

**INCLUSION IN SCIENCE EDUCATION: A COMPARATIVE ANALYSIS OF ESSENTIAL
LEARNING IN PHYSICS AND CHEMISTRY IN THE 12TH-GRADE IN PORTUGAL**

**INCLUSÃO NO ENSINO DAS CIÊNCIAS: UMA ANÁLISE COMPARATIVA DAS APRENDIZAGENS
ESSENCIAIS DE FÍSICA E QUÍMICA NO 12.º ANO EM PORTUGAL**

**INCLUSIÓN EN LA ENSEÑANZA DE LAS CIENCIAS: UN ANÁLISIS COMPARATIVO DE LOS
APRENDIZAJES ESENCIALES DE FÍSICA Y QUÍMICA EN EL 12.º CURSO EN PORTUGAL**

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ABSTRACT | Essential Learning (EL) guides science teaching in the Portuguese education system by shaping the selection and application of scientific knowledge. This study comparatively analyses 12th-grade ELs in Physics and Chemistry, identifying convergences and divergences in the History of Science, socioscientific issues, STEM orientation and inclusive approaches, with particular attention to gender. A mixed-methods approach was adopted, based on documentary analysis of official curriculum texts. The results reveal differences in the operationalisation of shared curricular principles: Chemistry emphasises socioscientific contextualisation and argumentation, while Physics adopts a more formal, technocentric approach. Although ELs does not constitute a normative barrier to inclusion, these differences have implications for teaching practice, calling for deliberate pedagogical choices that support equitable science education and scientific literacy.

KEYWORDS: Essential Learning, Chemistry, Physics, Gender, Upper Secondary Education.

RESUMO | As Aprendizagens Essenciais (AE) constituem o referencial curricular que orienta o ensino das ciências no sistema educativo português, influenciando a seleção e aplicação do conhecimento científico. O presente estudo analisa comparativamente as AE de Física e de Química do 12.º ano, identificando convergências e divergências na História da Ciência, na dimensão socio-científica, na orientação STEM e na promoção de abordagens inclusivas, com particular atenção à questão do género. Recorreu-se a uma metodologia mista, baseada na análise documental de textos curriculares oficiais. Os resultados evidenciam diferenças na operacionalização dos princípios curriculares comuns, destacando-se maior centralidade da contextualização socio-científica e da argumentação na Química, em contraste com uma abordagem mais formal e tecnocêntrica na Física. Conclui-se que, embora as AE não constituam um obstáculo normativo à inclusão, estas diferenças têm implicações para a prática docente, exigindo opções pedagógicas conscientes que favoreçam uma educação científica mais equitativa e a literacia científica.

PALAVRAS-CHAVE: Aprendizagens Essenciais, Química, Física, Género, Ensino Secundário.

RESUMEN | Los Aprendizajes Esenciales (AE) constituyen el marco curricular que orienta la enseñanza de las ciencias en el sistema educativo portugués e influyen en la selección y aplicación del conocimiento científico. Este estudio analiza comparativamente los AE de Física y Química del 12.º curso, identificando convergencias y divergencias en la Historia de la Ciencia, la dimensión sociocientífica, la orientación STEM y la promoción de enfoques inclusivos, con especial atención a la cuestión del género. Se utilizó una metodología mixta, basada en el análisis documental de textos curriculares oficiales. Los resultados muestran diferencias en la aplicación de los principios curriculares comunes, destacando una mayor centralidad de la contextualización sociocientífica y la argumentación en Química, frente a un enfoque más formal y tecnocéntrico en Física. Se concluye que, aunque las AE no constituyen un obstáculo normativo para la inclusión, estas diferencias tienen implicaciones para la práctica docente y la alfabetización científica.

PALABRAS CLAVE: Aprendizajes Esenciales, Química, Física, Género, Enseñanza Secundaria.

1. INTRODUCTION

In the current paradigm of science education, curricular frameworks play a central role in shaping the image of science conveyed to students. In Portugal, the Essential Learning (EL) (*Aprendizagens Essenciais* [AE]) constitute the normative framework that guides planning and assessment, aiming at the development of competencies aligned with the Student Profile at the End of Compulsory Schooling (*Perfil do Aluno à Saída da Escolaridade Obrigatória* [PASEO], 2017), which go beyond the purely conceptual domain. In the 12th-grade of upper secondary education, Physics and Chemistry are offered as optional subjects that deepen the scientific education initiated earlier in secondary school, aiming to provide a comprehensive and up-to-date view of core areas of scientific knowledge.

The Physics curriculum is anchored in the interpretation of natural phenomena and technological devices through theoretical models of Classical Mechanics and Modern Physics. In contrast, Chemistry is presented as a central science with a markedly socioscientific orientation, focused on its interface with other disciplinary areas, such as Biology and Engineering. Its curriculum emphasises understanding new materials, fuels, and plastics in line with the principles of sustainability and the responsible use of resources.

The divergence in the operationalisation of these two subjects raises critical questions regarding equity and inclusion in science education. The literature suggests that how science is narrated influences students' sense of belonging and motivation, particularly regarding gender-related issues. Gourlay and Mujtaba (2025) argue that physics curricula frequently operate as a gatekeeping mechanism, with curricular and assessment decisions that are perceived as androcentric and Eurocentric contributing to the persistent underrepresentation of girls in post-compulsory physics. This pattern has remained largely stable over the past three decades despite successive curricular reforms.

Although existing studies have analysed gender representation in science textbooks and students' perceptions of physics and chemistry, systematic comparative analyses of the curricular frameworks that guide these subjects at the upper secondary level remain scarce in the Portuguese context. Specifically, no study has yet examined how the Essential Learning documents for Physics and Chemistry operationalise, or constrain, inclusive and gender-equitable pedagogical approaches at the 12th-grade level. This study addresses this gap by providing a document-based comparative analysis that maps the epistemological and narrative choices embedded in these normative texts, contributing empirical evidence to inform curriculum revision and teacher practice.

Against this backdrop, the present article provides a comparative analysis of the ELs for Physics and Chemistry in the 12th-grade. The aim is to understand how these documents, as instruments of educational policy, foster or constrain the implementation of inclusive pedagogical practices.

2. THEORETICAL FRAMEWORK

This study assumes that curriculum frameworks are not epistemologically neutral and that the way scientific knowledge is structured, narrated, and contextualised influences students' perception of science, their sense of belonging, and the reproduction of gender inequalities.

For this study, inclusion is understood as the active creation of curricular and pedagogical conditions that enable all students, regardless of gender, cultural background, or social identity, to develop a sense of belonging, participation, and identification with science (Godec et al., 2017; Archer et al., 2015). This concept is distinct from, though related to, adjacent constructs mobilised in this study. Gender specifically refers to the socially constructed roles and identities associated with being male or female and constitutes one axis of inclusion (Kim et al., 2018). Socioscientific contextualisation denotes a pedagogical strategy that situates scientific content within real-world social, ethical, and environmental problems (Sadler, 2004; Zeidler et al., 2005); it may serve inclusion by increasing relevance and accessibility, but does not, in itself, guarantee equitable outcomes. Scientific literacy, in its contemporary formulation, refers to the capacity to mobilise scientific knowledge in civic and social contexts; while it represents an inclusive educational aim, it is an outcome rather than a structural condition of inclusion (Coppi et al., 2025). Inclusion, as operationalised here, is assessed at the curricular level through the presence or absence of representations, argumentation spaces, and epistemic diversity in official learning documents (Caramaschi et al., 2022).

The concept of curriculum has changed over time, reflecting different ways of theorising and understanding it. Curricular knowledge refers to the body of knowledge about what should be taught to a given group of students to ensure equitable and comparable education (Caramaschi et al., 2022). On the other hand, the concept of curriculum lacks a consensus definition in educational literature. The differences in its conceptualisation stem from the multiple functions and characteristics attributed to it in curricular studies (Kranjc Horvat et al., 2022). This study focuses on the formal curriculum, understood as the set of official guidelines that prescribe what should be taught in school and which are developed by the entities responsible for the education system.

In Portugal, ELs (DGE, 2018) are structured to provide a deep understanding of the world and to foster informed decision-making in society. According to the curriculum documents, science teaching should transcend mere memorisation, focusing on grasping the essence of scientific knowledge and its consequences for society, technology, and the environment. The concept of scientific literacy has also evolved significantly over the last few decades, moving from a vision centred on the acquisition of fundamental scientific knowledge to a broader and more integrated perspective. Initially associated mainly with the mastery of scientific concepts and facts, it has progressively incorporated dimensions related to understanding the nature of science, its methods, its limits, and the processes of knowledge validation. Currently, scientific literacy is understood as the ability to use scientific knowledge to interpret the world, analyse evidence-based information, formulate arguments and participate critically and responsibly in socioscientific issues with individual and collective impact. This contemporary approach attributes a central role to scientific literacy in the education of informed citizens capable of making decisions in social, environmental, technological, and ethical contexts, thereby reinforcing its relevance as a cross-cutting educational objective (Coppi et al., 2025).

According to Coppi et al. (2024), scientific literacy has been gaining recognition in Portugal through curriculum guidelines and educational discourse. Still, its implementation in teaching practices remains uneven and limited. In particular, the authors emphasise that although curriculum documents value understanding science, critical thinking, and the connection between science and society, these principles do not always translate into consistent classroom teaching strategies, with approaches focused on content transmission and solving more technical exercises still prevailing. The authors argue that strengthening scientific literacy in the Portuguese context requires greater consistency across the curriculum, textbooks, and pedagogical practices, as well as investment in teacher training, to favour approaches that link science, technology, and society and promote a more inclusive, contextualised understanding of science. According to the literature (Lederman et al., 2013; Sadler, 2004), science teaching should transcend the transmission of facts, using socioscientific issues as contexts for application in which understanding the nature of scientific knowledge serves as a critical filter for evaluating evidence and exercising responsible citizenship.

The way these principles are implemented in curricular contexts and educational resources may not be gender neutral. Research in science education has shown that representations, examples, application contexts, and models of scientists conveyed in teaching materials can reinforce or mitigate gender stereotypes associated with scientific fields (Archer et al., 2020). Makarova et al. (2019) refer to the association of masculinity with 'hard' sciences such as physics and mathematics. The authors state that in most studies, masculinity in science is more associated with physics and mathematics than with chemistry. In a study conducted in Portugal with 12th-grade students, some participants reported that, in subjects such as chemistry, girls participate more than boys. In contrast, in physics, boys are more eager to 'be right', suggesting a gender divide in knowledge domains (Fernandes et al., 2024). This may be related to the social perception that physics is a male-dominated field (Francis et al., 2017).

Abraham and Barker (2023) show that physics curricula tend to favour abstract, decontextualised approaches that are heavily focused on conceptual formalisation, while curricula in other sciences, such as chemistry, more frequently integrate applied contexts, observable phenomena and practical activities. According to the authors, these curricular choices influence students' engagement patterns, as overly abstract curricula removed from meaningful contexts can limit the identification and interest of certain groups, particularly girls. Thus, curricular differences between physics and chemistry can be understood not only as variations in content but as the result of distinct conceptions of the relevance, contextualisation, and accessibility of scientific knowledge, with direct implications for equity and inclusion in science education.

The epistemological differences between physics and chemistry, as mentioned by Baird et al. (2006), are reflected, for example, in the fact that physics seeks the fundamental laws that establish ontological limits on what is impossible in nature, while chemistry asserts its autonomy by operating within these limits through the discovery of specific mechanisms and the synthesis of new phenomena, processes that cannot be merely deduced from basic physical equations. Chemistry asserts its autonomy by operating within these limits through the discovery of specific mechanisms and the synthesis of new phenomena and processes that cannot be deduced solely from basic physical equations. Physics and Chemistry are distinguished epistemologically not only by their objects of study, but above all by how they produce scientific knowledge. Because physics has historically been taken as the paradigmatic model of science, favouring universal laws,

mathematical formalisation and deductive explanations, the history of physics in the philosophy of science has assumed centrality and erased alternative epistemological styles, such as that of chemistry (van Brakel, 2014).

Although the literature emphasises the centrality of scientific literacy in guiding documents in Portugal, there are still few empirical studies that systematically analyse how these principles are implemented, particularly in Physics and Chemistry. The main objective of this research is to compare the 12th-grade Physics and Chemistry ELs, as normative instruments of Portuguese educational policy, and to identify the opportunities and limitations for implementing inclusive and equitable pedagogical approaches. More specifically, the study seeks to identify disparities between the two subjects and how these may influence the construction of a learning framework that favours diversity and a sense of belonging, with a particular focus on deconstructing gender stereotypes and promoting scientific literacy geared towards the exercise of citizenship.

3. METHODOLOGY

To meet the research objective, this study is based on a sequential mixed methodology, in which the quantitative results obtained from the analysis of ELs (frequency of verbs, nominal references, STEM and socioscientific categories) serve as the basis for an in-depth qualitative phase, which uses content analysis through coding by categories (Bardin, 2024). This methodological choice aims to compare the explicit curriculum guidelines underlying EL, as normative documents that frame the teaching of Physics and Chemistry in secondary education.

The quantitative component involved the systematic enumeration of three categories of textual elements across both ELs documents: (1) proper names of historical scientists, extracted from all sections including knowledge descriptors, competency objectives, and strategic actions; (2) action verbs associated with student learning outcomes, drawn exclusively from the "Knowledge, Skills and Attitudes" descriptors; and (3) thematic terms linked to STEM, society, and environment, identified through keyword search and confirmed by contextual reading. The unit of analysis was the individual occurrence of each element within the document. No occurrence was counted more than once within the same descriptor, unless it was repeated across different domains. The two authors independently enumerated each category, and disagreements were resolved through discussion until consensus was reached.

A mixed-methods sequential design was adopted because the research questions require both the systematic mapping of linguistic and structural features across the two documents (quantitative phase) and the interpretative analysis of the meanings, contexts, and implications of those features (qualitative phase). The quantitative phase provides descriptive comparability, ensuring that patterns identified are grounded in the frequency and distribution of textual elements, while the qualitative phase enables depth and contextualisation of findings (Creswell & Plano Clark, 2018). This sequential integration is particularly appropriate for curriculum analysis, where counting occurrences of verbs, names, or thematic categories establishes an empirical basis for subsequent interpretive claims about epistemological and ideological orientations.

The corpus of analysis consists of two official documents from the Portuguese Ministry of Education, both published in August 2018, which define the ELs for the 12th-grade of the Scientific-

Humanistic Course in Science and Technology: ELs for Physics, 12th-grade and ELs for Chemistry, 12th-grade.

These documents were selected because they constitute the current curriculum framework, which guides the planning, implementation and assessment of learning, and because they have a comparable structure, allowing for systematic analysis across subjects. It should also be noted that the two subjects coexist independently only in the 12th-grade. The analysis was conducted in two stages. Stage one consisted of the exploratory reading of the documents to identify the general structure, the organising domains, the targeted competences, and the language used; Stage two aggregated analytical and comparative reading across several substages (Figure 1).

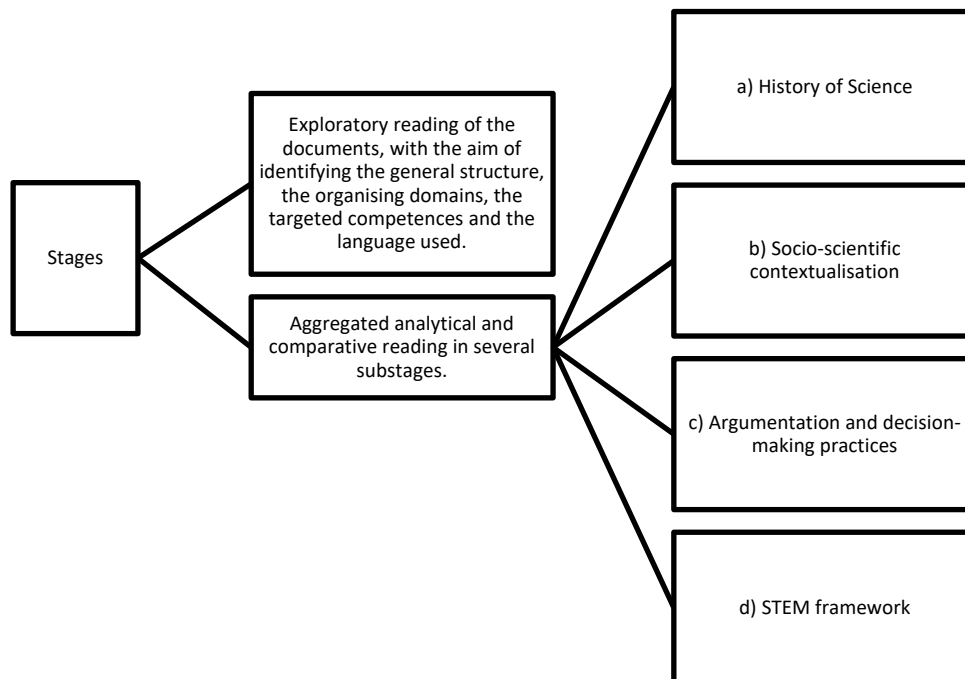


Figure 1 Methodological design.

Source: Self-elaboration.

In this first stage, the names of historical figures related to the history of science were collected. In a second stage, the verbs present in both documents were collected, in relation to the students' objectives. In the final stage, the various dimensions for text analysis were categorised: a) History of Science; b) Socioscientific contextualisation; c) Argumentation and decision-making practices; d) STEM framework; e) Representations of gender and diversity in science, as shown in Table 1.

Thematic coding was developed using the analytical categories previously defined within the study's theoretical framework, enabling the identification of convergences and divergences between the two disciplines. Finally, an interpretative analysis was carried out, linking the coding results to the literature to understand the curricular implications of ELs for pedagogical practices that are more or less inclusive from a gender perspective.

The qualitative phase drew on content analysis following Bardin (2024), structured around five analytical categories (Table 1). Category development followed a hybrid approach: categories were initially derived deductively from the theoretical framework (e.g., "gender and inclusion" from the literature on gender in STEM; "socioscientific dimension" from Sadler, 2004) and subsequently refined inductively through exploratory reading of the documents. Each category was defined by explicit descriptors of presence and absence, enabling consistent application across both texts (see Table 1). The relationship between categories and the construct of inclusion was theoretically grounded as follows: the History of Science category captures the extent to which scientific knowledge is presented as the product of diverse or homogeneous human agency; the socioscientific and argumentation categories assess the degree to which the curriculum opens spaces for students to engage with science as active, critical citizens; the STEM orientation category reflects the accessibility and contextualisation of scientific content; and the gender and inclusion category directly examines representational diversity. To ensure coding reliability, the three researchers independently coded 10% of the text segments. Disagreements were discussed and resolved through iterative negotiation, with the final codebook adjusted accordingly.

These categories enabled a cross-sectional and comparative analysis of the Physics and Chemistry ELs, ensuring consistency between the study objectives and the analysed data.

Table 1 – Categories of analysis

Categories	Description
History of Science	Explicit/implicit; personified/contextual.
Socioscientific dimension	Presence of social, environmental and ethical problems.
Scientific argumentation	Promotion of debate, justification and decision-making.
STEM orientation	Technocentric vs contextualised.
Gender and inclusion	Presence/absence of references to diversity, gender neutrality, and scope for inclusive practices.

Source: Self-elaboration.

4. RESULTS

A preliminary analysis of the two documents shows that both Physics and Chemistry cover three areas, which are respectively: Mechanics, Force Fields, Modern Physics, Metals and Metal Alloys, Fuels, Energy and the Environment, and Plastics, Glass and New Materials

Physics presents a nominal centralisation, anchoring knowledge in male historical figures. At the same time, Chemistry adopts a procedural and anonymous approach, focused on the evolution of materials and society (the evolution of knowledge in a non-personified way). The

Physics curriculum offers fewer entry points for inclusive approaches, though it does not explicitly prevent them.

Table 2 shows the frequency of explicit mentions of scientists' names in the descriptors of "Knowledge, Skills and Attitudes" (what the student should be able to do).

Table 2 - Frequency of Nominal References (History of Science).

Scientist's name	Frequency	
	Physics	Chemistry
Newton	2	0
Kepler	1	0
Planck	1	0
Einstein	1	0
Josef Stefan/ Ludwig Boltzmann/ Wilhelm Wien	1	0
Others	0	0
Total	6	0

Source: self-elaboration.

Table 3 shows the frequency with which certain action verbs appear in learning objectives to define the type of competence required.

Table 3 – Typology of verbs.

Action Verb	Physics	Chemistry
Apply (Resolution/Laws)	10	2
Interpret/Characterise	12	11
Investigate/Research	4	10
Argue/Debate/Discuss	0	4
Analyse/Justify	1	5

Source: self-elaboration.

Verbs such as 'debate' and 'argue' appear in the Strategic Actions for Physics, but they are not integrated into the direct objectives of what the student should be able to do, unlike in Chemistry. Chemistry favours higher-order skills related to scientific literacy (argumentation and research), while Physics maintains a strong focus on the technical and formal application of

models. It should be noted that in Physics, verbs such as 'argue/debate/discuss' have zero frequency.

To strengthen the analysis, Table 4 presents concrete examples extracted from the ELs that relate to the defined analytical categories.

Table 4 – Terms Related to STEM and Society.

Analytical Category	Examples in Physics (12 th -grade)	Examples in Chemistry (12 th -grade)
History of Science	Nominal and chronological references to figures such as Kepler and Newton in the study of gravitation, and Planck and Einstein in the genesis of quantum physics.	Integrated and implicit approach, focused on the use of metals throughout history and the evolution of chemical knowledge associated with social needs.
Socioscientific Dimension	Technical contextualisation through examples such as road safety (airbags), barometer function, and radon risks in buildings.	Focus on global dilemmas such as climate change caused by the oil industry, sustainability in the life cycle of materials, and the toxicity of metals.
Argumentation and Debate	Emphasis on problem solving, interpreting concepts, and applying laws and models to the analysis of natural phenomena.	Explicit promotion of skills to 'argue', 'debate' and 'discuss' controversial topics, such as biofuel production and oil recycling.
STEM Orientation	Technocentric perspective, focused on devices such as mass spectrometers and mathematical modelling of force fields.	Perspective of 'central' and applied science, interfacing with biology and engineering, focused on new materials, fuels, and polymers.
Gender and Inclusion	Scientific narrative personified exclusively in male models (7 male names cited).	An anonymous, procedural approach that, although it does not mention women scientists, offers greater neutrality and scope for inclusive contextualisation.

Source: self-elaboration.

The documents show that Chemistry has a much higher socioscientific thematic density, which provides more explicit curricular entry points for inclusive STEM education focused on citizenship.

5. DISCUSSION

A comparative analysis of the ELs Outcomes for Physics and Chemistry reveals that, although both documents share the Profile of Students Leaving Compulsory Education matrix and aim to develop scientific literacy skills, their pedagogical and epistemological operationalisations diverge substantially.

In the field of the History of Science, Physics adopts a markedly personified narrative, linking knowledge to canonical figures such as Newton, Kepler, Planck and Einstein. This approach, by anchoring scientific evolution in individual male geniuses, may textually reproduce an image of science as a domain of individual, exclusively male figures, hindering its perception

as a collective and diverse construction. In contrast, Chemistry presents a procedural and integrated history, focused on the evolution of the use of materials over time, without highlighting specific names, which gives it a neutrality that facilitates the social contextualisation of the discipline. Chemistry has a distinct epistemology from physics, operating with its own concepts (substance, molecular structure, synthesis, reactivity) and involving an intrinsic relationship between knowledge and experimental practice (Brenner & Gayon, 2009).

Concerning the socioscientific and argumentative dimensions, Chemistry plays a clear central role in discussions of environmental and ethical impacts. Chemistry ELs explicitly promote the use of scientific language to 'argue', 'debate' and 'discuss' controversial topics such as air pollution and sustainability in the life cycle of materials. On the other hand, Physics ELs, although they mention the consequences for society and the environment, tend to focus on interpreting 'technological devices' and the formal application of models and laws, resulting in a more technocentric approach.

About gender equality and inclusion, the analysis reveals a cross-cutting gap: the total absence of explicit references to women scientists or diversity in science in both reference frameworks. However, chemistry offers space for inclusive practices due to its emphasis on social contexts and the 'quality of life of citizens,' which allows teachers greater flexibility to integrate diverse perspectives. Physics, by maintaining a rigid conceptual structure anchored in historical male examples, poses greater challenges for deconstructing stereotypes, requiring a more pronounced pedagogical intention to become 'girl-friendly.' This finding aligns with Brotman and Moore's (2008) systematic review, which identifies curriculum and pedagogy as one of the key dimensions through which girls' engagement with science is shaped, arguing that curricular choices, including how scientific knowledge is narrated and contextualised, can either reproduce or challenge gender inequalities in science education

In this regard, it is worth citing Sin (2014), which analyses the relationship between epistemology, sociology and pedagogy in the teaching of physics, arguing that the subject has traditionally been taught within a positivist epistemology that emphasises objectivity, universality and the cumulative nature of scientific knowledge. This approach presents physics as a body of consolidated laws and theories, often dissociated from the social and historical processes of its construction. The article also highlights a gap between actual scientific practice, characterised by uncertainty, controversy and the collective construction of knowledge, and the way physics is taught, which tends to obscure the human and social dimensions of science. As a result, students are exposed to a decontextualised view of physics, focused on the end products of scientific knowledge, to the detriment of understanding the processes of production, validation and negotiation of scientific knowledge.

Finally, it should be noted that reproducing a physics curriculum designed in the post-war period (1950s) during the space race suggests that Newtonian mechanics is overrepresented and may not allow for an understanding of the nature of science, according to van der Veen (2012). This author points out that physics is taught, for the most part, with an excessive focus on Newtonian mechanics, which emphasises topics such as projectiles and explosions, traditionally more appealing to boys. Francis et al. (2017) suggest that girls often perceive school physics as abstract, outdated, and disconnected from real-world relevance, contributing to lower levels of identification with the subject and persistent gender inequalities in participation. Another aspect to consider is the low representation of modern physics, relegated to the last domain. Specifically,

according to Johansson et al. (2018), quantum physics is presented as a domain that challenges classical conceptions of objectivity, determinism and neutrality in scientific knowledge, emphasising the role of models, interpretation and the limits of scientific knowledge. These characteristics have been pointed out in the scientific education literature as potentially favourable to more inclusive approaches to physics teaching, suggesting that quantum physics could be a fertile context for exploring strategies to reduce the gender gap.

Based on the analysis, a critical reading of the ELs proposed in this study can serve as a pedagogical reflection tool for physics and chemistry teachers, showing that curriculum documents, although formally neutral, contain epistemological and narrative choices that shape how science is presented to students. By recognising the differences identified between the two disciplines, namely in the degree of socioscientific contextualisation, the centrality of argumentation and the personification of the history of science, teachers can make more informed decisions when planning their practices, compensating for any gaps in the curriculum by intentionally selecting examples, contexts, and teaching strategies that promote a sense of belonging and participation among all students.

In educational terms, the results suggest that, in teaching physics, teachers can benefit from greater integration of socioscientific contexts, debate activities and open-ended problem situations that transcend the formal application of models, bringing the subject closer to issues relevant to scientific citizenship. The deliberate introduction of more diverse historical narratives, as well as the valorisation of domains such as Modern Physics as spaces for epistemological questioning, can contribute to a more human and inclusive image of Physics. In the case of Chemistry, teachers have a frame of reference that already favours argumentation and the connection between science, technology and society, and can further this potential through practices that explore ethical, environmental and social dilemmas, reinforcing scientific literacy and equity in access to STEM knowledge.

6. CONCLUSIONS

This study provides three main contributions. First, it offers a systematic, document-based comparison of the 12th-grade Physics and Chemistry Essential Learning in Portugal, demonstrating empirically that the two curricula diverge in their epistemological orientations: Physics relies on nominal, decontextualised, and formalised scientific knowledge, while Chemistry foregrounds socioscientific contextualisation and argumentation. Second, it operationalises a multi-category analytical framework that can be applied to other curriculum documents to assess their inclusive potential. Third, it shows that normative neutrality, the absence of explicit exclusionary content, is insufficient to ensure equitable science education, and that the curricular choices embedded in official documents shape conditions of belonging and identification with science, particularly along gender lines.

Chemistry appears to be closer to the ideals of citizenship and sustainability, while Physics maintains a matrix that, although rigorous, lacks a more human and diverse representation of scientific production. Possibly, the conceptual structure of physics, marked by the centrality of universal laws and well-defined paradigm shifts, favours a more personalised historical and didactic narrative, in contrast to chemistry, whose development is more cumulative and systematic.

In addition to the empirical analysis of EL, this study contributes to the discussion on the role of the curriculum as a space for the materialisation of epistemological and cultural options that influence inclusion in science education. By highlighting systematic differences between Physics and Chemistry in how scientific knowledge is narrated, contextualised, and operationalised, this work reinforces the idea that gender equity in STEM does not depend solely on explicit curriculum reforms but also on how existing references are interpreted, mediated, and translated into pedagogical and editorial practices. Thus, rather than introducing new content, it is essential to rethink the science narratives privileged in pre-university education, when students make their career choices, recognising that inclusion is an active process, anchored in conscious didactic, epistemological, and cultural choices. In short, for STEM education's potential to be fully realised in a more equitable sense, textbook authors and teachers must use curricular flexibility to address the identified gaps in representation. It is recommended that future research analyse how these guidelines are translated into classroom practices and whether school textbooks perpetuate the invisibility of women and the technocentric view discussed here.

7. IMPLICATIONS

Given the analysis of ELs and their articulation with the Student Profile, it is imperative to plan future revisions to these normative documents and to examine the mediating role of school textbooks in promoting equity in STEM.

Concerning the future restructuring of the EL, it is imperative to overcome formal neutrality, which, although it does not impose direct restrictions, proves insufficient to mitigate historically consolidated gender stereotypes and images of science. Specifically in Physics, future references should seek to diversify the historical narrative, transcending the current nominal centrality of canonical male figures such as Newton, Kepler, Planck, and Einstein. This revision should aim to explicitly include female contributions and diverse scientific paths, humanising the construction of knowledge.

At the same time, it is suggested that Physics adopt a matrix closer to Chemistry in terms of socioscientific argumentation. While Chemistry already operationalises the debate on sustainability and environmental impacts as a structuring component, Physics would benefit from descriptors that encourage ethical and social decision-making in the face of technological development, rather than merely the formal validation of models and laws. In short, future science education should evolve from passive neutrality to active inclusion, integrating reflection on 'who does science' as an integral part of scientific literacy.

The persistence of decontextualised views of science in secondary education often results from editorial and cultural choices, rather than formal curricular impediments. The next generation of school textbooks should therefore serve as an instrument of social justice, translating the potential of science education into pedagogical practices that are effectively inclusive and representative of the diversity of the STEM domain.

Finally, it will be important to triangulate the data from this study with future editorial decisions. Some historically rooted ideas may explain the bias, rather than any formal curricular constraints.

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