledge in a non-dogmatic way. | The PEEC curriculum presents statements of expected knowledge framed within a scientific and technological problem. |

| Parameters/Indicators | | | |
|---|---|---|---|
| | **CP5c** | Provides information about the work and function of the scientist, as well as possible social, political, religious, or economic pressures they may face. | The PEEC curriculum suggests exploring content related to the nature of the scientist's work and the relationship of their work to social and political aspects/responsibilities, etc. |

Source: Authors' elaboration.

Finally, in the Dimension of Methodological Procedures, considering the parameter "Nature and diversity of suggested teaching activities and strategies," the proposed PEEC curriculum presented here is entirely favorable to the type of exploration suggested (Table 10). In general, it encompasses a variety of activities, both conducted outside and inside the classroom, providing, through PEEC, activities, and resources that support the active involvement of students in different moments of the activity.

**Table 10 –** Methodological Procedures Evaluation Instrument

| Parameters/Indicators | | | |
|---|---|---|---|
| DIMENSION: METHODOLOGICAL PROCEDURES | PMP1 - Nature and diversity of suggested teaching activities and strategies | | |
| | PMP1a | Proposes the use/manipulation of different resources inside and outside the classroom. | The PEEC curriculum suggests manipulating various observation support instruments (e.g., magnifying glass and camera) and measurement tools (e.g., stopwatch, ruler, thermometer, scale, rain gauge, anemometer, graduated cylinder, etc.). |
| | PMP1b | Proposes implementing practical, experimental, laboratory activities, field trips, etc., to explore CTSA relationships. | The PEEC curriculum suggests various activities to mobilize learning (knowledge, skills, attitudes, and values) with experimental, laboratory, and field trip activities related to CTSA. |
| | PMP1c | PMP1c Proposes the active involvement of students in activities such as debates, problem-solving, discussions, and research on issues where CTSA interactions are evident. | The PEEC curriculum suggests activities that involve students in debates, problem-solving, and research activities. |

Source: Authors' elaboration.

As the TIMSS 4th-grade Science test is one of the criteria for selecting Science curricula, the content evaluated in the 2019 edition was surveyed, and a comparison was made with the curriculum proposal presented here. This survey is systematized in Table 5, where a correspondence of over 90% of knowledge can be observed. Considering that this type of test aims to assess children's scientific literacy (ROSA *et al*., 2022) the fact that the proposal shows such a high degree of correlation is a relevant quality indicator.

**Table 5 –** Comparison of TIMSS 2019 statements and PEEC learnings

| | Number of Learnings in TIMSS 2019 | Number of TIMSS 2019 Learnings Covered in PEEC |
|---|---|---|
| Life Sciences | 26 | 25 |
| Physical Sciences | 19 | 17 |
| Earth Sciences | 12 | 11 |
| Total | 57 | 53 |

Source: Authors' elaboration.

These indicators, along with the entire process of implementations and validations carried out throughout the development of the proposal, point to the quality of the present science curriculum proposal with IBSE and CTS orientation and the feasibility of its operationalization in primary schools.

## Final considerations

This article is based on the necessary curricular reforms for the 1st Cycle of Basic Education (CEB), as proposed by some recent studies (SILVA; RODRIGUES; VICENTE, 2021; SILVA; RODRIGUES; VICENTE, 2023b; RAMOS *et al.,* 2023), especially within the scope of the Essential Learnings in the Study of the Environment, which encompass the science area. In this context, efforts are made to address identified gaps, outlining the process of developing a science curriculum proposal for primary education in Portugal, initially focused on restructuring the existing Essential Learnings. Following the recommendations of some authors (LEITE; DOURADO, MORGADO, 2018), constant validation throughout the development process of the curriculum proposal is valued to prevent possible gaps, contributing to its refinement and enrichment in iterative cycles.

Implementing this curriculum proposal in multiple classes and with a significant number of children allowed teachers to be involved in co-construction, a crucial aspect of research and studies of this nature. The assessments conducted on the curriculum proposal, in terms of the CTS perspective and the learnings assessed in the last edition of TIMSS for 1st CEB science, gauge its quality in light of international guidelines for science education in the early years.

Moreover, the process of evaluating the curriculum proposal in light of current assumptions for science education identified in the literature goes against the trend of predominantly transmissive and demonstrative teaching (SILVA; RODRIGUES; VICENTE, 2023a), abandoning the reliance on the textbook as the primary resource for science teaching, as still observed (RODRIGUES *et al.,* 2022).

The possibility and relevance of including didactic resources for teachers to support the curriculum proposal are emphasized by various authors who highlight the importance of suitable educational resources for quality science teaching (AIKENHEAD, 2009). In this context, the project underpinning this study ensures the development and evaluation of didactic resources (PEEC Activities) to support the proposal's implementation and activities and assessment tools (PEEC Assessment) to monitor children's learning, thereby facilitating teachers' work. It is worth noting that all PEEC resources will be available for free on a website and in editable format, allowing for adaptations per teachers' needs.

Regarding the limitations of this curriculum proposal, the impossibility of creating a curriculum that ensures the sequential and progressively complex nature of the learning statements across various teaching cycles is highlighted. This is because constructing a curriculum solely for the first four years of primary education does not guarantee a fully progressive logic, as envisaged throughout students' educational cycles.

Progressivity can be ensured when there is a single guiding document for that specific area, as observed in the analyzed curricula, which is desirable and recommended. However, during the construction of this curriculum, Essential Learnings for the 5th and 6th years of schooling were considered, avoiding knowledge repetitions and providing foundations for future content exploration.

In this exercise, the absence of topics related to physics and chemistry was noted, accentuating the lack of progressivity in science education over the years. On the other hand, the growing advocacy for curricular flexibility (COHEN; FRADIQUE, 2018; COSME, 2018; FERREIRA, 2020) contradicts the conceived proposal.

However, other authors advocate for including explicit guidelines, emphasizing the importance of incorporating essential learnings to guide teaching practice without hindering contextualized, individualized, interdisciplinary, and creative instruction. Furthermore, studies indicate teachers' difficulties in terms of didactic and disciplinary content (BORGES; REIS; FERNANDES, 2012; CAVADAS; SÁ-PINTO, 2021; GLÓRIA; ROSA; CAVADAS, 2012), highlighting the pressing need for a curriculum proposal with the suggested logic.

One of the identified limitations was the selection of the curricula that served as the basis for constructing the PEEC curriculum. With the definition of other selection criteria, other curricula could have been analyzed, which would have resulted in a different proposal with different contents. However, based on the TIMSS 2019 Science for defining the criteria, the analysis conducted in light of the PEEC learnings found that over 90% of the assessed knowledge is present in the curriculum proposal, unlike the Essential Learnings, making it an indicator of the quality of this curriculum proposal.

Despite the mentioned limitations, this curriculum proposal arises in response to the scarcity of research regarding science curricula, a concern highlighted by Rodríguez-Miranda, Carrapiço, and Sousa (2016). This call emphasizes the importance and necessity of improving science education to develop students' scientific literacy, preparing them for an uncertain scientific and technological future. Dissatisfaction with a predominantly transmissive experimental science education, supported by textbooks incapable of promoting the development of scientific skills in children, underscores the need to reform science education.

In one of the reports from the European Commission, it is mentioned that "educational systems whose curricula refer to socioscientific themes have a higher proportion of 15-year-old students who can achieve some basic scientific literacy" (COMISSÃO EUROPEIA / EACEA / EURYDICE, 2023, p. 14, our translation). Thus, the developed curriculum proposal is expected to contribute to future reflections and policy decisions, aiming to achieve the desired levels of scientific literacy among students necessary for active, conscious, and democratic citizenship.

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