

Article

In-Service Teacher Education Program through an Educational Design Research Approach in the Framework of the 2030 Agenda

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Abstract: Science education plays a key role in promoting Education for Sustainable Development (ESD) through the training of informed and participatory citizens committed to the management of our planet and its resources. This work presents the design and assessment of an In-Service Teacher Education Program (ISTEP) through an Educational Design Research approach aiming at developing skills that make it possible to operationalize the experimental practical teaching of science topics, within the scope of ESD, in an articulated, coherent, and progressive way throughout Basic Education. It was implemented with 14 teachers from the three cycles of Portuguese Basic Education (ages 6–15), and focused on “Soils”. An integrated set of activities and respective didactic resources were co-built (the trainer-researcher with the in-service teachers) with a progressive, systematic, and sequential vision of the “Soils” theme. The content analysis of the teachers’ answers to questionnaires and during the final reflection point to an improvement in their practices regarding the ability to plan and design didactic resources on science topics from a Sustainable Development perspective. This ISTEP can be adapted to other themes and educational contexts, namely through close cooperation on education issues, which is one of the lines of action of the Community of Portuguese-Speaking Countries.

Keywords: In-Service Teacher Education Program; Educational Design Research; 2030 Agenda; geoscience education; soils



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1. Introduction

The promotion of Sustainable Development (SD) has been a priority area in research carried out in recent decades, namely in the educational context, leading to the need to reflect on new paradigms for education and for research in education [1–4]. Science education has a fundamental role here, namely through the increase in the levels of scientific literacy, thus enhancing the improvement of the effective and responsible participation of citizens in 21st century societies [5–8].

Quality education is considered a crucial issue to achieve the 2030 SD Goals (SDGs), which do not depend only on governments, but also on all citizens, so “children and young people are central in this global call for participation and the school is essential to make the new global agenda known [and] inspire and encourage people to participate in community development” [9].

Over the last few years, there has been significant effort in the Portuguese education system to integrate international guidelines related to Education for Sustainable Development (ESD), namely those launched by the United Nations, assuming the concept of SD in a multidimensional and transversal perspective, both in curricular and reference documents. In this regard, it may be important to start by clarifying the current organization of the Portuguese education system. In Portugal, the education system includes one year of pre-school education and a further 12 years of compulsory schooling, organized in Basic and Secondary Educations Cycles (BEC and SEC, respectively) [10].

Basic Education (BE) lasts for nine years and is structured into three cycles: the first cycle is organized over 4 years (pupils aged 6 to 10), the second cycle is a 2-year period (pupils aged 10 to 12), and the third cycle is 3 years (pupils from 12 to 15 years old). Throughout BE, all students attend the same subjects (with just a few exceptions).

Secondary Education (SE) extends over three years (pupils aged 15 to 18) and students can choose the area of study that most interests them (Science, Literature, Arts, etc.), varying the subjects they attend according to the selected area.

The integration of SD concerns into the Portuguese Curricular Guidelines took several years, of which it is worth highlighting some milestones and relating them to several United Nations initiatives to promote ESD (Figure 1). This systematization has already been previously described in detail by the authors [11,12], but a summary will be presented here to support a more consistent understanding of the concerns underlying the Portuguese educational system.

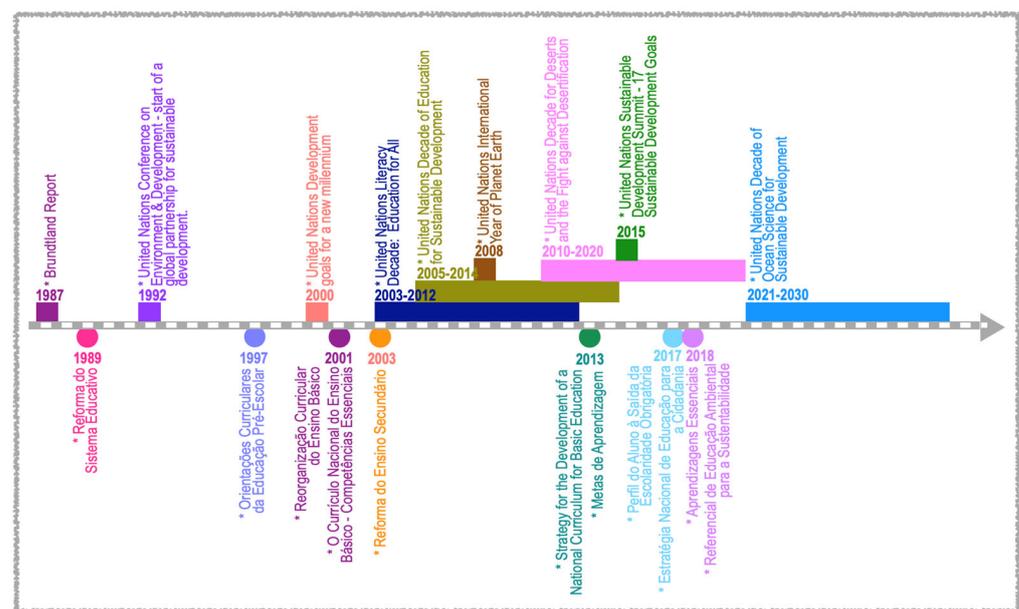


Figure 1. The integration of Sustainable Development concerns among Portuguese Curricular Guidelines during the last three decades as a response to several United Nations Initiatives fostering sustainability.

In Portugal, the guidelines for citizenship implementation in educational curricula across different school grades were developed in 1989 as part of the Reform of the Educational System. The School-Area subject and related extracurricular activities were also introduced during this reform. These are significant references in this context because they allowed for interaction between the school and the community, which encouraged the creation of projects for environmental education.

The Curriculum Guidelines for Pre-School Education—OCEPE were later issued in 1997 and stimulated the discussion of environmental issues from a young age.

Since education for citizenship became a required transversal area, it is now present in all disciplines. The Curricular Reorganization for Basic Education (ages 6 to 15) in 2001 and the Reform of Secondary Education (ages 16 to 18) in 2003 improved the implementation of education for citizenship in a more systematic way.

The National Curriculum for Basic Education—Essential Competencies was introduced and put into effect in 2001 as well. The Basic Law of the Portuguese Educational System is used as a frame of reference in this document for defining the skills to be attained at the conclusion of BE. This document suggests a set of specialized skills for each disciplinary field of each BE cycle, as well as a set of transversal skills that are shared by all three BEC. Four themes—Earth in Space, Earth in Transformation, Sustainability on Earth, and Living Better on Earth—are recommended as the foundation for science

education over the course of the three cycles. The revocation of the National Curriculum for Basic Education—Essential Competencies occurred in 2011. In accordance with the Strategy for the Development of a National Curriculum for Basic Education (Ministry of Education), which aims to promote clarification and operationalization of the curricular documents that guide educational action, new Learning Goals were recommended guidelines for the 2013–2014 academic year. The Learning Goals statement makes clear mention of sustainability-related issues that can be found in a variety of academic fields and grade levels. As an illustration, we can highlight the Sustainability on Earth domain and the Sustainable Resource Management sub-domain in the Natural Sciences subject of the 8th grade.

In 2017, the Student Profile upon Completion of Compulsory Education was approved [13]. The Student Profile at Completion of Compulsory Education serves as a roadmap for managing the curriculum and aids in the definition of techniques and tactics to be applied in the context of classroom education. The principles, vision, values, and areas of expertise in this text are structured according to eight principles: Learning, Inclusion, Stability, Adaptability and Boldness, Consistency and Flexibility, Sustainability, Humanist Base, and Knowledge. The values taken into consideration include Responsibility and Integrity, Excellence and Demand, Curiosity, Reflection and Innovation, Citizenship and Participation, Freedom, and Citizenship and Sustainability.

The Directorate-General for Education (DGE) unveiled the National Education Strategy for Citizenship [14] in the same year (2017). The Essential Learnings document [15] and the Student Profile at Completion of Compulsory Education are two reference documents that are being used in conjunction with this strategy from early childhood education through the conclusion of SE.

The Education for Citizenship document is organized into three groups of six domains each. All levels and cycles of schooling must include the first category, which comprises the SD and Environmental Education domains, because it incorporates transversal and longitudinal areas. At least two cycles of BE must include the second category, which encompasses the fields of institutions, democratic participation, financial literacy, and consumer education.

The topic programs were replaced by the Essential Learnings document, which was homologated in 2018, and is aligned with the Student Profile at Completion of Compulsory Education document. The definition of Essential Learnings, which serves as a guide for students' learning, is based on the knowledge, abilities, and attitudes that need to be acquired as the curriculum develops.

In summary, the documents and legal guidelines mentioned in this brief systematization enable us to conclude that the concerns about an education that promotes SD are present in the legal guidelines and have emerged, in the Portuguese curriculum, as being closely related to Environmental Education, Education for Citizenship, and Natural Sciences.

This is the current educational context for which this In-service Teacher Education Program (ISTEP) was designed and implemented, involving a group of science teachers from the three BEC, and following an Educational Design Research (EDR) approach [16,17]. As a result of the ISTEP, this work presents a proposal for the organization of a didactic sequence and respective resources on a selected theme—"Soils"—throughout the BE in a perspective of ESD.

The proposal of organizing a didactic sequence is because the themes included in the Essential Learning documents [15] are organized in a spiral perspective, i.e., the same themes reappear throughout the whole BE, aiming at a successively deeper approach [18]. According to Martins and Veiga [19], however, this perspective may compromise the students' learning, due to gaps and/or repetitions in the exploration of these themes throughout their schooling, which is intended to be minimized with this proposal.

The topic "Soils" was chosen because it is featured in curriculum guidelines for nearly all science classes at the BEC and is one of the geoscience topics specifically relevant to the 2030 Agenda and the Sustainable Development Goals. According to Lal et al. [20], under the

“Soils” theme, several SDGs can be approached: 1 (No Poverty), 2 (Zero Hunger), 3 (Good Health and Well-being), 5 (Gender Equality), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), 13 (Climate Action), and 15 (Life on Land). Other scientific themes with strong environmental, economic, and social relevance can be approached in the frame of pre-service and in-service teacher education using principles and methods developed in this ISTEP.

Recent studies on the representation of SD guidelines in the Portuguese curriculum documents show that, although all SD dimensions (environmental, economic, and social) are present in most curriculum and guidance documents, they are not equitably explored [11,12]. Those studies also concluded, however, that the existence of guidelines and legal framework for the implementation of SD in the context of Portuguese schools does not by itself guarantee its operationalization in the teaching and learning process. Teachers’ conceptions and practices are crucial in this process, so it is essential that their practices are aligned with ESD, which requires rethinking pre-service and in-service teacher education from a perspective of promoting SD [21]. In addition, the development of quality educational resources to assist teachers in the implementation of ESD also seems to be of major relevance. For this, the integrated development of didactic resources suitable for the promotion of SD is also required, as well as continuing education programs corresponding to the needs and expectations of teachers [22] and reoriented towards SDGs [21,23].

As such, this paper aims to answer to two different but complementary questions:

Q1. *How can experimental practical teaching of science topics within the scope of ESD be operationalized inside and outside the classroom in an articulated, coherent, and progressive way throughout BE?*

Q2. *What in-service teacher education strategies will enhance the performance of teachers in the development of didactic sequences that promote this type of experimental practical teaching of science topics, within the scope of ESD?*

2. Methodology

The ISTEP was designed and developed based on the theoretical and methodological framework underlying an EDR approach. This approach requires close integration between theory and practice as the pathway to achieve solutions, as well as continuous, complex, and multifaceted research work [24]. The EDR is described as having great potential to assist researchers in understanding variables in real-life settings, namely in schools [25,26].

2.1. The Educational Design Research Approach

The EDR approach emerged at the end of the 20th century and the beginning of the 21st century, when some researchers shared concerns about the methodologies that were being used in education research [17,27–32]. According to these authors, investigations were increasingly being removed from everyday practical problems and issues, which led to a lack of credibility of the respective outputs and did not result in “usable” knowledge [16,29]. In 2006, Reeves stated that “the educational research community has often been its own worst enemy as a result of focusing more on establishing the legitimacy of one educational research tradition over another (such as the long-term struggle among the adherents of quantitative, qualitative, and critical methodological paradigms) rather than on improving education per se” ([17], p. 88).

As a way of overcoming some of these constraints, several researchers have pointed to an alternative approach: the Design Research. This approach, already described at the end of the 20th century [28], encompasses a set of Design Research types, which vary in denomination but which, in their structure, only differ in small details (in objectives or in one or another characteristic).

The “variants” of Design Research include Design-based Research [33], Development Research [32], Design Experiments [28,34], Formative Research [35], and Education Design Research or EDR [24,36–38]; the latter being particularly suitable for the present research.

The EDR is considered an approach that integrates the development of solutions to practical problems in learning environments with the identification of replicable principles [26]. It aims at the emergence of new theories, strategies, and practices with the purpose of boosting teaching and learning in appropriate environments [27].

The EDR approach aims at implementing investigative paths that bridge theory with practice to reach solutions, which implies continuous, complex, and multifaceted research work [24]. It requires a constant analysis of the effectiveness of the project, involving the different participants, to adapt the processes whenever necessary [39].

According to Anderson and Shattuck [40], an EDR study should consider aspects such as:

- *To be developed in a real educational context*

This study had a real educational context with the presence of the trainer-researcher (the first author of this work) in a group of schools, co-organizing an ISTEP for the co-construction/validation/reconstruction of teaching resources, including the assistance to the in-service teachers in their classes.

- *To constitute a significant intervention and likely to be replicated*

In this study, the objective was to create didactic resource for the development of practical work in Geosciences. The theme “Soils” was selected after analyzing the literature and considering the need for training in this Geosciences field by the participants in the study (the in-service teachers). Throughout the ISTEP, there was a clear collaborative interaction in the co-construction of didactic resources between the trainer-researcher and the in-service teachers, namely, to promote the articulation between intra and inter-cycle of schooling years, i.e., 1st, 2nd, and 3rd of the BECs.

- *To promote repetition of cycles during the process*

In this study, the co-construction of didactic resources involved several steps, with the repetition of some of them, with the purpose of creating didactic resources easy to adapt to any reality, i.e., that could be used by any teacher in their classes.

- *To develop collaboration between researchers and professionals in the field, in this case the in-service teachers*

In this study there was a strong involvement of the in-service teachers in the co-construction of the didactic resources with the trainer-researcher, either during the ISTEP design or during its implementation in the in-service teachers’ classes (since the trainer-researcher attended all these classes). This partnership involved several stages, from the selection of sub-themes and the strategies that each in-service teacher would use in their didactic resources, as well as different phases of evaluation/validation. There has always been collaborative work between the in-service researcher and all the in-service teachers. These were organized in teams from the same school grades, from the same teaching cycles, and even from different cycles to understand the relationship between the same subject over the various schooling years. Thus, the repetition of the same strategies for the same topics in different schooling grades was avoided.

- *To show methodological flexibility*

According to Plomp [16], the EDR assumes itself as an approach based on four pillars:

- (i) It uses scientific knowledge to support design proposals;
- (ii) It produces scientific knowledge, in addition to often directly enriching its participants;
- (iii) It organizes itself in three phases that can be cyclically repeated throughout the project: analysis/orientation phase; design/development creation phase; and evaluation/retrospective phase. Gravemeijer and Cobb [39] also consider three phases, but with slight differences: design research preparation; design research guidance; and retrospective analysis. There are other authors who present four-phase EDR

organization models, where there is an unfolding of phase three already presented. Reeves [17,41] suggests developing the EDR in four phases: problem analysis; development of solutions; iterative refinement; and reflection to produce design principles. All this diversity of perspectives brings the capacity to adapt the EDR approach to the different challenges, areas, and themes. In the present study, we opted for the organization in four phases, which are described in detail in Section 2.2. (Design and implementation of the In-Service Teacher Education Program);

(iv) It develops interventions in practice that result in reusable knowledge.

- *To evolve throughout the phases of the EDR* According to Reeves [41], in the final phases of an EDR there is a need for reflection to improve the design and implementation phases of the solution. The improvement of these phases is essential as they should not be watertight, but adaptable to various realities/contexts, depending on the conditions in which they are being implemented. A strong point of the EDR, when compared to other approaches, is that the evolution of the phases takes place in a real context and in a collaborative environment between the researcher and the other participants in the research. Thus, there is a greater probability of appropriation of the developed activities and strategies, and these are incorporated into real contexts, even after the researcher finishes his/her intervention. In this study, this evolution throughout the EDR phases allowed a strong collaboration between the trainer-researcher and the in-service teachers, with an appropriation by all, not only in the elaboration of the final products (the didactic resources), but throughout the entire creation and co-construction process, as well as its validation and, when necessary, its reconstruction.

In the following section, it will be described how the ISTEP was designed following the EDR approach.

2.2. Design and Implementation of the In-Service Teacher Education Program

In this study, the proposed EDR approach by Reeves [17,41] was adopted. In an EDR approach, participants are central to the investigation. If the ISTEP has only one trainer, the ideal number of participants is up to 20 in-service teachers per class. The in-service teachers were selected, taking into account the following criteria: (i) to be teachers of the school cluster where the ISTEP took place; (ii) to belong to the disciplinary cluster selected for the study (cluster 110—teachers of the 1st BEC; cluster 230—teachers of Natural Sciences of the 2nd BEC; and cluster 520—teachers of Natural Sciences of the 3rd BEC); and (iii) to show interest in participating in this study, agreeing with its pre-planning. Thus, 14 in-service teachers participated in this ISTEP: six from the 1st BEC, five from the 2nd BEC, and three from the 3rd BEC. There was also at least one in-service teacher from each school grade, from 1st to 9th grades. The total duration of the ISTEP was 50 h, 25 of which were face-to-face (after work), and 25 h of which was autonomous work. Table 1 represents the four phases and a summary description of the tasks that make up the design of this ISTEP.

Table 1. Synthetic description of the design of the In-Service Teaching Education Program (adapted from [17,41]).

EDR Phases	Tasks
Phase 1: Identification and analysis of practical problems by researchers with the collaboration of other professionals	<ul style="list-style-type: none"> ○ Problem identification ○ Meetings with researchers ○ Formulation of research questions ○ Literature review
Phase 2: Search for solutions and design proposals for its implementation	<ul style="list-style-type: none"> ○ Construction of the theoretical framework ○ Intervention design development to implement solutions ○ Description of the proposed design
Phase 3: Iterative cycles of testing and refining solutions in practice	<ul style="list-style-type: none"> ○ Implementation of the intervention (1st cycle) ○ Data collection ○ Data analysis

Table 1. *Cont.*

EDR Phases	Tasks
Phase 3: Iterative cycles of testing and refining solutions in practice	<ul style="list-style-type: none"> ○ Reformulation of design proposals, if necessary and as many times as necessary, repeating the last three steps ○ Implementation of the cycle ○ Data collection ○ Data analysis
Phase 4: Reflection to evaluate the design principles and improve the solution	<ul style="list-style-type: none"> ○ Formulation of design principles ○ Reformulation and presentation of didactic resources created by those involved in this process ○ Assessment and reflection on the entire process by the trainer-researcher and the in-service teachers

The data collection techniques and respective instruments were selected and adjusted during the study whenever deemed necessary and are referred to in Table 2. The results were previously published [42,43], and data were crucial for the successive validations of this ISTEP, thus adjusting and improving it until the model described below (Table 1).

Table 2. Techniques and respective instruments for data collection used in this work.

Data Collection Techniques	Data Collection Instruments
Inquiry	- questionnaire [42–44]
Documents compilation	<ul style="list-style-type: none"> - in-service teachers' works (didactic resources) [42] - in-service teachers' final posters (oral communication of the developed work) - in-service teachers' self-assessment [42]
Participant observation	<ul style="list-style-type: none"> - researcher's notes - researcher's diary (notes, reflections) - video recording - summary of video records

Phase 1—Identification and Analysis of Practical Problems by Researchers

The first phase included the EDR “guiding tasks”, with the identification of the problem, and the holding of meetings with the researchers and other professionals who participated in the study, to formulate the research questions (Table 1). At the same time, the literature review was carried out on the themes that integrated the investigation, to contextualize the problems. The literature review was a continuous process that followed the entire study, since new themes may arise to solve the problem that require the clarification of essential concepts [26]. Although these procedures may be common to other research approaches, in EDR they are essential to start the process.

Only after the identification of an educational problem is it possible to develop a research plan that creates conditions for its solution, and this path must have practical and scientific relevance. As in many other countries, the teaching of Natural Sciences in Portugal is usually less focused in Geology than in Biology, although within the programs and curricular guidelines both sciences display the same relevance. According to Carvalho [45] in “our schools and with the always necessary and honorable exceptions, this discipline [Geology] is limited to a set of disjointed subjects and disconnected from a unifying context, considered uninteresting and even boring”. To overcome this problem and contribute to stimulate interest in the Earth Sciences within society at large [46], it is necessary to adopt fundamental measures regarding the Didactics of Geology, namely in teacher education (pre-service and in-service).

Strong collaborative work between researchers and other professionals supported by the literature was also carried out. Several meetings were held with experts in Didactics and Geosciences, as well as with some teachers from the 1st, 2nd, and 3rd BECs, who collaborated in defining the previously referred to research questions.

Phase 2—Search for Solutions and Design Proposals for Its Implementation

The second phase included the construction of the theoretical framework (which accompanied all the work) required to start the development of the intervention design

to implement solutions (Table 1). This is a dynamic process, susceptible to constant adaptations necessary to solve the problem identified at phase 1. It led to the description of the design proposal, which at this early stage is not yet very detailed, leaving room for readjustment whenever necessary. It involved the collaboration with in-service teachers: (i) in the conception of the design proposal for the co-construction, validation, implementation and sharing of a didactic sequence (articulated and sequential throughout the BE) and respective resources on the theme “Soils” in an SD perspective, working in formal and non-formal educational contexts; (ii) in providing them with accredited teacher education, where they were able to develop this design proposal, with the aim of improving student learning and achieving international SD measures and commitments [21], and also through education in Geosciences [47].

Phase 3—Iterative Cycles of Testing and Refining Solutions in Practice

At this stage, the implementation of the intervention started, which took place over successive cycles. The co-construction, validation, implementation, and evaluation of the didactic sequence with the respective resources took place, in a collaborative work between the trainer-researcher and the in-service teachers (Table 1). During this phase, there were several changes throughout the cycles, which were necessary to adjust the investigation to the context and to the participants, until the intended solution was reached.

The co-construction of teaching resources with the in-service teachers involved five cycles:

- 1st cycle—initial version of the co-built didactic sequence and respective resources;
- 2nd cycle—validation of the didactic sequence and its resources by experts;
- 3rd cycle—review of the didactic sequence and respective resources by the in-service teachers;
- 4th cycle—implementation of the didactic sequence and respective resources, in the classroom, by the in-service teachers with the assistance of the trainer-researcher;
- 5th cycle—final adjustment, in cases deemed necessary.

Simultaneously, at various moments, data collection was carried out for later data triangulation and analysis (Table 2).

Phase 4—Reflection to Produce “Design Principles” and Improve the solution

In this final phase, according to Herrington et al. [26], it is necessary to reflect on: (i) the design principles, that is, on the possible generalizations of the EDR investigations carried out, in order to allow other researchers to adopt and recognize what may be relevant to their own specific configurations (scientific products); (ii) the products designed to address problems in teaching, learning, performance, or other, which can be from software packages, professional development programs, educational resources or other products (practical results); (iii) the professional development of the participants, that is, taking into account that these studies are carried out in collaboration with various actors (in this case in-service teachers and trainer-researcher), implications are expected for the professional development of the participants themselves (social products).

This reflection allowed progress towards the achievement of the results of this investigation, which are presented in the next section.

3. Results and Discussion

As a result of the tasks carried out in this ISTEP, a set of products was obtained, namely scientific products, practical results, and social products:

(i) *The design principles*

Table 3 describes in detail the organization of the ISTEP developed for the “Soils” theme, which is usually approached in Geosciences but can be adapted to other research contexts, themes, and disciplines.

Table 3. Description of the organization of the ISTEP, developed according to an EDR approach, which can be adapted to other research contexts and disciplines.

EDR Phases	EDR Phase Description	EDR Tasks Applied to the ISTEP	Approximate Duration ****
Phase 1	Identification and analysis of practical problems by researchers with the collaboration of other professionals	Problem raising by the trainer, relevant to be developed in the context of teacher education.	3 months
		Brainstorming with researchers and other professionals to assess the relevance of the theme, to solve the problems, and to formulate the research questions.	
Phase 2	Search for solutions and design proposals for its implementation	Planning of the intervention and elaboration of the initial design to solve the identified problems. *	
		Establishment of contacts to define the location, calendar, and participants of the ISTEP. *	
		Preparation of instruments for data collection (for example for the ISTEP assessment), with validation by experts in the field. *	
		Request for necessary authorizations to the Competent Entities for the development of studies in school contexts and accreditations for the ISTEP. * **	
Phase 3	Iterative cycles of testing and refining solutions in practice	The trainer promotes brainstorming sessions among in-service teachers so that they can describe their own practices to develop a given topic.	2 h of face-to-face work
		Presentation, by the trainer, of a set of resources to develop a given topic, in an SD perspective, then challenging the in-service teachers' teams to prepare a didactic resource.	5 h of face-to-face work
		Analysis and discussion on existing curricular documents and benchmarks by the different working groups (e.g.: continuity of the themes over the years, the existence or not of a clear orientation for ESD).	2 h of face-to-face work
		Each in-service teacher, with the guidance of the trainer ***, defines and develops a plan, including diversified strategies and respective didactic resources, which will be validated by specialists (this task can be repeated several times if necessary).	10 h of face-to-face work; 12 h of autonomous work
		Classroom validation, where each in-service teacher implements in a class (with the assistance of the trainer, whenever possible) the strategies and resources that they co-built.	3 h of autonomous work
		At the end of the implementation, if necessary, make small adjustments and corrections in the co-constructed didactic sequence.	1 h of face-to-face work; 2.5 h of autonomous work
		Preparation and oral presentation of a poster communication (10 min) by each in-service teacher to the others, describing the activities developed during the ISTEP.	5 h of face-to-face work; 5 h of autonomous work

Literature review and construction of the theoretical framework

ISTEP preparation

During the ISTEP

Table 3. Cont.

EDR Phases	EDR Phase Description		EDR Tasks Applied to the ISTEP	Approximate Duration ****	
Phase 4	Reflection to evaluate design principles and improve the solution	Literature review and construction of the theoretical framework	After the ISTEP	Ask the in-service teacher for a reflection (with guidance points provided by the trainer), for the ISTEP assessment, with the main objective of understanding whether, for the in-service teachers, the identified problem has been solved.	2.5 h of autonomous work
				Reflection on the idealized and implemented design, and formulation of adjustments for the elaboration of the ISTEP's design principles.	
				Organization of the plannings for sharing with in-service teachers [42] and, if possible, dissemination for use by other teachers (for example, creating an e-book).	2 months
				Final reflection: ISTEP assessment by the trainer and in-service teachers.	

* Tasks that occurred simultaneously. ** Tasks required in some countries if the ISTEP is to be included in a research work. *** Depending on the schooling grade of each in-service teacher, the creation of a didactic sequence should be promoted, with planning for different years of schooling on the same subject, displaying sequentially and ensuring the non-repetition of the proposed activities. **** Having as a reference for this ISTEP a full-time trainer.

The importance of ISTEP is fully recognized, as these programs allow in-service teachers to consolidate knowledge of disciplinary and didactic content on the selected topic, and to support its proper implementation with students [22]. The ISTEP in Geosciences are fundamental to face many of the current environmental challenges, since most geologists are far from environmental concerns for which their knowledge can be decisive [47], and the public perception of their role to promote sustainability is also quite unknown [46]. To overcome this situation, it is urgent that SD principles and practices are explicitly integrated into Geoscience education. The organization of suitable ISTEPs, which can correspond to the needs and expectations of teachers, may contribute to improving their self-confidence in the implementation of innovative approaches in their practices, and in line with the SDGs [21,23].

If planned from an EDR perspective, the results generated by an ISTEP can support other research projects in science education fostering improvements in teachers' practices and, consequently, in students' learning (e.g., [11,12]).

(ii) *The practical results*

As a result of the ISTEP, all co-constructed resources were organized, creating an e-book with the didactic sequence on the theme "Soils" throughout the BE, which reinforces the role of research in the design and validation of didactic resources to support teaching and learning for SD [22]. Table 4 presents the proposals developed by the in-service teachers and the trainer-researcher by schooling grades, as well as the topics covered in each grade.

Table 4. Activities organized by schooling grade.

Grade	Contents Underlying the "Essential Learning" (Curriculum Guidance Document)	Activity/Strategy	Guiding Question
1st	Natural elements of the local landscape	Fieldtrip	What natural elements can we find in the park next to the school?
2nd	Goods common to humanity	Experimental practical activity	What is the influence of fires on soil loss?
3rd	Importance of different environmental factors	Experimental practical activity	What is the influence of soil type on chive development?
4th	Ways of contamination	Research activity	Does soil contamination only have local implications?
5th	Soil components Soil characteristics	Experimental practical activity Experimental practical activity	How to simulate a mature soil profile? What is the influence of constructions (housing, roads ...) on soil permeability?
6th	Influence of several factors on photosynthesis Autochthonous forest and its conservation	Experimental practical activity Lecture and research activity	Does the type of soil influence photosynthetic activity? What is the influence of the autochthonous forest on the richness of the soils? And in biodiversity?
7th	Human intervention and its impacts on sediments transport and sedimentation processes: the role of dams	Experimental practical activity	What is the impact of dams on sediment transport for the formation of alluvial soils?
8th	Influence of abiotic factors on ecosystems	Experimental practical activity	What is the influence of earthworms in soil enrichment?
9th	Healthy food, food production, and sustainability	Virtual field trip and discussion	What are the advantages and disadvantages of organic farming compared to conventional farming?

Each chapter is assigned to one schooling grade, and it includes information about the curricular framework, the purpose of the activities and the exploration proposals. It also contains bibliographic references for teachers who want to delve deeper into a given topic, and Appendices, which are editable documents ready to be used or adapted to each context (such as planning, diagnostic activity, students' activities, observation grids for the teacher).

(iii) *The social products*

Social products refer to the professional development of participants [26]. The analysis of the in-service teachers' answers to the ISTEP assessment instruments and the reflections they shared show that participants highlighted as positive aspects for their professional development the fact that the program: (i) stimulated innovation within the syllabus of each subject; (ii) covered the three BECs attended by teachers from different schooling grades, from the 1st to the 9th grades; (iii) allowed the sharing of sensitivities and knowledge among the participants; and (iv) reinforced self-confidence in exploring topics related to Geosciences, an area for which some in-service teachers initially recognized the need to

improve their scientific and didactic knowledge. These results are in line with the results of similar studies, where the in-service teachers recognized that they acquired skills that they did not have or that were not sufficiently developed [22,48].

As an aspect to improve, the in-service teachers mentioned the duration of the ISTEP, which they consider very long, a comment also made by the in-service teachers who participated in the program described by Richter et al. [49].

4. Conclusions

Science education is crucial to train citizens who are increasingly challenged to overcome environmental disruptions with strong social and economic impact [3,7], such as desertification or soil contamination [20,23].

Like other natural resources, the sustainable management of soils can contribute to achieve several SDGs, namely by reducing poverty and hunger, by providing healthy food and well-being, or by helping to increase clean water supplies, among others. However, teachers are not always adequately qualified to deal with these issues in their practices, especially because their previous training is essentially disciplinary. Education to face environmental problems requires innovative approaches integrating transversal and interdisciplinary knowledge that must be clearly focused on SDGs.

ISTEPs are particularly relevant in providing teachers with adequate abilities to foster ESD [2]. When organized based on their needs and expectations, such programs are likely to develop skills that make it possible to support and sustain science teaching and learning considering the 2030 SDGs.

This work presents the design of an ISTEP developed through an EDR approach, and its implementation with 14 teachers from the three cycles (from the 1st to the 9th grades) of Portuguese Basic Education (ages 6–15), taking “Soils” as the theme to focus on.

As a result, an integrated set of activities and respective didactic resources organized by schooling grade (from the 1st to the 9th) were co-built (the trainer-researcher with the in-service teachers) with a progressive, systematic, and sequential vision of the “Soils” theme, through an SD perspective.

The results point to an improvement in the practices of the in-service teachers regarding the ability to plan and design didactic resources on science topics from a DS perspective. For these improvements to be effective and lasting, however, it is necessary that teachers understand, value, and be able to implement these new or revised strategies. This seems to have been achieved given the participation and commitment of the in-service teachers during the ISTEP, as well as the content analysis of their answers to the questionnaires and in the final reflection. The relevance of this ISTEP, considering the results presented, is in line with the recognized need to reorganize teacher education oriented towards ESD, in this case having theme of soil.

The ISTEP presented here can be more easily be achieved for the Portuguese BE, i.e., in Portuguese schools located either in Portugal or in Portuguese-Speaking Countries that are guided by official Portuguese curriculum documents (Angola, Cape Verde, East Timor, Guinea-Bissau, Macao Special Administrative Region of the People’s Republic of China, Mozambique, and São Tomé and Príncipe) [50,51]. Furthermore, it can guide the national curricula of most of the former Portuguese colonies because of the close cooperation, as it frequently happens, between the members of the Community of Portuguese Speaking Countries in all areas, including education [52,53]. The methodology adopted for its design and implementation may also contribute to inspire similar initiatives adapted to other educational contexts and to other themes that seek to promote quality education, among other SDGs inscribed in the 2030 Agenda.

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