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Sustainable Development and Soils in the Portuguese Education System: Open Problems and Further Challenges

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Abstract: The curricular documents for Basic Education Sciences in Portuguese schools (ages 6 to 15) that currently affect teachers and students across the world integrate Sustainable Development concerns regarding soils. A sharp gap emerges between the official documents and the teachers' perceptions of how to approach such issues. Urgent measures are required to bridge both worlds: reformulations of the official documents that guide teachers' practices and educational resources focused on soils from a Sustainable Development perspective. A new organization of the curricular documents for this theme that aims to promote quality education among Portuguese Basic Education schools worldwide is proposed.

Keywords: Sustainable Development Goals 2030; soils; Portuguese Science Curriculum of Basic Education; geoscience education; science teachers

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1. Introduction

In 2015, the United Nations [1] established the Sustainable Development Goals (SDGs) with the purpose of creating achievable goals by 2030, aiming to improve quality of life and safeguard the planet. This vision of the future reflects concerns about the various challenges that societies face, which result from a growing imbalance between what citizens need and the resources available on Earth. As so, radical changes in citizens' unsustainable consumption rates are required to mitigate current problems affecting society, namely those emerging from the fragility of the physical environment [2]. To this end, it is essential to promote an education that encourages the integration of all knowledge in inter- and transdisciplinary approaches, which demands overcoming the traditionally established gap between the natural and the human and social sciences and integrating natural and social and humanistic scientific knowledge with non-scientific and non-Western forms of knowledge [3].

The conservation of Earth's resources for future generations is everyone's responsibility and imposes new challenges for all sectors of society (politicians, businessmen, educators, media), including the geoscientists, as their activity is focused on the production and use of geoscience knowledge [2,4].

The role of geosciences in achieving SDGs is widely recognized, namely in areas such as agrogeology (where SDGs 1, 2, 3 and 15 can be enhanced), climate change (that meets SDGs 1, 2, 11, 13 and 14), geological hazards (that promotes SDGs 1, 2, 11 and 13), or hydrogeology (that relates to SDGs 1, 2, 3, 6, 11, 12, 13, 14 and 15) [5]. To this end, the development of specific skills in geosciences education is particularly important, such as practical work, whether in the laboratory or in the field. However, the role of geosciences can be extended to other less obvious domains that are the target of the 2030 Agenda, such as achieving gender equality and empowering all women and girls at all levels of

decision making, which is the aim of the 5th goal of the 2030 Agenda [6], or to provide teaching resources regarding fieldwork activities [7] in geoconservation studies to assist geoeducation practices (e.g., [8,9]), therefore meeting the 8th, 11th and 12th goals of the 2030 Agenda [5].

However, there is a lack of recognition of the role of geosciences in achieving these and other SDGs, one of the explanations being that, in most countries, there is no commitment to this area of knowledge in school curricula [10]. Another recognized justification is the worrying underrepresentation of geologists in scientific publications on sustainability [11]. As a way of overcoming these constraints, Stewart and Gill [12] suggest, "Firstly, our geoscience community needs to substantially broaden its experience. And secondly, we need to explicitly integrate "sustainability" into geoscience education, training and continued professional development" (p. 167).

The current organization of the Portuguese education system covers pre-school education and 12 years of schooling. It includes 9 years corresponding to three cycles of Basic Education (the 1st cycle is 4 years, i.e., ages 6 to 10; the 2nd cycle is 2 years, i.e., ages 10 to 12; and the 3rd cycle is 3 years, i.e., ages 12 to 15) and three years of Secondary Education (ages 15 to 18). In the 1st cycle, the teaching of geology is dispersed in other areas of knowledge (i.e., biology, physics, history) in the subject of Environmental Studies. In the 2nd and 3rd cycles of General Basic Education, geology is included within the discipline of Natural Sciences with Biology themes. In secondary education in the Scientific Area, in the first two years, the subject is called Biology and Geology, with an equitable division of topics in the two areas per academic year. In the third year of secondary education, Geology is an independent discipline, but it is optional [8].

The organization of the Portuguese education system decisively influences not only school communities in Portugal but also those that are guided by the same curriculum in Portuguese-speaking countries spread across Africa, Asia and Oceania [13–16]. The Network of Portuguese School in Portugal during the academic year 2020/2021 involved a total of 147,041 teachers and 1,595,312 students, and the Network of Portuguese Schools Abroad involved a total of 925 teachers and 10,525 students (Figure 1).

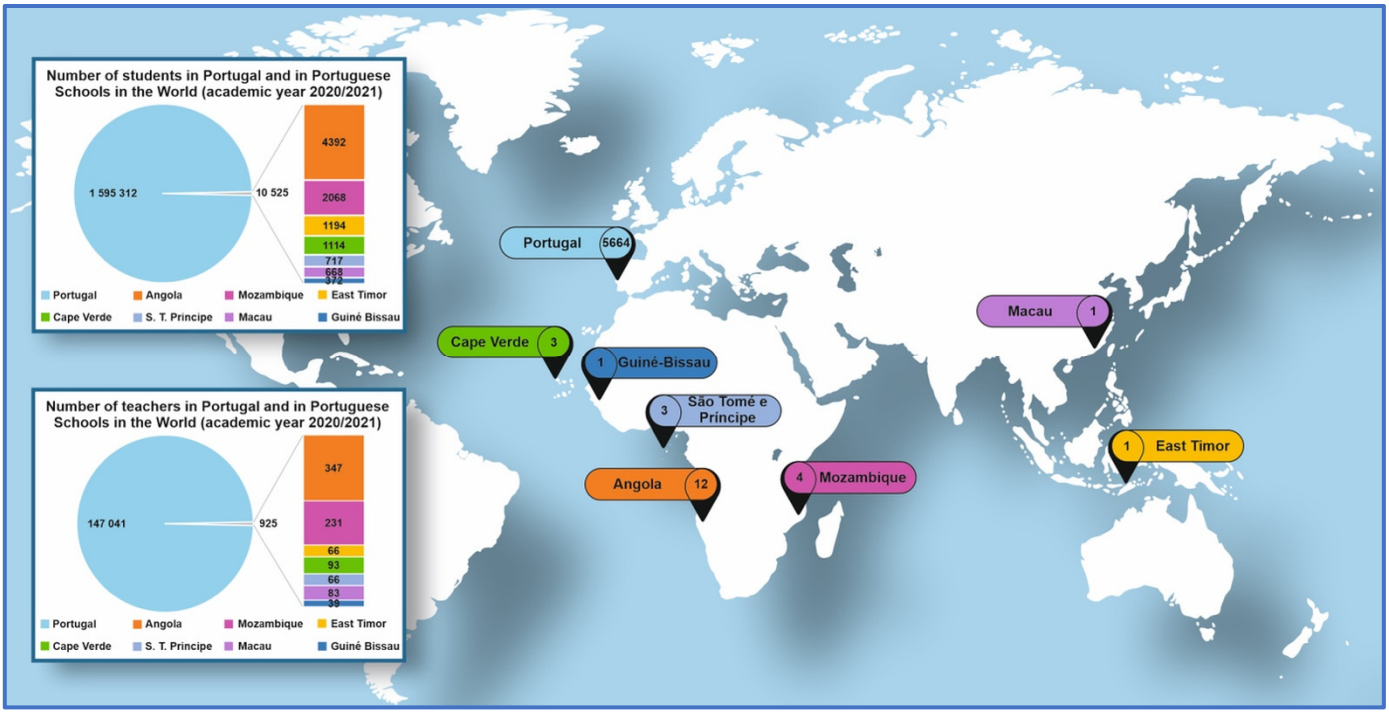

Figure 1. Number of schools, students and teachers during the academic year 2020/2021 involved in the Network of Portuguese School in Portugal and abroad. São Tomé and Príncipe: Saint Thomas and Prince.

The United Nations General Assembly voted unanimously to approve 2008 as the International Year of Planet Earth (IYPE) framed within the United Nations Decade for Education for Sustainable Development (2005–2014). The IYPE aimed to build on the existing knowledge of some half a million Earth scientists all over the world and make it more available for the improvement of everyday life, as expressed in the Year's subtitle: Earth Sciences for Society. "Soil: Earth's living skin" was among the scientific themes selected for the IYPE, and promoting sustainable extraction of Earth's resources was among the range of the initiative's objectives [17,18]. In fact, the thematic "soil" is one of the geosciences issues that provide close relationships with the 2030 Agenda and, according to Lal et al. [19], its sustainable use is critical to meet several SDGs. Table 1 suggests several examples that show how learning about soils can contribute to achieving different SDGs.

Table 1. Examples that express how learning about soils can contribute to achieving different SDGs (adapted from [19]).

SDGs	Goal	How Developing the Theme "Soils" Can Promote the Achievement of SDGs
1	No poverty	• Depending on the characteristics of each region, sustainable soil management and improved agricultural exploitation can be key factors in eliminating poverty.
2	Zero hunger	• Sustainable soil management is fundamental to achieve SDG2, thus mitigating one of humanity's greatest enemies (hunger), currently exacerbated by the COVID-19 pandemic.
3	Good health and well-being	• Healthy soils generate healthy crops which, in turn, nourish the animals, enabling their health and productivity. • Soils can also indirectly contribute to well-being and health, as they are important in creating medicines, filtering water, providing shelter, creating clothes, forming fuel...
4	Quality education	• Soil education can contribute considerably to improve the quality of education due to its holistic and interdisciplinary character. • Curriculum changes should incorporate dimensions that aim to increase awareness about soils, i.e., to educate and communicate about soils to promote quality education, in an integrated approach to face environmental problems. • The relationship between soil and its role in food security, women's empowerment and environmental sustainability (SDGs 2, 5 and 15) are important themes for students to explore in a school context, thus promoting work capacity, leadership, collaboration and inclusiveness.
5	Gender equality	• Equal opportunities are sought for women in soil sciences, which continue to be few in this area (and others), namely in the composition of editorial boards of journals and funding panels, in the leadership of conferences, . . .
6	Clean water and sanitation	• Soils play an important role in the circulation, storage and transformation of water and influence the quality and availability of water supply. • For example, unsustainable agricultural practices imply less soil organic matter, facilitating the transfer of pollutants to groundwater and causing problems in water quality.
9	Industry, Innovation and Infrastructure	• Promote local soil-based food production and appropriate and sustainable strategies, thus reducing, for example, dependence on food imports. • A stable soil with a high infiltration capacity can decrease the rate of surface runoff and keep soil particles together, reducing sediment loads in the runoff, which can help, for example, in reducing the accumulation of sediments in channels and dams. • It is important to know how soils are handled, stored and reused in construction projects, always encouraging best practices promotion.
11	Sustainable cities and communities	• Urban development affects local soils in terms of sealing, densification, excavation and pollution. The original soils are highly impacted and are partially eliminated or mixed. • Possible solutions include urban gardening or vertical gardening. Lately, with the COVID-19 pandemic, awareness of the positive effects of gardening and agriculture in urban contexts has increased considerably. • Additionally, the production, management and potential recycling of urban waste are important issues for the sustainability of cities, as the organic fraction of urban waste could (and should) be conveniently treated and recycled through composting, to later be used in agricultural soils.

Table 1. *Cont.*

SDGs	Goal	How Developing the Theme "Soils" Can Promote the Achievement of SDGs
12	Responsible consumption and production	• Learning from small-scale farming methods, enhancing the sustainable use of soils and scientific knowledge of sustainable food systems. • Food production in local food chains fosters a local circular economy and reduces the associated pollution. • The need to produce animal products (meat, dairy products) compared to plant production requires changes in the human diet, namely more plant-based consumption.
13	Climate action	• Climate change has a major impact on soils and vice versa. Therefore, sustainable land management is essential so that we can face a climate crisis and produce enough food while adapting to a changing climate.
15	Life on land	• It is intended to promote the sustainable use of terrestrial ecosystems, reverse soil degradation affected by desertification, drought and floods, and mitigate the loss of biodiversity, thus achieving neutrality of soil degradation and benefiting our own survival.
16	Peace, justice and strong institutions	• Fertile and productive soil plays an important role in establishing food security. • A safe and healthy agricultural sector plays a vital role in preventing conflicts and migration and, ultimately, building peace and stability. • Soil science also assists in the characterization of illegal environmental deposits with toxic residues and environmental contaminants. • Deep cooperation in criminal justice can reduce corruption and bribery, associated, for example, with illegal trade in geological resources.

All these examples of articulations between the theme "soils" and the SDGs imply the need for collaboration between professionals from various sectors, namely, politicians, engineers, researchers, technicians, and other professionals in areas related to soil (directly or indirectly), in addition to teachers.

The present study aims to characterize the approach to the theme "soils" in Portuguese schools, considering the SDGs of the 2030 Agenda. To this end, the framework of the curricular documents of the Sciences of Basic Education was analyzed, as well as the perceptions of a group of science teachers of Basic Education (from 6 to 15 years old) about these curricular documents and about their educational practices. Suggestions are also presented that aim at a better adaptation of the contents and the organization of the Essential Learning documents for Basic Education in the approach of the theme "soils" in a Sustainable Development (SD) perspective.

2. Methodology

The accomplishment of the present investigation was based on two methodologies aimed at: (1) verifying whether the curricular documents of Sciences for Basic Education in Portuguese schools (ages 6 to 15) present guidelines to develop themes related to soils that promote SDGs; (2) analyzing science teachers' perceptions about their practices and the approach to the theme "soils" from an SD perspective.

2.1. Methodology for the Analysis of Curriculum Documents

This investigation fits into the interpretive paradigm with a qualitative approach to the study subject [20,21]. It followed a descriptive-interpretative strategy of an exploratory nature [20], privileging the content analysis [22] of the documents that constituted the corpus of analysis.

In this research, a content analysis was carried out on the curriculum documents of Sciences for Basic Education in Portuguese schools. The pre-defined categories, understood as rubrics with specific meanings according to which the corpus was classified by the researchers [23], allowed us to situate the apprehension of the object of analysis and make it relevant in relation to its objectives [20]. These categories resulted from a theoretical framework based on the proposal by Lal et al. [19], which is presented in Table 1. Table 2

shows the relationship between the SDGs and the category that will be considered for this analysis and the respective coding.

Table 2. Definition of the categories of the analysis instrument used in the present study. The relationship between soils and SDGs was established according to Lal et al. [19].

SDG's	Category	Codification
1	No poverty	C1
2	Zero hunger	C2
3	Good health and well-being	C3
4	Quality education	C4
5	Gender equality	C5
6	Clean water and sanitation	C6
9	Industry, Innovation and Infrastructure	C7
11	Sustainable cities and communities	C8
12	Responsible consumption and production	C9
13	Climate action	C10
15	Life on land	C11
16	Peace, justice and strong institutions	C12

The analysis instrument used was designed and adapted for documents with specific characteristics (curricular and transversal). Thus, the proposed analysis/categorization reflects the researcher's experience as a teacher, namely in the correlations she establishes when interpreting these documents, which may be questionable for other researchers.

The collected corpus consists of official curricular documents for science subjects in Basic Education, as well as two documents considered transversal to different subjects, but which are deemed crucial to understand the DS concept (Table 3).

Table 3. List of eleven documents of the corpus by cycles of Basic Education, subjects, grade and respective bibliographic references.

Documents	Cycle	Science Subjects	Schooling Grade
Essential Learning	1st (ages 6 to 10)	Environmental Studies	First [24]
			Second [25]
			Third [26]
			Fourth [27]
	2nd (ages 11 to 12)	Natural Sciences	Fifth [28]
			Sixth [29]
	3rd (ages 13 to 15)	Natural Sciences	Seventh [30]
			Eighth [31]
			Ninth [32]
Student's Profile by the End of Compulsory Schooling	1st, 2nd and 3rd (ages 6 to 15)	Transversal	First to ninth [33]
Referential Environmental Education for Sustainability	1st, 2nd and 3rd (ages 6 to 15)	Transversal	First to ninth [34]

After all the categorization of these documents, the analysis was validated by three specialists in different but converging areas (Science Education, Geology and SD), because "with the help of experts, the researcher confronts whether his categories of analysis may represent (or not) aspects of a theory or topic he intends to investigate" [21] (p. 222). This

validation resulted in minor adjustments to the categorization already included in the results presented in Section 3.1.

In the following subsections, the analysis methodology adopted will be described per document.

2.1.1. Essential Learning

The *Essential Learning* documents are organized by subjects and schooling grades (Table 3). Taking into account the twelve categories of the analysis instrument (Table 2) used to categorize the corpus, the evidence related to soils in the Geosciences Topics of these documents was grouped. Section 3.1.1 presents the results of this analysis, as well as its discussion, also considering the SDGs to which they are related.

2.1.2. Student's Profile by the End of Compulsory Schooling

This document is described "as a reference document for the organization of the entire education system, contributing to the convergence and articulation of decisions inherent to the various dimensions of curriculum development" [33] (p. 8). It defines Principles, Vision, Values and Areas of Competence that are intended to be developed throughout the 12 years of compulsory education.

"Sustainability" is defined as one of the eight guiding principles, and "one of the greatest existential challenges of the contemporary world, which consists of establishing, through political, ethical and scientific innovation, lasting and safe synergy and symbiosis relationships between social, economic and technological systems and the Earth System, on whose fragile and complex balance the historical continuity of human civilization depends" [33] (p. 14). The results of this analysis are presented in Section 3.1.2.

2.1.3. Referential Environmental Education for Sustainability

This document is part of the set of references prepared by the General Directorate of Education in the context of Education for Citizenship, aiming to guide the implementation of sustainability within the curriculum in the different teaching cycles. Thus, this categorization was made by the teaching cycle.

The document is organized by themes, sub-themes and objectives. In this work, what was categorized was Table III of this document [34] (pp. 16–19), where the themes, sub-themes and objectives by teaching cycle appear; the themes related to "soils" were identified in the geoscience topics. Only the organizing table of the topics covered in this document was analyzed, highlighting the references that can be included in the categories of analysis that were established in Table 4. Section 3.1.3 presents the results of this analysis, as well as its discussion, also considering the SDGs with which they can be related.

Table 4. Number of references by category of the *Essential Learning* documents.

Categories	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	TOTAL
Number of references	2	2	11	37	0	9	12	11	9	4	28	3	128

2.2. Methodology for Analysis of the Perceptions of Teachers on Teaching Practices

This investigation used a quantitative approach, with statistical analyses being carried out on the collected data. A search was made using a questionnaire that was applied to 14 teachers from a group of schools in central Portugal, who were selected because they were interested in attending an in-service teacher education on Geoscience Didactics. The design and validation of this questionnaire were included in João et al. [35]. This questionnaire consists of two parts: one regarding the teachers' characterization and another that assesses the teachers' perceptions about their educational practices in the development of geology themes, namely from an SD perspective. The group of teachers answered the questionnaire before starting an in-service teacher education program on

Geoscience Didactics designed to overcome teachers' needs as a result of the research outputs presented in the following section.

3. Results

This section reports the results of the Analysis of Curriculum Documents (Section 3.1) and the Analysis of perceptions of teachers on teaching practices (Section 3.2) regarding the approach to the theme "soils" in the Portuguese education system, taking the SDGs of the 2030 Agenda into account.

3.1. Analysis of Curriculum Documents

In the following subsections, the results of the analysis are presented for each type of curriculum document.

3.1.1. Essential Learning

The *Essential Learning* documents were analyzed by school grade, identifying the references related to each of the defined categories. Table 4 shows the number of references identified by category, and the graph in Figure 2 represents the number of references by category and by school grade.

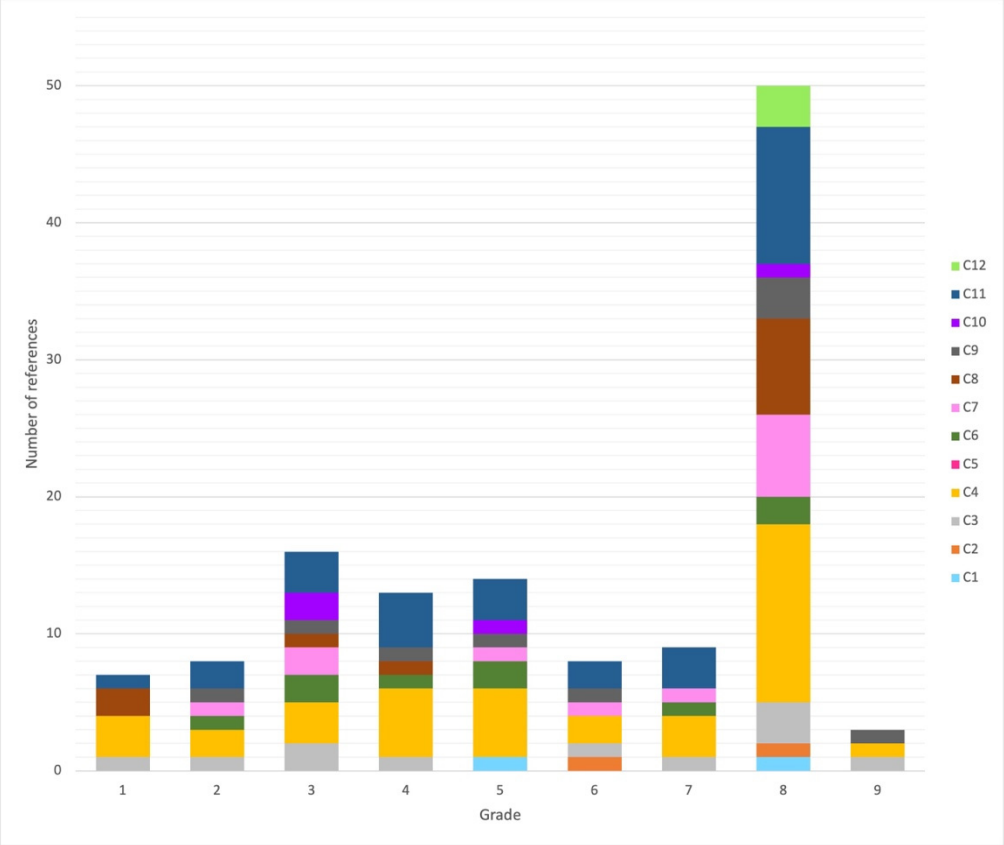

Figure 2. Number of references by category and by school grade of the *Essential Learning* documents.

Category C4 "Quality education" stands out with 37 references, as it was considered that all references identified relating the soil to the SDG's contribute to the promotion of quality education. Regarding all these references, which are important topics for students to explore in a school context, they show that: or they are presented with a holistic and interdisciplinary character; and/or they promote soil awareness, as well as soil education and communication, in an integrated approach to environmental problems; and/or they emphasize the relationship between soil and its role in food security.

The second category with the highest number of references (28) is C11, "Life on land," as the theme "soils" often arises from the need to reverse its degradation, minimize desertification and face drought, and from the implications that those phenomena have on ecosystems balance and biodiversity conservation. For example, the *Essential Learning* document for the 8th grade refers "Critically analyze the role of rocks and soil in the existence of life in the terrestrial environment and of the subsystems in the maintenance of life" [31] (p. 8). Category C5 "Gender equality" is the only category among these documents that does not have any reference associated with the theme "soils".

Of the 128 categorized references, most are concentrated in the 8th grade, and this fact may be associated with the themes of this school grade, in which the promotion of sustainability on Earth planet is clearly highlighted. It should be noted that category C4 "Quality education" is the one that has references in all analyzed school years. Categories C3 "Good health and well-being" and C11 "Life on land" have references in eight of the nine schooling grades under study. The 9th grade displays the lowest number of references, only three. Most schooling grades have references in different categories of analysis, which shows how easily the theme "soils" from a DS perspective can be approached in different ways by relating it to different areas, namely agriculture, health, infrastructure, water, biodiversity and justice.

3.1.2. Student's Profile by the End of Compulsory Schooling

The *Student's Profile by the End of Compulsory Schooling* document, which supports all curriculum documents, is organized into eight guiding principles, one of which is sustainability. Thus, as this document is articulated with the *Essential Learning* document, sustainability is considered a principle that cuts across all themes.

3.1.3. Referential Environmental Education for Sustainability

Figure 3 represents the number of references per analysis category in each cycle of Basic Education recognized from the analysis of the *Referential Environmental Education for Sustainability* document. In a total of 245 references, all categories have references in this document, but the highest number of references (83) is in the 3rd Cycle of Basic Education.

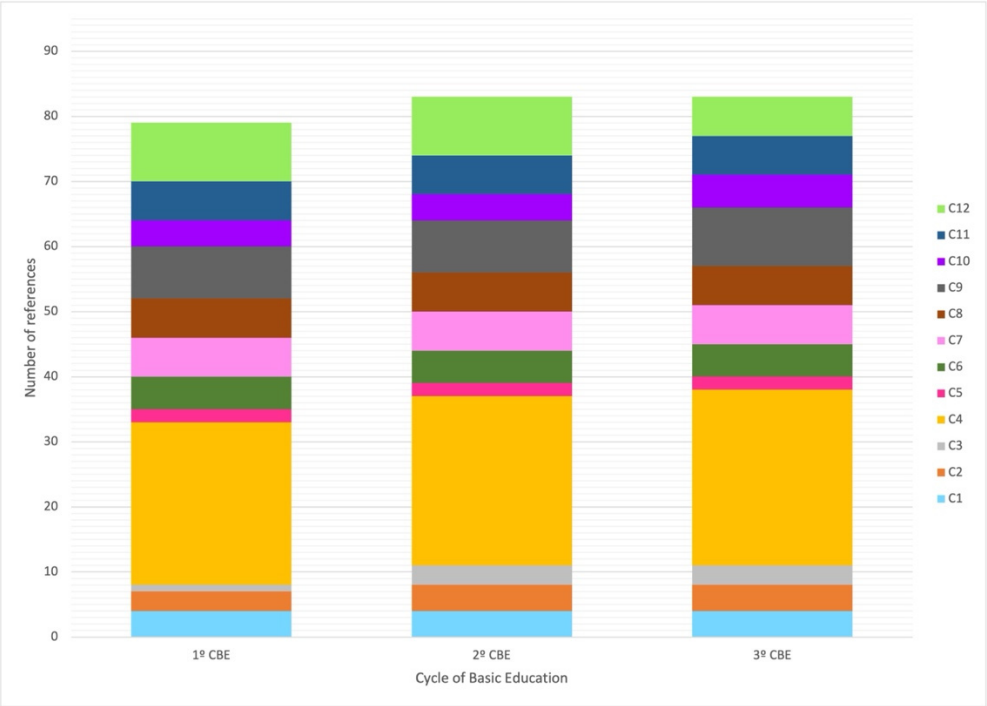

Figure 3. Number of references by category and by cycle represented in the *Referential Environmental Education for Sustainability* document.

The category that displays the highest number of references throughout Basic Education is C4 "Quality Education," as once again it was considered that all references promote this SDG.

3.2. Analysis of Perceptions of Teachers on Teaching Practices

The 14 teachers involved in this analysis have a permanent contract with the same school cluster and have more than 25 years of practice (6 between 25 and 29 years, 4 from 30 to 34 years, and 4 from 35 to 40 years). With regard to their academic profile, Table 5 shows the number of teachers by teaching cycle with a Primary Teaching Course + Complementary Training, Graduation and Master degrees.

Table 5. Academic profile of the teachers participating in the study by teaching cycle of Basic Education.

1st Cycle			2nd Cycle	3rd Cycle	
Primary Teaching Course	Complementary Training	Master Degree	Graduation Degree	Graduation Degree	Master Degree
6	5	1	5	3	1

The preservice teacher education of the 1st Cycle of Basic Education is generalist, including several subjects that cover different knowledge areas. Regarding the 8 teachers of the 2nd and 3rd Cycles, who teach Biology and Geology contents, 4 have preservice teacher education only in Biology, 3 only in Geology and 1 in Natural Sciences (Biology and Geology).

The results related to teachers' perceptions of their educational practices are described in the following subsections. They are presented in accordance with three different dimensions: "Actions/valences that they consider as facilitators for science education" (3.2.1); "Strategies/activities they adopt to teach geoscience topics" (3.2.2); and "Constraints they identify to teach geoscience topics" (3.2.3).

3.2.1. Actions/Valences Considered as Facilitators for Science Education

The teachers considered almost all actions/valences presented as important or very important in promoting science education (Figure 4). The actions/valences to be implemented/to have in science classes that all teachers considered "Very important" for the training of young citizens are: (i) "Include practical science activities in all teaching cycles"; (ii) "Explore the importance of scientific literacy in everyday life"; (iii) "Teaching science using active teaching and learning strategies (teaching by research, by projects...)"; (iv) Address science topics provided in the curricular guidelines from a perspective of promoting sustainable development".

Thirteen of the fourteen also consider as "Very important": (i) "Having science resources and equipment in schools (lab material, teaching kits...)," (ii) "Having a science laboratory at school since the 1st Cycle of Basic Education," (iii) "Show the useful/practical nature of science contents," and (iv) "Identify and explore the presence of S&T in the different dimensions of students' daily lives, namely at home (e.g., reading labels), in health (e.g., more effective drugs), in the media (e.g., computer; mobile phone)".

On the contrary, the action that is classified by more teachers (two) as "Nothing/Little important" was "Stimulating meetings between researchers and the educational community." Moreover, the action "Start science education from the earliest years" was classified as "Not at all/Little important" by one of the teachers.

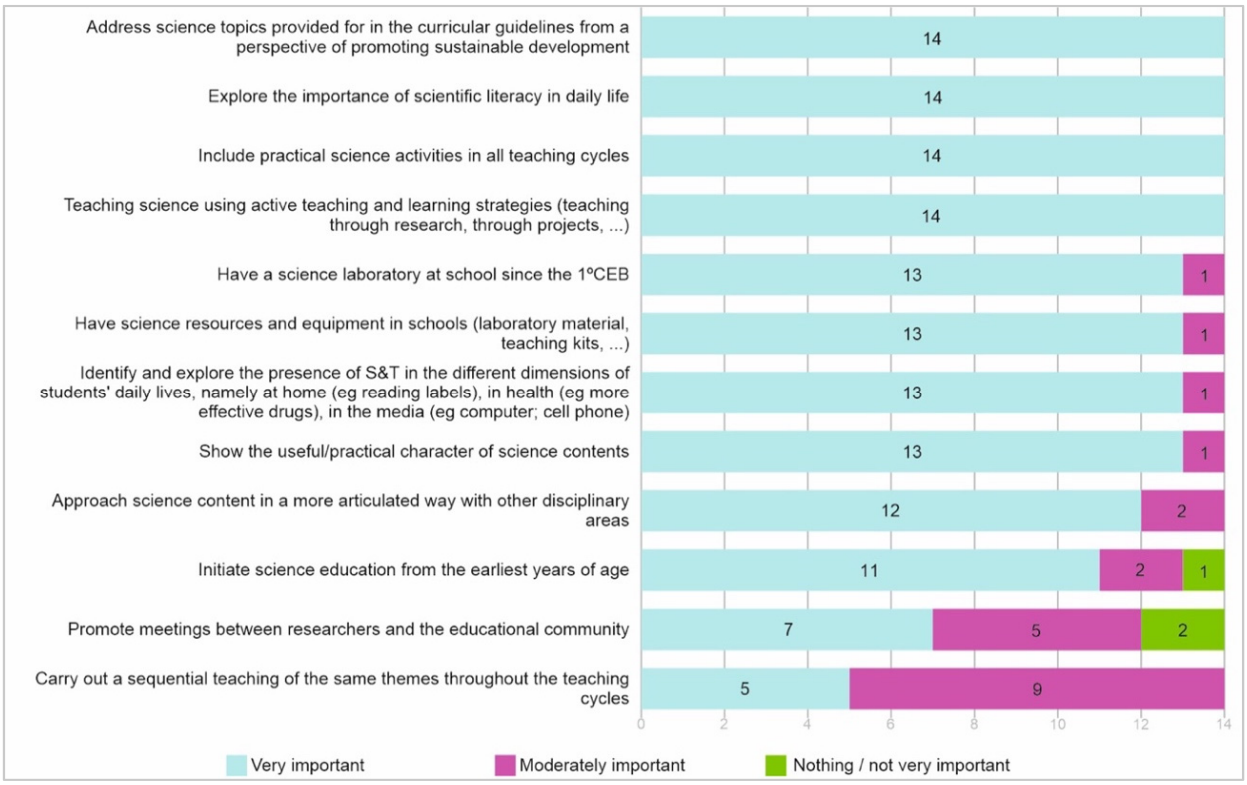

Figure 4. Classification by teachers of each of the actions/valences presented for the promotion of science education.

It is also worth noting the actions considered "Moderately Important" by more teachers (five): (i) "Conduct a sequential teaching of the same topics throughout the teaching cycles" and (ii) "Promote meetings between researchers and the educational community." The issue regarding the relevance of promoting the sequential teaching of the same themes throughout the different teaching years/cycles is highlighted because, although all teachers consider it as "moderately important" (five) or "very important" (nine), in another questionnaire, three teachers admitted that they do not consider this concern (Figure 5).

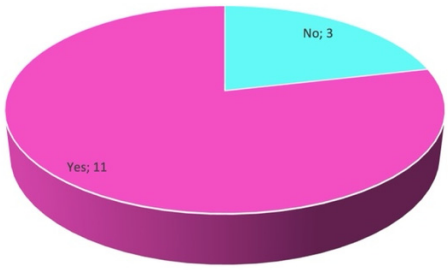

Figure 5. Teachers' perceptions of the need to promote sequential teaching of the same theme throughout the different teaching years/cycles.

Eleven teachers mentioned that when planning their classes, they consider whether students have already addressed the same topics in previous years and if/how they will address them in later years. Of these eleven, the majority (seven) claim that they seek to analyze "(. . .) the official documents of the other schooling grades of the same education cycle." In relation to the other grades of other teaching cycles, fewer teachers referred to this analysis, only three. Some even mentioned that they met with colleagues from the same cycle who teach different grades (four) and only two with colleagues from other cycles.

It should also be noted that all the teachers considered "Very important" "To approach science topics provided in the curricular guidelines in a perspective of promoting sus-

tainable development." Given the importance, it was deemed necessary to deepen the understanding that teachers have about the SD dimensions through the type of relationships that they establish between the environmental, economic and social dimensions of SD and the theme "soils" (Figure 6).

Figure 6. Themes inherent to the three dimensions of sustainability with which teachers established a relationship with the theme "soils" (adapted from [36]).

All teachers related the theme "soils" to the environmental dimension of SD (14 to "Natural resources—exploitation and consumption"; 13 to "Risks and consequences of the use of natural resources"). Still in the environmental dimension, the category "Social and ethical issues in STSE" was mentioned by only one teacher, while the category "World human population" was mentioned by only two teachers. The four categories that no teacher related to the theme "soils" are all included in the social dimension. Moreover, the remaining categories of this dimension have little expressiveness. The economic dimension of the "soils" theme is recognized by some teachers but less frequently than the environmental one.

3.2.2. Adopted Strategies/Activities to Teach Geoscience Topics

Figure 7 shows the implementation frequency of strategies/activities to teach geoscience topics in teachers' practices. All teachers reported that they frequently adopted two of the strategies/activities presented: the "Exploration of the themes relating them to the daily lives of the students" and the "Resolution of exercises from the manuals by the students, which are later revised in the class group." Also, all teachers say that they often or sometimes adopt the "Elaboration of concept maps with students," the "Exploration of PowerPoint® presentations," the "Exploration of the textbook (e.g., reading aloud, underlining parts of the textbook...)," the "Survey of the students' previous ideas about the curricular themes before starting their exploration," and the "Conducting of practical experimental activities by the teacher for the students to see".

On the other hand, the strategies/activities that most teachers admit they do not adopt (not once) are "Exploration of digital resources (e.g., sensors, mobile applications—APP...)," "Organization of visits by researchers/specialists for dialogue and/or development of some activity," and "Participation with students in contests and/or meetings and/or science seminars." Also noteworthy is the strategy/activity "Exploration of themes from a sustainable development perspective," which twelve teachers admit to frequently use, one a few times and another says never to do so.

It should be added that three teachers mentioned that they adopted other strategies/activities not referred to in the presented list of statements. Two did not specify which ones, and one added that he sometimes guides research work about a certain theme with a subsequent presentation of the results by the students to the class.

3.2.3. Identified Constraints in Teaching Geoscience Topics

Figure 8 shows the opinion of teachers in relation to a list of statements (adapted from [37]), which are presented as possible constraints for the teaching of geoscience topics (rocks, minerals, soils, earthquakes, volcanoes, fossils...).

All the statements/constraints presented were recognized by some teachers. Eleven of the fourteen teachers surveyed agreed that "The number of students per class sometimes makes it difficult to carry out practical activities," and ten teachers agreed that "The lack of laboratory technicians greatly limits the performance of practical activities, namely geosciences," "The carrying out of fieldtrips has logistical and financial constraints," and "Laboratories do not have adequate resources to carry out practical geoscience activities." Half of the teachers (seven) agreed that "The lack of supporting documents/guides/guidelines for the teacher makes it difficult to carry out practical activities on geoscience topics." In the context of this work, it is also worth noting that five teachers agreed that "The exploration of geoscience themes in the context of Sustainable Development implies more work for the teacher, in the planning and definition of teaching resources to be used" and three understood that "The preparation of geosciences themes from a perspective of Education for Sustainable Development is not part of the program/curriculum guidelines/goals/*essential learning*." In addition to the constraints presented, more related to teaching practices, teachers were also asked for their opinions on their own training, initial and continuous, to understand whether this issue would also be a possible constraint for teaching geoscience topics (Figure 9).

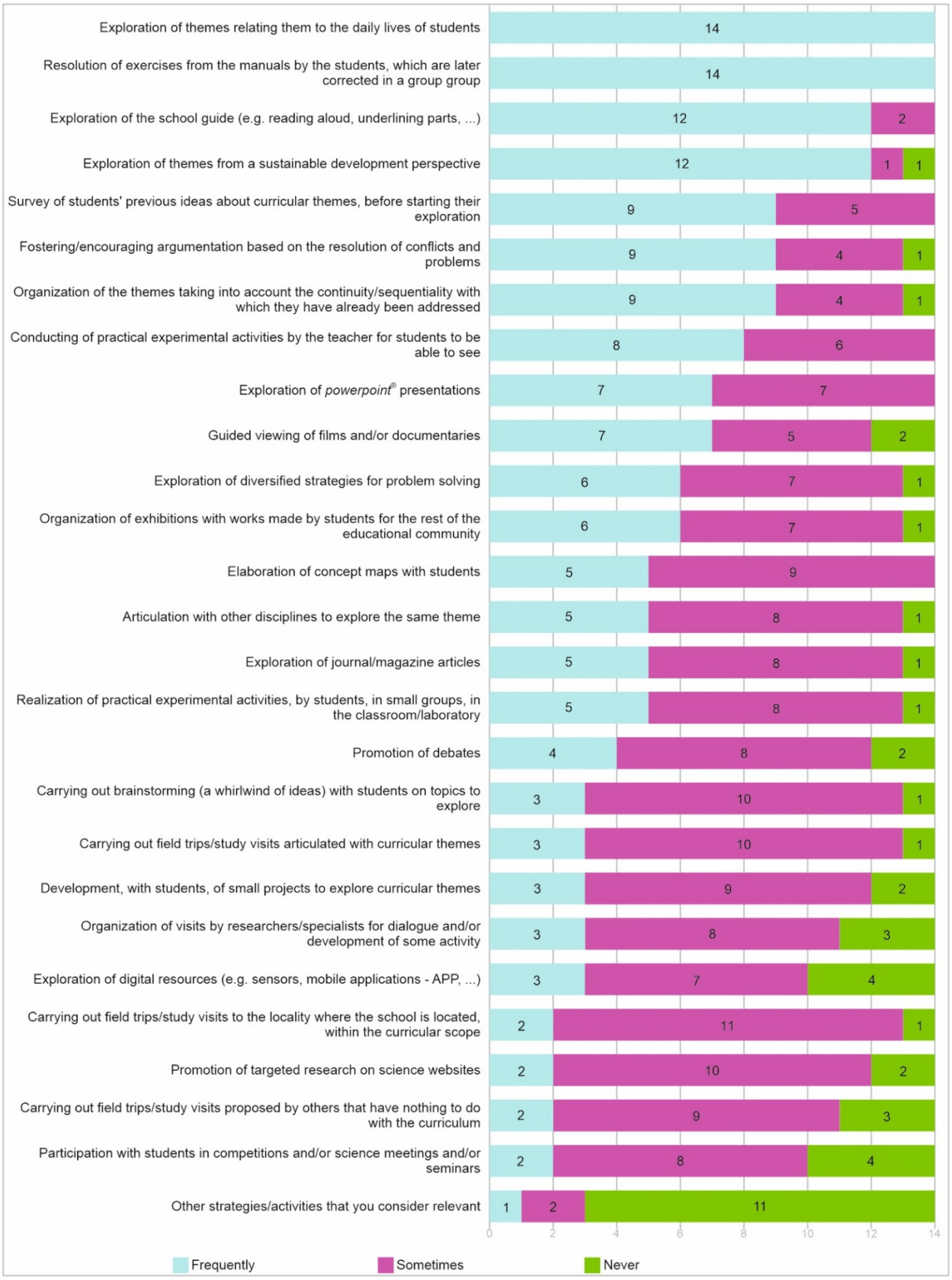

Figure 7. Implementation frequency of strategies/activities to teach geoscience topics in teachers' practices.

Figure 8. Teachers' opinions about the constraints they recognize in the teaching of geoscience topics (adapted from [37]).

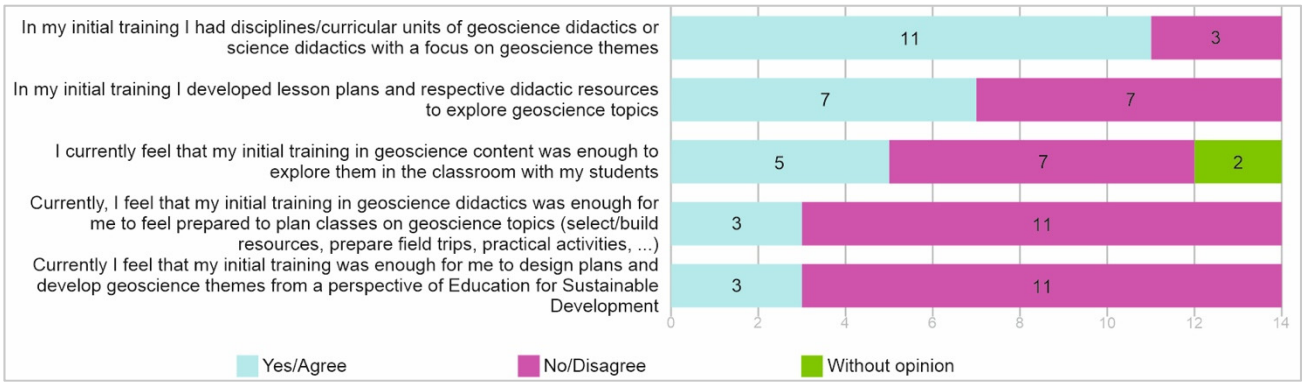

Figure 9. Teachers' opinions about the suitability of their initial training to teach geoscience topics.

Although the majority stated that they had specific training in geoscience didactics, half of the teachers said that they had not developed plans and didactic resources to explore geoscience topics, the majority admitting that today they recognize that the initial training they had was not enough to feel prepared to teach geoscience topics in Basic Education.

Teachers' opinions on the need for continuing education to teach geoscience topics are represented in Figure 10. Most of the surveyed teachers felt the need to undergo continuous training, both in didactics and geoscience topics. However, only a minority had attended these programs or others specifically in SD. The justification that most teachers gave for this low attendance was "because I never found training on this topic here in the area that I could attend".

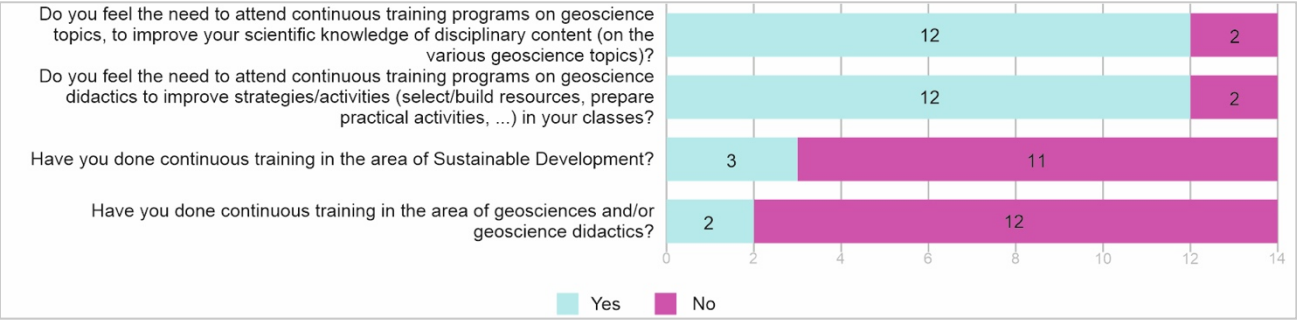

Figure 10. Teachers' opinions on the need for continuing education to teach geoscience topics.

4. Discussion

The theme "soils" is represented in all analyzed documents of *Essential Learning* (from the 1st to the 9th grades of Basic Education). However, it appears that these references are mostly aimed at exploring the properties and characteristics of soils, while orientations to explore other articulations, namely with food and water resources, are less frequent. However, such articulations are indispensable in view of the need to reduce the levels of hunger in the world and of poverty in general (SDG 2 and SDG1, respectively). According to [19], it is necessary to review school curricula periodically, and the theme "soils" must be present at all levels of education, properly articulated with the problems that emerge from its unsustainable use, from the perspective of promoting environmental, social and economic sustainability. Among these documents (*Essential Learning* of Environmental Studies and of Natural Sciences), the environmental dimension is overestimated [38], leading teachers to strongly link the term sustainability to environmental aspects and rarely to economic and social aspects [39,40]. However, sustainable solutions require global thinking and local actions, fostered by true transdisciplinary education, at all levels, that overcome the established division between the natural and the human and social sciences that guides current education visions [3].

In the *Student's Profile by the End of Compulsory Schooling* document, there is an explicit reference to the concept of sustainability, defined as one of the eight guiding principles across all years and themes. This document is articulated with the *Essential Learning* documents; therefore, it assumes, although not explicitly, the relevance of promoting sustainability. One of the Competency Areas defined ("Well-being, health and environment") specifically aims to foster education for SD.

The *Referential Environmental Education for Sustainability* document, in its entirety, aims to promote education for sustainability. It is organized by teaching cycles, and although it defines "Themes," "Sub-themes," "Objectives" and "Performance Descriptors," it does not present a clear orientation of how to relate them with the themes of the *Essential Learning* documents. Thus, it is necessary to establish a clear articulation between these two documents, that is, to point out references from the *Referential Environmental Education for Sustainability* document in the *Essential Learning* documents, thereby contributing to assisting teachers' practices in sustainability issues.

The themes included in the *Essential Learning* documents are organized from a spiral perspective; that is, the themes reappear throughout basic schooling, aiming at a successively more in-depth approach. However, according to [41], this perspective can compromise students' learning due to gaps and/or repetitions in the exploration of these themes throughout their schooling. Those gaps and/or repetitions can essentially emerge

from the fact that most teachers do not know the curricular documents assigned to other schooling grades and/or cycles, which can normally result in a repetition (and not a more in-depth approach to the themes) noticed by the students [42]. In addition, the results obtained from the answers to the questionnaire applied in this work show that not all teachers are concerned about knowing if their students have already worked on the themes they will teach to avoid these repetitions and/or gaps. Some mentioned that they analyzed the official documents of the schooling grades of the same education cycle, but few considered documents related to other cycles. This question is included in the *Essential Learning* Implementation Assessment Report [43], in which the issue of vertical and horizontal articulations is one of the greatest difficulties recognized by the surveyed teachers. Other international studies corroborate these difficulties [44–46] and add, as possible justifications, the lack of didactic resources and the inadequate training of teachers. Orale and Uy [44] identified another problem in this spiral organization, calling it "When the spiral is broken", which refers to students' difficulties when they were not able to master the previous themes and then are subject to them, but approached in a more complex way.

As for the most frequently used strategies/activities, we highlight the exploration of the themes relating them to the students' daily lives, the resolution of exercises in the school textbook, and subsequent revision in the classroom. According to a recent study developed by the Observatory of Educational Resources, more than 92% of teachers (out of the 4590 teachers from 1st to 12th grades who participated in that study) systematically resort to textbooks to prepare their plans [47]. The over-use of school textbooks in guiding pedagogical practices, therefore replacing official curriculum documents when teachers plan their classes, is very worrying since there is practically no articulation between the *Essential Learning* documents and the textbooks [43]. This situation was also emphasized in other studies [48,49] that recognized the occurrence of some mismatch between school textbooks and current curricular documents, which makes the school textbook an unsuitable working tool in the teaching and learning process.

Another highlight derives from the fact that all the teachers involved in the present investigation assume that they carry out (sometimes or frequently) experimental practical activities for the students to see; that is, the students do not carry them out, being limited to observing them. This situation, in the approach to geoscience themes, is justified by the teachers participating in this investigation: (i) by the high number of students per class, (ii) by the lack of conditions in the laboratories, (iii) by the lack of guides to support the teacher, and even (iv) by the deficient initial training they had and the reduced offer of continuous training in the experimental teaching of geosciences. These arguments were also recognized in other similar studies, namely by Andrade & Massabni [50] and by Souza et al. [51].

Regarding infrastructures, whose inadequacy the teachers considered to limit the performance of practical work in geosciences, Rodrigues et al. [52] found this difficulty in implementing experimental activities in the 1st Cycle of Basic Education, and in the 2nd and 3rd Cycles of Basic Education in 152 schools in central Portugal: only 24% of those have properly equipped science laboratories, in 8% of the schools the science rooms are spaces that have the same furniture as any other classroom intended for the teaching of another subject, and in 68% of the schools the spaces fall within the typology called "pseudo-laboratories" (i.e., they correspond to rooms intended for science teaching, but without the appropriate characteristics to promote practical activities, having only, for example, side benches or water points, therefore corresponding to normal classrooms).

Some of the results from this investigation open the door for further exploration of this issue in other studies, which may incorporate data gathered using other instruments to enable triangulation of findings and enhancement of the conclusions that are given here.

5. Towards a New Approach to "Soils" in Portuguese Curricular Documents

To promote quality education regarding the role of soils in achieving the 2030 Agenda goals Basic Education teachers at Portuguese schools need adequate teaching resources

and education focused on soils from an SD perspective. However, above that, the official documents that guide their practices require some improvements to make them clearer, better organized, and more efficient, namely by promoting the sequential implementation of the soil theme, encouraging students to carry out practical work, and suggesting new assessment strategies.

Appendix A includes a new proposal for the implementation of the theme "soils" in the *Essential Learning* documents of Basic Education in Portuguese schools. To support this proposal, curricular documents in Earth Sciences from other countries were analyzed (Singapore, Canada, United States of America, England and Australia). The selection criteria for these countries were: (i) having obtained good results in the TIMSS 2019 in Earth Sciences, (ii) covering different continents (different cultures), (iii) having the curriculum documents available for consultation, (iv) having a more complete structure than the current Portuguese *Essential Learning* documents, namely presenting possible articulations of the theme with other schooling grades (thus promoting its sequential implementation), and displaying proposals for evaluation strategies.

6. Conclusions

The importance of studying soils to achieve DSGs is unavoidable, and the school's role in this purpose is widely recognized. The present work reports research aimed at characterizing the approach to the theme "soils" in Portugal and in Portuguese schools across the world (around 148,000 teachers and more than 1.5 million students during the 2021/2022 school year), considering the SDGs of the 2030 Agenda.

This research reveals that the curricular documents of the Sciences of Basic Education that guide geoscientific education integrate SD concerns regarding soils as an important natural resource to achieve SDGs. They include nine documents of *Essential Learning*, i.e., one per schooling grade, and two transversal reference documents (i.e., *Student's Profile by the End of Compulsory Schooling* and *Referential Environmental Education for Sustainability*). However, the content analyses of these documents show that they lack articulation between them, therefore being of limited use to the teachers for whom they are intended. In fact, although all teachers relate the theme "soils" to the environmental dimension of SD, their perceptions about how to approach such issues during their practices show a great discrepancy in relation to the official documents' aims and scope. Reasons include the replacement of curricular documents by textbooks in their practices despite their recognized inadequacy to meet the official documents rationale, the logistics constraints in the teaching of geoscience topics and their need to undergo continuous training, both in didactics and on geoscience topics.

Policy makers in charge of conceiving curricular norms and conditions for their implementation on the ground and education actors seem to inhabit worlds apart, making it difficult to educate students to face current problems resulting from the unsustainable use of soils. Urgent measures are required to bridge both worlds and provide effective quality education.

On the one hand, official documents need to be clearer, more coherent and designed to be understood and used by the educational actors in real scenarios. However, any reformulation of curriculum documents presupposes the previous discussion and validation by in-service teachers, and it cannot be exclusively determined by policy makers. To overcome the current gap that separates the world of curriculum documents from the world of educational practices, teachers should be consulted, as they are particularly aware of the day-to-day constraints that they face to equip their pupils with adequate skills to mitigate current problems affecting society and that jeopardize their future.

This work proposes reorganization for the implementation of the theme "soils" in the *Essential Learning* of Basic Education documents in Portuguese schools that emerged from the results obtained throughout this research. However, for the proposed suggestions to have an impact on teachers' practices, it is essential to provide them with didactic resources aligned with SD concerns regarding soils, as well as to conceive and develop education pro-

grams designed to assist the teachers in the development of their work with the respective students. These programs will have to correspond to the needs and expectations of teachers and must be in line with the SDGs, thus contributing to improving their self-confidence in implementing innovative approaches in their practices and promoting quality education.

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Appendix A

Appendix A includes a new proposal for the implementation of the theme "soils" in the *Essential Learning* documents of Basic Education in Portuguese schools, supported by similar documents from other countries (Singapore, Canada, United States of America, England and Australia). The selection criteria for these countries are explained in the text.

CONTEXTUALIZATIONz OF PROPOSED AMENDMENTS TO THE CURRICULUM DOCUMENTS *ESSENTIAL LEARNING*

Starting from the analysis of the documents *Student's Profile by the End of Compulsory Schooling* and *Essential Learning*, curricular guidelines currently in force in Portugal, we have conceived a proposal for the (re)organization of *Essential Learning* focused on the theme "soils" with SD guidelines and with a perspective of continuity throughout Basic Education, therefore minimizing gaps or repetitions of themes that are revisited over the years. For this purpose, several Science curricula from other countries available online were consulted and analyzed, having as a reference some of the countries with the best results in science in TIMSS 2019 (4th and 8th grades), namely Australia, Canada, United States, England and Singapore. Not only were the contents analyzed, but also the organization itself, which led to the proposal that is presented below for the discipline of Environmental Studies (1st CBE) and Natural Sciences (2nd and 3rd CBE) for the theme "soils" throughout Basic Education.

This proposal was validated by teachers from the three teaching cycles and experts in didactics and geosciences. These were asked to comment on this proposal, namely on the clarity and adequacy of the organization of the document. From the comments collected, it was possible to verify that the proposal became more accessible to teachers. Small suggestions were given that have already been included in the version that follows.

***ESSENTIAL LEARNING* IN ARTICULATION WITH THE *STUDENTS' PROFILE BY THE END OF COMPULSORY SCHOOLING* FROM A SUSTAINABLE DEVELOPMENT PERSPECTIVE**

This document intends to present the *Essential Learning* of Environmental Studies (1st CBE) and Natural Sciences (2nd and 3rd CBE) for the theme "soils." Different themes related to "soils" will be addressed, and these will also be articulated with the *Student Profile*. A suggestion will also be made regarding which SDGs can be worked on in each of these themes. For each year, the *Overall Expectations* are presented at the level of the three dimensions of learning provided for in the curricular guidelines (knowledge, skills, attitudes and values), as well Vertical Articulations proposals of the theme and referred to the Areas of Competencies and Values to be developed, according to the *Students' Profile*. It should be noted that this document should be seen as a guide for approaches to the suggested themes. Teachers are given flexibility to develop their practices, taking into account the interests, prior knowledge and abilities of the students, incorporating ideas, material resources and strategies of different natures, and thus promoting a fruitful teaching of science.

ASSESSMENT PROPOSALS

The main objective of the evaluation should be to improve the students' learning, that is, with the information collected, that the teachers can guide the students, in order to overcome their possible difficulties. The feedback students receive from their teachers can be descriptive, motivating them to improve or maintain their performance, or, in the case of a summative assessment, with the attribution of a value that represents its performance, based on pre-established criteria. During schooling, it is intended that students develop scientific knowledge, but also that they develop skills, attitudes and important values for understanding and disseminating science. Thus, it is essential to have an assessment of the three dimensions of learning provided in the curricular guidelines, gathering different information from different sources.

Tests (written and oral) are perhaps the most used assessment strategy. However, in order to assess the three dimensions, it is suggested to use other data sources, namely: practical activities, project development, teacher observations, checklists, reflections/diaries, portfolio, modeling, posters, games and tests, debates...

This list is intended to present only examples, and teachers may adopt any other strategies they deem relevant and appropriate.

PROPOSED AMENDMENTS TO THE *ESSENTIAL LEARNING* DOCUMENT

1st GRADE	ENVIRONMENTAL STUDIES			
	Soil—A Natural Element			
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Society/ Nature/ Tecnology	Reveals knowing that... • On our Planet, we can find natural elements (plants, animals, soil, rocks, water...) and anthropic elements (houses, roads, statues...), the latter of which may have natural elements in their constitution. • There are anthropic actions that affect the sustainability of natural elements, namely soils.	Reveals being able to... • Directly observe and describe natural and anthropic elements in the surrounding landscape. • Relate natural elements with anthropic elements. • Formulate critical opinions on human actions that affect soil sustainability.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different).	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (D) Critical thinking and creative thinking.
- Values: Curiosity, reflection and innovation.

Vertical articulations: In the 2nd grade, they will address the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they will study the soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they will explore the characteristics and applicability of soils. In the 5th grade, they will study the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they will address soils from the perspective of their importance and influence on food production. In the 7th grade, they will address local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the discipline of Portuguese, through the production of a short text describing the surrounding landscape, for example. In the Visual Arts discipline, different techniques of expression can be integrated to reproduce the surrounding landscape, for example.

2nd GRADE	ENVIRONMENTAL STUDIES			
Soil—A Common Good for Humanity and the Need for Its Preservation				
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Society/ Nature/ Tecnology	Reveals knowing that... • There are natural elements (e.g., water, air, soil...) that are common to humanity. • It is necessary to preserve them for the promotion of Sustainable Development.	Reveals being able to... • Perceiving and identifying natural elements and the relationships between them. • Describe the natural elements that they identify in the locality where they live/or at school. • Formulate problem questions on this topic. • Create solution proposals (individually and in groups, through the development of a project, involving practical activities...). • Argue about the importance of preserving these assets for the promotion of Sustainable Development.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different).	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (C) Reasoning and problem solving; (B) Information and communication.
- Values: Responsibility and integrity.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 3rd grade, they will study the soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they will explore the characteristics and applicability of soils. In the 5th grade, they will study the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they will address soils from the perspective of their importance and influence on food production. In the 7th grade, they will address local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the discipline of Portuguese, through the production of a short text about a natural element common to humanity, for example. In the Visual Arts discipline, different techniques of expression can be integrated to reproduce the surrounding landscape, for example.

3rd GRADE	ENVIRONMENTAL STUDIES			
	Soil—Environmental Factor and Its Relationship with Plants and Animals			
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Society/ Nature/ Tecnology	Reveals knowing that... • There are environmental factors (air, light, temperature, water, soil) that are essential for different stages of plant and animal life. • The existence of environmental changes (deforestation, fires, silting and pollution) causes imbalances in ecosystems and can influence the lives of plants and animals (survival, death and migration). • There are environmental or social problems in the respective communities (urban solid waste, pollution, poverty, unemployment, social exclusion, etc.).	Reveals being able to... • Justify the importance of knowledge and the preservation of these environmental factors. • Formulate problem questions on this topic. • Plan experimental activities (with or without variable control). • Carry out experimental activities (measure mass, temperature . . . ; use instruments/devices (scales, stopwatch, beaker...; record data (in a table, diagram...). • Formulate critical opinions on environmental or social problems, promoting Sustainable Development.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different). • Valuing the scientific work.	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (D) Critical thinking and creative thinking; (C) Reasoning and problem solving.
- Values: Curiosity, reflection and innovation; Responsibility and integrity; Citizenship and participation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 4th grade, they will explore the characteristics and applicability of soils. In the 5th grade, they will study the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they will address soils from the perspective of their importance and influence on food production. In the 7th grade, they will address local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the discipline of Portuguese, through the production of a text with the purpose of describing, for example, any of the identified environmental problems. In the Visual Arts discipline, they can create a poster to raise awareness of an identified problem, choosing appropriate techniques and materials. In the Music discipline, they can create, in a group or alone, a small piece of music to raise awareness of an identified problem.

4th GRADE	ENVIRONMENTAL STUDIES			
	Soil—Characteristics and Applicability			
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Society/ Nature/ Tecnology	Reveals knowing that... • There are different types of rocks and soils, with different properties (color, texture, hardness, smell, permeability). • Technological evolution is important for the evolution of society, relating objects, equipment and technological solutions with different needs and problems of everyday life (forecasting/mitigating the occurrence of natural and technological disasters). • The increase in world population and consumption of goods can cause changes in the quality of the environment (destruction of forests, pollution, depletion of resources, extinction of species, etc.). • It is essential to have individual and collective measures that minimize the negative impact of the increase in world population and consumption.	Reveals being able to... • Collect rock and soil samples in the field (school area, for example), and group them according to their properties. • Compare land use in the region with that of other regions. • Formulate problem questions about technological evolution and the increase in world population. • Justify the importance of individual and collective measures that can minimize the negative impacts of the increase in world population and consumption, thus contributing to promote Sustainable Development.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different).	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (A) Language and texts; (D) Critical thinking and creative thinking.
- Values: Responsibility and integrity; Curiosity, reflection and innovation; Citizenship and participation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they studied soil as an environmental factor and its relationship with plants and animals. In the 5th grade, they will study the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they will address soils from the perspective of their importance and influence on food production. In the 7th grade, they will address local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the discipline of Portuguese, through the production of a text with the purpose of describing, for example, any of the identified environmental problems. In the Visual Arts discipline, they can create a poster to raise awareness of an identified problem, choosing appropriate techniques and materials. In the Music discipline, they can create, in a group or alone, a small piece of music to raise awareness of an identified problem.

5th GRADE	NATURAL SCIENCES			
	Soil—Genesis, Properties and Functions. The Importance of Soil in Human Activities.			
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Water, air, rocks and soil—terrestrial materials	Reveals knowing that... • Biological and atmospheric agents interfere in the genesis of the soil. • Different soils have different constituents, properties and functions. • Minerals, rocks and soil are important in (local and/or regional) human activities. • Minerals, rocks and soil are important in human activities, recognizing local or regional examples. • There is water suitable for consumption (drinking and mineral) and water not suitable for consumption (brackish and contaminated). • Biodiversity can be conditioned by human actions. • The preservation of biodiversity is fundamental.	Reveals being able to... • Reflect on the importance of biological and atmospheric agents in the genesis of the soil. • Distinguish drinking water from water inappropriate for consumption. • Analyze local, regional or national problematic issues on soils and water. • Formulate critical opinions about human actions that condition sustainability.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different). • Valuing the scientific work.	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (C) Reasoning and problem solving; (D) Critical thinking and creative thinking; (B) Information and communication; (G) Wellness, health and environment.
- Values: Responsibility and integrity; Curiosity, reflection and innovation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they have studied soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they have explored the characteristics and applicability of soils. In the 6th grade, they will address soils from the perspective of their importance and influence on food production. In the 7th grade, they will address local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the discipline of History and Geography of Portugal, through the identification of landscapes as (natural, cultural) heritage, such as the Alto Douro Wine Region or the Landscape of the Pico Island Vineyard Culture (both included in the UNESCO World Heritage List), and relating them to leisure and tourism. In the English discipline, through the writing of simple descriptions of these landscapes, for example. In the discipline of Information and Communication Technologies, through research about issues related to the topic, the information for later presentation to the class was critically analyzed.

6th GRADE	NATURAL SCIENCES			
	Soil—Importance and Influence for Food Products			
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Life processes common to living beings	Reveals knowing that... • Science and technology are important in the evolution of food products (articulating with knowledge from other disciplines). • Several factors influence the photosynthesis process.	Reveals being able to... • Argue why science and technology are important in the evolution of food. • Plan experimental activities to study factors that influence the photosynthesis process (with or without variable control). • Carry out these experimental activities (measuring mass, temperature...); use instruments/devices (scales, stopwatch, beaker...; record data (in a table, diagram...).	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different). • Valuing the scientific work.	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (C) Reasoning and problem solving; (D) Critical thinking and creative thinking; (B) Information and communication.
- Values: Responsibility and integrity; Curiosity, reflection and innovation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they have studied soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they have explored the characteristics and applicability of soils. In the 5th grade, they have studied the genesis, properties and functions of the soil, as well as its importance for human activities. In the 7th grade, they will address local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the Mathematics discipline, for example, through an experimental activity requiring the measurement of chives growth in different soils, which involves different data, which may have to be grouped into classes. In the discipline of Information and Communication Technologies, through research about the role of science and technology in the evolution of food products, the information for later presentation to the class was critically analyzed. With the Portuguese and English

disciplines, for example, if the final product is an informative flyer, it can be written in both languages.

7th GRADE	NATURAL SCIENCES			
Soil—Observe and Characterize the Surrounding Landscape. Local or Regional Problems Related to Soils, with a STSE Nature (For Example: Dynamics in Watercourses—Transport and Deposition of Materials; Occurrence of Diseases . . .).				
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Changing Earth	Reveals knowing that... • The dynamics of a watercourse implies transport and deposition of materials. • There is local/regional issues of a STSE nature associated with the dynamics of watercourses. • The geological environment can influence the health and occurrence of diseases in living beings that live in that environment. • Geological knowledge is important for the sustainability of life on Earth.	Reveals being able to... • Describe implications of the dynamics of a watercourse. • Plan experimental activities to study implications of the dynamics of a watercourse (with or without variable control). • Carry out these experimental activities (measuring mass, temperature...); use instruments/devices (scales, stopwatch, beaker...; record data (in a table, diagram...). • Arguing about the influence of geological environments on the health of living beings. • Arguing about the importance of geological knowledge for the sustainability of life on Earth.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different). • Valuing the scientific work.	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (C) Reasoning and problem solving; (D) Critical thinking and creative thinking.
- Values: Responsibility and integrity; Curiosity, reflection and innovation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they have studied soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they have explored the characteristics and applicability of soils. In the 5th grade, they have studied the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they have addressed soils from the perspective of their importance and influence on food production. In the 8th grade, soils will be studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the Geography discipline, for example, by drawing up landscape sketches that include a watercourse, describing its essential elements and locating them using the geographic coordinate system (latitude, longitude). They can also relate the location of landforms to the hydrographic network using topographic sections. With the Physical-Chemistry discipline, by carrying out an investigation exploring possible water contamination, then applying the separation techniques necessary in its treat-

ment for consumption and effluents, as well as communicating the conclusions obtained, highlighting the importance of this treatment for the balance of ecosystems and quality of life. Reports can be articulated with the disciplines of Information and Communication Technologies, Portuguese and English in the aim of text research and production.

8th GRADE	NATURAL SCIENCES			
Soil—As an Abiotic Factor. Influence on Ecosystems. Measures for the Sustainable Exploitation of Resources.				
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Changing Earth	Reveals knowing that... • Rocks and soil play an important role in the existence of life on Earth. • There are ecosystems in the area surrounding the school and their levels of biological organization. • There are abiotic factors—light, water, soil, temperature—that influence ecosystems. • Some living beings adapt to these (abiotic) factors. • It is important to maintain the dynamic balance of ecosystems in order to achieve sustainable development goals. • Ecosystems can be affected by pollution, deforestation, fires and biological invasions, for example. • Science and technology are important for the conservation of ecosystems. • The exploitation/transformation of natural resources can have impacts on ecosystems. • The collection, treatment and sustainable management of waste are fundamental for the reduction of risks and minimization of damages, for example, in the contamination of water and soils, thus promoting sustainable development.	Reveals being able to... • Arguing about the importance of rocks and soil in the existence of life on our planet (possibility of carrying out experimental activities). • Describe levels of biological organization of an ecosystem from data collected in the field. • Argue about the influence of some abiotic factors on ecosystems, namely in the region surrounding the school. • Formulate questions about the influence of science and technology on ecosystem conservation. • Formulate answers to these questions through research. • Analyze local or regional issues associated with the balance of ecosystems. • Propose solutions to the identified problems, with a view to promoting sustainability. • Arguing about scientific and technological development and its environmental, social and ethical impacts, as well as in improving the quality of life of human populations.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different). • Valuing the scientific work.	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (C) Reasoning and problem solving; (D) Critical thinking and creative thinking.
- Values: Responsibility and integrity; Curiosity, reflection and innovation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they have studied soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they have explored the characteristics and applicability of soils. In the 5th grade, they have studied the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they have addressed soils from the perspective of their importance and influence on food production. In the 7th grade, they addressed local, regional or national issues of an STSA nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 9th grade, soils can be associated with the production of healthy foods, thus preventing contemporary diseases.

Interdisciplinary horizontal articulations: With the discipline of Geography, by carrying out research about the balance or rupture between the population and natural resources in different geographical and economic contexts. With the discipline of History by carrying out discussions about the theme of advances in science and technique and the consequent development of the scientific method (18th century), as well as with confidence in the scientific method during the industrial revolution (19th century). With the discipline of mathematics through the development of works related to data processing (e.g., Pordata). With this data, they will be able to explore different topics, for example, analyze the evolution of the number of tons of garbage collected in an undifferentiated or selective way, process this data and prepare a presentation for the class, where there may be articulation with Information and Communication Technologies, Portuguese and/or English.

9th GRADE	NATURAL SCIENCES			
	Soil—Importance for the Production of Healthy Food, Thus Preventing Contemporary Diseases			
Organizer Domain	**Knowledge**	**Abilities**	**Attitudes and Values**	**SDGs that Can Be Promoted**
Changing Earth	Reveals knowing that... • Healthy eating is related to the prevention of contemporary diseases. • The Mediterranean diet is important for health promotion.	Reveals being able to... • Research about the characteristics of food and its production. • Organize the information to be able to disseminate it. • Argue about the importance of the Mediterranean diet for health promotion.	Reveals attitudes of... • Curiosity. • Critical spirit. • Objectivity. • Respect for material resources and the environment. • Respect for the ideas of others (different).	

Articulations with the *Students' Profile*:

- Areas of competence: (I) Scientific, technical and technological knowledge; (C) Reasoning and problem solving; (D) Critical thinking and creative thinking.
- Values: Responsibility and integrity; Curiosity, reflection and innovation.

Vertical articulations: In the 1st grade, students have already studied the soil as a natural element. In the 2nd grade, they have addressed the soil as a common good for humanity and the need for its preservation. In the 3rd grade, they have studied soil as an environmental factor and its relationship with plants and animals. In the 4th grade, they have explored the characteristics and applicability of soils. In the 5th grade, they studied the genesis, properties and functions of the soil, as well as its importance for human activities. In the 6th grade, they have addressed soils from the perspective of their importance and influence on food production. In the 7th grade, they addressed local, regional or national issues of a STSE nature, where soils may arise, namely in the dynamics of water courses (transport and deposition of materials) or in the occurrence of diseases. In the 8th grade, soils are

studied as an abiotic factor and their influence on ecosystems, as well as in the exploration of measures for the sustainable exploitation of resources.

Interdisciplinary horizontal articulations: With the Information and Communication Technologies discipline, through the planning of research and research strategies on the subject of food, namely on the characteristics of food and its production. Then, select the technological option that best suits the performance of collaborative work, which can be synchronous or asynchronous. Provide a presentation session on the work process and products using digital media. With Physical Chemistry through research on some chemical elements present in the human body and also relating them to the food we eat.

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