EXPLORING ROCKS AND MINERALS: AN EXPERIENCE OF INTEGRATED EDUCATIONAL APPROACH

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Abstract

Science education begins long before children enter school. Indeed, when children go to school they carry out with them different learning experiences, developed in informal and non-formal contexts, that School cannot ignore. Therefore, teachers should not only consider learning experiences developed both in non-formal and informal settings, but also know how to integrate them in classroom activities. The purpose of this chapter is to present a study that consisted in the conception, planning, implementation and assessment of an in-service training programme for teachers of Primary School (pupils from 6 to 10 years old), in Portugal, which aimed at the development of science education integrated practices, by focusing on a specific theme of Geology, in this case "Rocks and Minerals".

In this training programme, science education practical activities in formal, non-formal and informal contexts were explored. The programme took place in the Integrated Centre of Science Education of the "Ciência Viva" School (a public primary school) of Vila Nova da Barquinha, from April to November 2015.

This qualitative descriptive-oriented study aimed to evaluate: (i) the effects of the teacher training programme in the professional development of the in-service teachers; (ii) in-service teachers' pedagogical practices, before and after the training programme, namely in what concerns the theme "Rocks and Minerals"; (iii) the didactic approach proposed to be developed with Primary School students.

Results indicate that the teacher training programme contributed positively to the professional development of the in-service teachers, namely by improving their practices with regard to the integration of formal, non-formal and informal sciences education contexts, in particularly in approaching the theme "Rocks and Minerals". Regarding the approach of the theme with Primary School students, which was explored in the training programme and implemented by some of the in-service teachers with their classes, results point to an appropriateness of the proposal.

It is therefore considered crucial to invest in the promotion of integrated practices of formal, non-formal and informal education, namely on themes of Geology, in the first years of schooling.

Keywords: Science Education; formal, non-formal and informal educational contexts; teacher training; Geology teaching in the early years of schooling.

1. Introduction

Society today is faced with problems, such as unemployment, poverty, hunger, part of the population aging, migration movements, wars and conflicts, depletion and exhaustion of natural resources, as well as the widespread impact of some of the levels and patterns of consumption, which evidence the planetary emergency situation we have reached and we need to face (Rodrigues, 2011). In order to deal with this planetary emergency, a citizenship exercise of global dimension that implies an insight into the scientific dimension of these issues is imperative, i.e., it is essential to increase the scientific literacy levels of the population, as it has been internationally acknowledged (Acevedo-Díaz, 2004; Fensham, 2004; Martins, 2004; Osborne & Dillon, 2008; Rocard et al., 2007; Sanmartí & Marchán, 2015).

According to the OECD, scientific literacy may be defined as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (OCDE, 2013, p. 7).

Thus, and according to Martins (2004), in order to promote students' scientific literacy it is necessary to encourage them to identify problems, to explain phenomena, to develop reasoned conclusions, as well as to develop creativity and critical thinking. These competences, which are considered essential for decision making and problem solving, go beyond the school context, aiming at the development, in the short and long term, of more emancipated citizens as far as the Science-Technology-Society (STS) interrelationships are concerned. Science Education plays an essential role in providing students with the opportunities and resources that may encourage them to develop these and other skills (DGEC, 2007), through innovative educational practices that motivate them to learn. However, many teachers still argue for a teaching-learning process focused on content and not on students, teaching as they were taught. A paradigm shift is therefore needed, so that, by promoting the development of students' scientific literacy, we may have an informed public, with critical thinking and rational and reasoned behaviour (Aikenhead, 2009). Innovative approaches to Science Education that take into account all the diversity, namely in terms of settings, available resources and social contexts, and that promote the development of these and other skills are then required. These approaches, in turn, demand reorientation in science teachers' training.

However, and in spite of the importance of formal science education for this increase in scientific literacy levels being widely recognized, it is acknowledged that this is not sufficient; indeed, non-formal and informal science education contexts are also key aspects for promoting the scientific literacy of the population in a perspective of lifelong learning. Currently, national and international guidelines for science education point in this direction, i.e., they aim at integrating experiences of non-formal and informal contexts, by valuing, in the students' formal education process, their personal and social experiences outside school (Guisasola & Morentin, 2007; ICSU, 2011; NRC, 2009; Pedretti, 2002). Additionally, with regard to this integration of formal, non-formal and informal educational contexts, several studies suggest a deficit in teachers' preparation. For example, in planning, guiding and assessing study visits to non-formal and informal educational settings, the preparation of the pre and post-visit is non-existent or incipient (Faria & Chagas, 2012; Guisasola & Morentin, 2007; Jarvis & Pell, 2005; Kisiel, 2006; Metz, 2005; Rodrigues, 2011). Thus, it becomes crucial to include these guidelines in pre and in-service teacher training programmes, in order to maximize the opportunities that visits to non-formal educational settings provide in terms of the children's learning development (DeWitt & Osborne, 2007).

According to Rodrigues et al. (2015), teacher education is a public policy area where best practices are demanded, thus contributing to the development of the best educational models with regard to the integration of science education formal and non-formal practices. It is therefore considered a promising way to develop a better scientific literacy in future teachers and, subsequently, in their future students.

Teacher education assumes, thus, a leading role in this change process, both in terms of theme and practices. However, so that these changes may have an effect in the classroom and/or in other non-formal (e.g. science interactive museums and centres) and even informal settings (e.g. factories, streets, monuments), it is necessary that teachers understand, value and are able to implement new science teaching approaches (Rebelo, 2014).

In the Science Education field, less attention has been given to Geology, although this is not evident in programmes and curriculum guidelines. According to Carvalho (2015), in "our schools, and notwithstanding the always necessary and honourable exceptions, this school subject is limited to a set of disconnected and decontextualized topics, often seen as uninteresting and even tedious" (our translation). Associated to this mind-set is the insufficient training of many, maybe the majority, of the teachers. Still according to Carvalho (2015), "there are many poorly qualified teachers that deliver themes unenthusiastically, by mere obligation […] uncritically, they follow the stereotyped and equally uncritical adopted textbook" (our translation). According to the author, it is in this context that the majority of men and women are graduating, including those who play decisive roles in politics, administration, businesses and the media. To reverse this situation, substantive measures are needed with regard to the teaching of Geology, such as changes in the programmes, school textbooks, the available teaching resources and even reformulations in teacher education.

Thus, in the context of the current curricula of Geology, teacher education should help teachers

develop an integrated and holistic view about the organization of geological knowledge, in order to adequately explore the "relationships between this type of knowledge (e.g. geological resource), technological applications (e.g. technology involved in the prospection and transformation of the geological resource) and society (e.g. use of geological resources by humanity)" (our translation) (Rebelo, 2014, p.7).

It is based on this issue that the present chapter gives an account of a study consisting in the conception, planning, implementation and assessment of an in-service training programme for Primary School teachers on integrated practices of science education, focusing on the exploration of a theme of Geology. Throughout the in-service teacher training programme, a proposal for the didactic exploration of the theme "Rocks and Minerals" by Primary School children was developed with the teachers. The proposal included the design of kits, as well as the elaboration of the respective teacher's guidelines concerning the exploration of the didactic resources and the conception of guiding documents for pupils (tasks to be done and the corresponding experiment report worksheets). Teachers participating in the programme adapted the activities to their classes and validated the didactic approaches proposed.

2. Teacher training programme "Integrated practices of formal and non-formal science education"

The in-service teacher training programme "Integrated practices of formal and non-formal science education" assumed the workshop format and emerged from the need expressed by a group of Primary School teachers of the "Ciência Viva" School of Vila Nova da Barquinha (VNB), which stands out for having an Integrated Centre of Science Education (CIEC) [1].

This innovative school project emerged in the context of the National Programme for the Re-qualification of the School Network of Preschool and Primary School in Portugal (2007-2015). In this sense, the municipality of VNB decided to develop, in collaboration with the University of Aveiro, the project of an innovative Primary School that would be based on guidelines emerging from research and that would have a strong focus on science education. It was in this context that the CIEC emerged, being also based on guidelines and recommendations on the importance of lifelong learning (PE & CE, 2006), in this case in science education and from the early years of childhood; it also derived from the urgency of conceiving strategies that would aim at the development of all individuals' scientific literacy, by integrating learning experiences resulting from different formal, non-formal and informal contexts (Rocard et al., 2007).

The CIEC falls into this perspective in the sense that it aims to engage individuals, from early childhood, with science and scientific phenomena, for the promotion of scientific literacy throughout life, namely by integrating different types of science learning, developed in formal, non-formal and informal contexts. The CIEC is embodied by the creation of a non-formal science education setting within a formal educational institution, and by the creation of a science laboratory specifically designed for the development of practical activities within the scope of Primary School formal education. It is an innovative perspective of the organization of science education, integrating formal and non-formal contexts (for further information see Rodrigues, 2011).

In was in this context that the in-service teacher training programme entitled "Integrated practices of formal and non-formal science education" [2] was conceived, implemented and assessed, a programme in which two themes were explored, one of which was "Rocks and Minerals".

2.1 Structure and organization

Some of the principles/guidelines underlying the design of this teacher training programme were: (1) teachers' needs and expectations; (ii) teachers' reflections and sharing of experiences, namely in previous teacher training programmes; (iii) the priority given to carrying out science practical activities of the STS kind that teachers could implement with their pupils; (iv) the value assigned to group work;

[1] Centro Integrado de Educação em Ciências (CIEC) — http://www.ciec.vnb.pt

[2] In-service teacher training programme accredited by the Scientific and Pedagogical Council for In-service Teacher Training, with the reference n. º CCPFC/ACC-83184/15.

(v) the existence of science education teacher training integrated activities (in formal, non-formal and informal contexts) (Rodrigues, 2011).

The following goals were defined:

- To raise teachers' awareness about the importance of the development of individuals' scientific literacy, from the earliest years of life;
- To optimize the teacher's role in introducing pupils to the learning of Sciences;
- To develop teachers' knowledge of disciplinary scientific and didactic content;
- To promote the exploration of didactic approaches for the teaching of Sciences in formal and non-formal educational settings, considering the age and the cognitive development levels of pupils;
- To promote the planning, implementation and assessment of science education integrated practical activities;
- To develop an attitude of interest, appreciation and fondness for Science and for Science Education, both personally and professionally.

The in-service teacher training programme, which took place between April and November 2015, comprised 25 contact hours and 25 non-contact hours and was attended by 12 in-service teachers (in-service teachers will be referenced when needed as teachers trainees (TT) – TT1, TT2,…, TT12).

Two researchers/teacher trainers developed this in-service teacher training programme: one, holder of a Ph.D. degree in Didactics and Teacher Education, has 16 years of experience in higher education, namely on experimental science in the early years of schooling; the other holds a Master degree in Heart Sciences.

The contact sessions took place in formal (laboratory), non-formal (CIEC) and informal (streets and the Almourol Contemporary Sculpture Park[3]) settings. In the non-contact sessions, the in-service teachers developed activities with a class of Primary School children, in formal, non-formal and informal contexts, and prepared a communication poster in which they described the whole process of conception, planning, implementation and assessment of the activities developed with the pupils, as well as an individual reflection about the effects of the training programme on their professional development.

Afterwards, they presented and orally defended the communication poster to their peers and registered in a table, with previously defined criteria, their self-assessment and the assessment of others' performances. The two researchers/teacher trainers also registered their assessment in an identical table.

The minimum criteria for being approved in the training programme were: the participation in 2/3 of the sessions and the delivery of the final assignments established in the programme. The researchers/teacher trainers' assessment of each in-service teacher resulted in the number of credits presented below (Table 1)[4].

Table 1 – Relationship between the quantitative and qualitative assessment scales and the number of credits.

Quantitative assessment (on a scale of 1 to 10)	Qualitative Assessment	Number of Credits
1 to 4,9	Insufficient	0
5 to 6,4	Sufficient	2
6,5 to 7,9	Good	2
8 to 8,9	Very good	2
9 to 10	Excellent	2

2.2 Themes

The themes of the training programme were selected by the teachers: (i) rocks and minerals, and; (ii) forces and motion. In this chapter, we will only present the module concerning the exploration of the theme "Rocks and Minerals".

2.3 Description of the training sessions

[3] http://www.barquinhaearte.pt/pt/

[4] This process was based on the joint guidelines of the CCPFC/DGRHE about the Qualitative Assessment of Teacher Training Programmes (Circular Letter CCPFC - 3/2007, September 2007).

Throughout the training programme, sessions of different nature and in different settings (formal, non-formal and informal) were developed. The sessions on "Rocks and Minerals" are summarised in Table 2, which also explains the setting (formal, non-formal and informal) where the sessions took place.

Table 2 – Scheduling of sessions and settings where they took place.

Session(s)	Date	Time	Setting		
			Formal	Non-Formal	Informal
S1	28 March 2015	10:00 a.m. – 01:00 p.m.	x		
		02:30 p.m. – 05:30 p.m.			x
S2	10 April 2015	04:30 p.m. – 07:00 p.m.	x	x	
S3	11 April 2015	09:00 a.m. – 01:00 p.m.	x		
		02:30 p.m. – 05:00 p.m.	x		
S4	2 July 2015	10:00 a.m. – 01:00 p.m.	x		

Next, we describe each one of the sessions of the in-service teacher training programme concerning the subject study "Rocks and Minerals".

Session I — A brief introduction to the topic was made, stating the importance of science education from the early years, comprising formal, non-formal and informal dimensions. The main guidelines in science education for these levels of education were also presented. The key topics discussed were:

(i) Scientific literacy: conceptual framework and pathways towards its development in formal, non-formal and informal contexts.
(ii) Science Education in Primary School: its importance and purposes.
(iii) Current perspectives on Science Education (e.g. STS approach, Inquiry Based Science Education).
(iv) Learning assessment in terms of knowledge, skills, attitudes and values.

The starting point for the exploration of the theme "Rocks and Minerals" was in-service teachers' experiences, identified by the means of an questionnaire survey, in which teachers were solicited to describe the way they usually explored this theme with their pupils in the classroom and in non-formal and informal contexts as well. Thus, starting from the sharing of those experiences new possibilities for the approach of the theme were discussed.

Then, the researchers/teacher trainers provided the in-service teachers with some background information on a study visit to an informal context (in this case, VNB streets and the Almourol Contemporary Sculpture Park), a visit to be carried out later on that day.

All the phases foreseen in a study visit (before, during and after) were explored with the in-service teachers, opting for a strategy similar to the one that they were expected to develop with their pupils.

In the afternoon, the study visit was carried out. It included a walk through the streets of VNB and the exploration of the Almourol Contemporary Sculpture Park, where sculptures (of different materials such as granite, concrete, iron, marble[5]) of the most representative Portuguese contemporary sculptors are exhibited. Throughout the visit (Figure 1) practical applications and uses of rocks and minerals in the daily life have been identified. It was aimed that the in-service teachers would experience and explore themselves, in a different teacher training environment, activities that they could develop with their pupils. In addressing the topics, particular attention was given to the identification of previous ideas on the subject (e.g. "all the dark rocks are basalt"; "limestone is always white"), to the simulation of experiences to be carried out with the pupils and to the discussion of didactic strategies that would enable the (re)construction of those ideas. Teachers were also asked to explore other alternatives for future visits, such as museums, science centres, geoparks – places to select depending on the issues teachers wanted to work with their pupils.

During this study visit, the in-service teachers made written and photographic reports on what they observed, for subsequent discussion among peers and with the researchers/teacher trainers.

[5] All these works of art are located in the seven hectares of the Almourol Contemporary Sculpture Park.

Figure 1 – Photographs of sites visited by the in-service teachers.

Session II — In this session, a reflection on the study visit was made, summarizing the direct and indirect practical applications of rocks and minerals. Photographs taken during the study visit were analysed, in order to clarify some ideas, concepts and processes, namely through the exploration of a Rock Cycle (Figure 2).

Figure 2 – Rock Cycle.

Then, a set of 19 hand samples (Table 3) was explored and classified according to the following categories: sedimentary, igneous and metamorphic.

Table 3 – List of the 19 hand samples of the rocks explored.

Rocks
Granite, Rhyolite, Diorite, Andesite, Gabbro, Basalt, Sands, Sandstone, Mudstone, Breccia, Conglomerate, Coal, Rock Salt, Limestone, Slate, Schist, Gneiss, Quartzite, Marble

Sedimentary rocks were subdivided according to the sediment class: clastic (sands, sandstone, mudstone, breccia and conglomerate), biogenic (coal) or chemical (rock salt and limestone); magmatic rocks were subdivided according to the place of formation – intrusive or plutonic (granite, diorite, gabbro) and extrusive or volcanic (rhyolite, andesite, basalt) – and features such as chemical composition, colour and texture were also analysed; metamorphic rocks were subdivided by type of metamorphism – regional (slate, schist, gneiss) or contact (quartzite, marble), classed as foliated and nonfoliated, respectively, by relating them to the temperature and pressure at the time of their formation.

In this exploration, emphasis was given to the relationships between the intrusive and extrusive magmatic rocks formed from the same magma, since during the exploration of the set of rocks it became evident that teachers considered the basalt and granite to be formed from the same magma. One of the factors that may be contributing to this erroneous conception is that in school textbooks this pair of rocks is often presented as an example of extrusive and intrusive magmatic rocks, respectively. Thus, this concept was discussed, by presenting the following peer examples of intrusive-extrusive magmatic rocks, formed from the same magma: granite-rhyolite, gabbro-basalt and diorite-andesite.

Afterwards, the place of origin of these hand samples was discussed by looking into the abovementioned Rock Cycle (Figure 2), and by trying to put the samples in the correct places.

Given that the purpose of this activity was to develop teachers' knowledge of disciplinary scientific content, it was not considered a didactic approach to be implemented with Primary School children.

In order to develop a didactic approach of the theme to be implemented with the pupils, 8 samples from that larger set were selected: granite, basalt, rock salt, sand, limestone, marble, schist and slate.

Criteria underlying the selection of these rocks comprised the existence of rock samples in the local area (e.g. granite in the Almourol Castle, sands in the banks of the Tejo River) and pupils' acquaintance with their practical applications in daily life (e.g. rock salt of the salt fields of Rio Maior; limestone of the traditional Portuguese pavement; marbles of kitchen countertops; schist in the Schist Villages). The selection of limestone and marble was also due to the relationship between them, taking into account that limestone is the protolith of marble. Basalt was included for being a typical extrusive igneous rock of the archipelagos of Madeira and the Azores. Schist and slate were included because, in spite of being both metamorphic, they present different degrees of metamorphism.

In-service teachers were then asked to carry out an activity, in small groups, in which they had to explore this set of 8 rocks according to typical features of sedimentary, magmatic and metamorphic rocks (Figure 3), namely:

- Metamorphic rocks (marble, schist and slate): observation of texture (foliated and nonfoliated), observable colour or colours, other observations;
- Magmatic rocks (granite and basalt): crystals visible to the naked eye or with the aid of a magnifying lens, observable colour or colours, other observations;
- Sedimentary rocks (rock salt, sands, limestone): consolidated or unconsolidated, observable colour or colours, other observations.

The relevance and adequacy of these sets of samples, as well as the significance of addressing these types of features in Primary School, were discussed with the in-service teachers.

Figure 3 – Worksheet for the observation of the hand samples of rocks by in-service teachers.

In the end, the in-service teachers organized 6 didactic kits, each one of them comprising 8 rock specimens (properly explored, numbered and catalogued) and a proposal for the exploration and registration of the rocks' features, to be implemented with the pupils afterwards (Figure 4).

Figure 4 - Kits of rocks organized by in-service teachers

In this didactic proposal, pupils were expected to explore the 8 rock samples with the aid of a magnifying lens, bearing in mind the observable features (as shown in Figure 3).
It was also proposed that pupils carried out some research (based on a research guideline, with questions, and suggestions of sites and bibliography) in order to find out information about the formation and practical applications of these rocks, as well as to confirm if there were any of them in the region where they lived. At the end, the teacher would explore the results obtained and help pupils summarize the main conclusions.

Then, teachers visited the CIEC, more specifically the module entitled "Rocks in which I stumble" (Figure 5), in which they could see the main rocks of the municipality and their location on a map, as well as observe some samples of these rocks. Since this is a resource that is available within the school walls, teachers cannot ignore it when exploring this theme with their pupils. In the same way, other modules on CIEC, such as "The tent of archaeology and palaeontology", should also be taken into consideration when exploring the theme of "Rocks and Minerals".

Figure 5 – Photographs of the module "Rocks in which I stumble" and of the map on CIEC.

Session III — This session began with the establishment of a link between rocks and minerals, i.e., by stating that all rocks are made of minerals. Then, a few hand samples of minerals were explored according to their features (colour, brightness and streak), and the corresponding written reports were made in a table (Figure 6).

Figure 6 – Worksheet for the observation of hand samples of minerals by in-service teachers.

Some of the criteria used to select the minerals to be analysed were their usefulness in everyday life, their exploration in nearby locations or the fact of they had a particular feature, such as: hematite and magnetite, due to their magnetic properties; talc, because of it is well-known use as talcum powder for babies; calcite, for its use in the manufacture of cement and also for its occurrence in the Serra dos Candeeiros, nearby VNB; graphite, because everybody uses it in pencils; fluorite, because it is a source of fluorine; the halite, for being a source of salt; the pyrite, due to its appearance similar to gold; quartz, for its abundance and practical uses, particularly in glass manufacturing, optical fibbers and watches, being also used as ornamental objects and jewellery; feldspar, for being also very abundant and for having numerous applications in industry, particularly in glass and ceramics; and plaster, due to its exploration in areas nearby VNB (Leiria) and to its uses in the construction industry.

The *Mohs* scale was then presented and explored, by explaining its purpose, how it should be used and how it could be replaced, by using, for the same purpose, a fingernail and more affordable tools with similar hardness to some of the minerals of the *Mohs* scale (fingernail – hardness 1/1,5; copper coin – hardness 3/3,5; nail – hardness 4/4,5; and glass plate – hardness 6).

The relevance and adequacy of this set of samples, as well as the approach proposed to analyse these properties/features with Primary School students was discussed with the in-service teachers.

Then, the TT organized 6 didactic kits, each one of them comprising 11 minerals (properly explored, numbered and catalogued) and a proposal for the exploration and register of the minerals' features, to be implemented with the pupils afterwards (Figure 7).

Figure 7 – Kits of Minerals organized by in-service teachers

In this didactic proposal, pupils were expected to explore the minerals, bearing in mind: (i) the observable features (colour, brightness), and others features, by carrying out small actions, such as (ii) determining the streak (by drawing a line with the mineral sample in the unglazed porcelain plate), (iii) verifying if the minerals had magnetic properties (by placing each mineral close to an iron object and verifying if it was attracted by it or not) and (iv) determining the minerals' hardness (by using the fingernail and the alternative tools previously presented). In order to accomplish these actions, the following items were included in the kits: a magnifying glass, an unglazed porcelain plate, a cooper coin, a nail and a glass plate. Pupils were also expected to do some research on the formation and practical uses of the minerals, and to confirm the existence of these minerals in the region where they lived. At the end, the teacher would explore these results with the class and help pupils summarize the main conclusions.

After these contact sessions, in which all in-service teachers accomplished these activities, five of them decided to do they final work on this theme, that is, they planned and implemented activities with their pupils either in classroom context or in the laboratory (formal setting), or in the context of study visit (CIEC – non-formal context; and streets of VNB and Almourol Contemporary Sculpture Park – informal context), having elaborated a communication poster where they explained the pathway pursued. In **session IV**, all teachers presented and discussed their communication posters.

3. Methodological procedures adopted

This qualitative descriptive-oriented study assumes the format of a case study (Stake, 2007). The data collection procedures used were: a questionnaire survey; participant observation and field notes produced by the researchers/teacher trainers; and documentary collection (lesson plans, descriptions of sessions, records kept by the in-service teachers during the sessions, communication posters, individual reflections and grids of self and hetero-assessment). Analysis of the data was conducted by resorting to the content analysis technique (Bardin, 2009).

3.1 Assessment of the effects of the teacher training programme in the professional development of the in-service teachers

In order to analyse the effects of the training programme in the professional development of the in-service teachers, a content analysis of their individual reflections was made, based on the research instrument presented in Table 4.

Table 4 – Research instrument "Professional development of in-service teachers"

Analysis dimensions	Analysis parameters
Science Education guidelines	He/she recognizes and understands the importance of science education for everyone from the earliest years of schooling.
	He/she is acquainted with the different perspectives of Science Education and understands their implications on the teaching of sciences in formal and non-formal contexts.
	He/she values the importance of an integrated science education.
Management of teaching and learning processes in Science Education	He/she masters the scientific contents inherent to the topics covered in the training programme, adjusting them to the level of education in which he/she teaches.
	He/she knows and masters different teaching methodologies and strategies on the topics covered.
	He/she develops science activities in formal, non-formal and informal settings.
Assessment of pupils' learning outcomes	He/she assesses pupils' learning progress.

At the end of the training programme, in-service teachers were also asked to assess their performance, bearing in mind each of the in-service teacher training programme objectives (corresponding with the analysis parameters presented in Table 4), on a scale of 1 to 5 (1 - minimum and 5 - maximum).

3.2 Assessment of in-service teachers' practices (before and after the teacher training programme) concerning the theme "Rocks and Minerals"

The analysis of the in-service teachers' practices concerning the theme "Rocks and Minerals" in formal, non-formal and informal contexts, was based on: (i) their answers to the initial questionnaire, which allowed us to characterize their practices before participating in the training programme; (ii) the activities developed by five of the in-service teachers with their classes at the end of the training programme (presented in a communication poster in the last training session). In order to ascertain changes in their practices, we resorted to two research instruments used by Rodrigues (2011), which focus on the main aspects to consider when developing a study visit (Table 5) and an experimental activity (Table 6).

Table 5 – Research instrument "Study visit" (adapted from Rodrigues, 2011)

Study visit	
	Pre-Visit
Teacher preparation	Definition of the intention / purpose of the visit (stimulate or motivate; introduce a topic; revise and consolidate)
	Collection and organization of information documents about the visit
	Visit to the site
	Planning of the visit (definition of the duration of the visit, research on the themes, selection of activities and modules, decision on the route(s) to follow...)
Pupils preparation	Contextualization of the study visit by addressing the themes studied or to be studied
	Providing basic information on the site
	Engaging pupils in the preparation of the visit (research on the themes and on the place to visit, elaboration of the visit guidelines...)
	Identification of pupils' preconceived ideas on the contents / phenomena to be explored during the visit
	Definition of the visit's learning outcomes
	Writing a list of questions to be asked during the visit, taking into account the learning outcomes on the theme(s) concerned
	Deciding and organizing registration procedures to be applied during the visit
	During visit
Beginning of the visit — guiding the pupils	
Exploration of activities / modules	Conducting the visit, teacher's and monitor's roles
	Implementation of the planned activities (e.g. exploration of modules, observation of animals or plants, conducting experiments…)
	Looking for answers to the questions raised in the classroom
	Data collection and registration (photographs, films, audio records, worksheets, notes on the exploration of modules, conclusions, doubts…)

End of the visit — guiding the pupils in the time they have left
Post-visit
Reflection on the study visit (what they learned, what they liked most, what they did not like, doubts...)
Organisation of the information and elaboration of posters, group reports...
Presentation of the assignments about the study visit (peers, educational community...)
Relate what they saw and did to the approaches implemented or to be implemented in subsequent classes
Planning of small projects, activities or experiences based on the study visit

Figure 6 – Analysis instrument "Experimental activity" (adapted from Rodrigues, 2011)

Experimental activity
Definition of pupils' learning outcomes
Contextualization of the activity
Formulation of the problem question
Identification and register of pupils' ideas
Planning of the experience
Selection and preparation of adequate resources
Experimentation: observation, measuring and systematized registration of data
Analysis and discussion of the data and systematization of conclusions
Answer to the problem question
Assessment of pupils' learning outcomes

3.3 Assessment of the proposed didactic approach on "Rocks and Minerals" for the Primary School level

In order to analyse de adequacy and relevance of the proposed didactic approach on the theme "Rocks and Minerals" for the Primary School level, we took into consideration: the comments of the 12 in-service teachers throughout the sessions, registered by the researchers/teacher trainers in their field notes; the development of proposals for the didactic approach of the theme "Rocks and Minerals" by 5 of the in-service teachers, whose pathway was presented in a communication poster and is also reflected in teachers individual reflections about these didactic experiences and, in particular, about their effects on fostering pupils' learning.

3.4 Assessment of the in-service teacher training programme strategy

To assess the in-service teacher training programme strategy, we analysed teachers' answers to the final questionnaire, bearing in mind the analysis instrument presented in Table 7, on a scale of 1 to 4 (1 – insufficient; 1 – sufficient; 3 – good; 4 – very good).

Table 7 – Analysis instrument "Assessment of the in-service teacher training programme strategy".

In-service teacher training programme	
Analysis dimensions	**Analysis parameters**
Objectives	Clear, relevant and achieved
Contents	Clear, relevant, fully explored and of practical application
Time management	Adequate duration of the training programme in relation to the objectives set and adequate time for both theory and practice
Organization and logistics	Schedule
	Diversification of teaching resources
Teacher trainers' performance	Clarity in the presentation of the training programme's goals and in the oral presentations made
	Successful motivation of the group, taking into account the expectations and needs of the teachers
	Appropriateness of the teaching methods to the target audience, demonstrating the practical applications of the themes studied

4. Data analysis and presentation of results

In this section, we present the analysis of data and some of the results, bearing in mind the research objectives defined.

4.1 Assessment of the effects of the training programme on in-service teachers' professional development

In order to assess the effects of the training programme on the professional development of in-service teachers, we applied the analysis instrument "Professional development of in-service teachers" (Table 4) to their individual reflections. Besides, we have also asked in-service teachers to self-assess their performance after the programme, with reference to the expected learning outcomes, which match the analyses parameters of the assessment instrument.

Thus, through the analysis of in-service teachers' individual reflections and of the self-assessment table (Table 8), we can observe that all of them consider the training programme has having provided a positive contribution to their professional development, having had direct implications on their teaching practices. In the self-assessment table, all the in-service teachers positioned themselves at the upper end of the scale; accordingly, individual reflections also seem to point to this result, as illustrated in this excerpt of TT4's individual reflection:

> *"In relation to my professional development, I assume that participating in this training programme has allow me to open new horizons regarding the implementation of experimental activities with pupils and I will certainly readjust my teaching practice, improving some of my teaching methodologies in this area."* (our translation)

Table 8 – In-service teachers' self-assessment after the training programme.

Analysis dimensions	Analysis parameters	Positioning of in-service teachers (%)				
		Minimum				Maximum
		1	2	3	4	5
Science Education Guidelines	He/she recognizes and understands the importance of science education for everyone from the earliest years of schooling.				17%	83%
	He/she is acquainted with the different perspectives of Science Education and understands their implications on the teaching of sciences in formal and non-formal contexts.			25%	68%	17%
	He/she values the importance of an integrated science education.				42%	58%
Management of teaching and learning processes in Science Education	He/she masters the scientific contents inherent to the topics covered in the training programme, adjusting them to the level of education in which he/she teaches.			17%	33%	50%
	He/she knows and masters different teaching methodologies and strategies on the topics covered.			25%	75%	
	He/she develops science activities in formal, non-formal and informal settings.				33%	67%
Assessment of pupils' learning outcomes	He/she assesses pupils' learning progress.				55%	45%

Regarding the "Science Education Guidelines" dimension, we observed that in-service teachers consider having had a good or very good performance (levels 4 and 5) in what concerns the analysis parameters "He/she recognizes and understands the importance of science education for everyone from the earliest years of schooling" and "He/she values the importance of an integrated science education", as the following excerpt of TT8 illustrates:

> *"Fostering science education implies the recognition of the interaction between Science and the improvement of the quality of life of individuals in general. In that sense, it is desirable that the integrated teaching of sciences in the school curriculum begins from the early years of schooling and that it is approached in non-formal and formal educational environments. Given the impact of this dimension in pupils' learning outcomes and civic education, it will also be essential to provide teachers with training programmes that make them grow fond of exploring didactic situations regarding the teaching of Sciences".* (our translation)

In what concerns the analysis parameter "He/she is acquainted with the different perspectives of Science Education and understands their implications on the teaching of sciences in formal and non-formal contexts", 25% of the in-service teachers position themselves at level 3 and 17% at level 5;

therefore, the remaining teachers considered themselves as "good". As an example, we present the excerpt from the individual reflection of the TT8:

> *"I decided [...] as a personal challenge, [...] to develop a research-oriented practical activity with pupils of the 2nd grade that aimed at:*
>
> *. Promote the experimental teaching [of Sciences] in context;*
>
> *. Make pupils active participants and not mere spectators;*
>
> *. Lead pupils to discover by themselves that, irrespective of being provided with some guidance, they can be responsible for the development of knowledge and that this process can be a delightful experience;*
>
> *. Develop basic competences; research and communicative competences".* (our translation)

As far as the analysis dimension "Management of teaching and learning processes in Science Education" is concerned, the parameter "He/she knows and masters different teaching methodologies and strategies on the topics covered" stands out for the absence of references to the level 5; however, 75% of the in-service teachers position themselves at level 4. In relation to the parameter "He/she masters the scientific contents inherent to the topics covered in the training programme, adjusting them to the level of the education in which he/she teaches", 50% if the in-service teachers position themselves at level 5. We present below an excerpt that evidences these results:

> *"this [training] programme has exceed my initial expectations. In this way, I was able to enhance some competences, by developing content and methodological knowledge; this has allowed me to improve my teaching practice with regard to science education".* (TT5) (our translation)

Concerning the analysis parameter "He/she develops science activities in formal, non-formal and informal settings", all teachers position themselves at the upper end of the scale (33% at level 4 and 67% at level 5). As an example, we highlight the following extract from the individual reflection of TT8:

> "*this [...] training programme [...] elucidated [me] about the best way to articulate non-formal and informal environments"* and *"[...] it allowed me to develop a greater self-confidence regarding the implementation of integrated practical activities in science education."* (our translation)

With reference to the dimension "Assessment of pupils' learning outcomes" and in relation to the parameter "He/she assesses pupils' learning progress", in-service teachers position themselves at the levels 4 and 5 (55% at level 4 and 45% at level 5). This was, however, the parameter in which teachers claimed having made fewer progresses. The following extracts from their individual reflections illustrate the abovementioned:

> "*personally, the item concerning the assessment of pupils' learning outcomes was the most significant and the one that led me to reflect on the learning process of students".* (TT5)
>
> *"increasingly aware of their [assessment instruments'] importance, the way in which learning occurs as well as their effects on pupils' lives are improved by the means of self and hetero-assessment instruments, essential and indispensable tools for a conscious and fair assessment."* (TT3) (our translation)

It is worth highlighting that none of the in-service teachers involved in this training programme positions him/herself at levels 1 or 2 in any of the analysis dimensions.

Throughout the sessions, in-service teachers' interest and commitment towards the training programme was clear, evincing the need they felt to attend it and how motivated they were to explore this theme with their pupils. The excerpt below, withdrawn from the individual reflection of TT5, confirms the researchers/teacher trainers' aforementioned perception:

> *"by participating in this [...] teacher training programme, I felt more motivated as well as more confident in exploring the science themes addressed, being also able to motivate and mobilise students to science learning*." (our translation)

4.2 Assessment of in-service teachers' practices (before and after the teacher training programme) concerning the theme "Rocks and Minerals"

4.2.1 In-service teachers' practices before the training programme

We present below the analysis of the 12 in-service teachers' responses to the initial questionnaire, concerning the description of what they say they to usually do when teaching the theme "Rocks and Minerals" to the pupils, in formal, non-formal and informal context.

In the initial planning of the visit to a non-formal and/or informal context, six teachers suggested visiting the Mira D'Aire Caves (limestone caves), five suggested visiting sites and attractions of the VNB municipality, one proposed a visit to a quarry and another recommended visiting a shale village.

As far as to the three fundamental stages to be considered in a study visit (pre-visit, during the visit and post-visit), it can be observed in the study visit plans elaborated that: half of the in-service teachers make no reference to the "pre-visit" stage; 17% does not refer the "during the visit" stage; and 25% makes no mention of the "post-visit" stage. However, 33% of the teachers refer to at least one of the parameters of each phase (pre-visit, during the visit and post-visit).

In planning the experimental activity for the exploration of "Rocks and Minerals", all the in-service teachers propose as activity the "exploration of the rock samples' features", however none of them specifies how this activity will be carried out. The exploration of the practical application and location of the rocks is mentioned by 25% of the in-service teachers. Half of them explicit some of the features that he/she would explore; however, they also evince theoretical weaknesses, such as pointing hardness as a feature to be explored in rocks.

Regarding the aspects to consider in the development of the practical activity, and as can be observed in the checklist presented in Table 9, we can verify that none of the in-service teachers made any reference in their plans to 50% of those aspects, namely: definition of pupils' learning outcomes; planning of the experience; selection and preparation of adequate resources; analysis and discussion of results and systematization of conclusions; assessment of pupils' learning.

The formulation of / answer to the problem question were mentioned by only one of the in-service teachers (TT7) and the identification and registration of pupils' preconceived ideas was referred by two of the teachers (TT7 and TT8). The contextualization of the activity is mentioned by 33% of the in-service teachers. The item mentioned by almost all the in-service teachers (92%) was experimentation (observation, measuring and systematized registration of data).

Table 9 – Checklist of the aspects to consider in a practical activity.

Practical activity	TT 1	TT 2	TT 3	TT 4	TT 5	TT 6	TT 7	TT 8	TT 9	TT 10	TT 11	TT 12
Definition of pupils' learning outcomes												
Contextualization of the activity	X	X	X					X				
Formulation of the problem question							X					
Identification and register of pupils' ideas							X	X				
Planning of the experience												
Selection and preparation of adequate resources												
Experimentation: observation, measuring and systematized registration of data		X	X	X	X	X	X	X	X	X	X	X
Analysis and discussion of the data and systematization of conclusions												
Answer to the problem question							X					
Assessment of pupils' learning outcomes												

4.2.2 In-service teachers' practices after the teacher training programme

As already mentioned, five of the 12 in-service teachers (TT1, TT3, TT6, TT9 and TT10) conceived and implemented an activity on "Rocks and Minerals" with their classes, integrating formal, non-formal and informal educational contexts. In this subsection, we aim to present and analyse these data, and to compare teachers'' answers to the initial questionnaire to the final didactic proposal presented by the 5 in-service teachers in their communication posters.

All the five in-service teachers taught the 3rd grade or the 2nd and 3rd grades of Primary Education and had on average 26 pupils *per* class.

In their final proposals, TT1 and TT6 integrated formal and non-formal educational contexts, TT9 integrated formal and informal educational contexts, while TT3 and TT10 integrated formal, non-

formal and informal educational contexts (Table 10).

Table 10 – Sequence of activities on "Rocks and Minerals" for each in-service teacher.

TT	Sequence of the integrated activity on "Rocks and Minerals"
TT1	Visit to the Almourol Castle | Follow-up activity about the visit | Formulating the problem question | Research on the topic "rocks" on recommend websites | Exploration of the module "Rocks in which I stumble" at the CIEC | Observation of rocks and exploration of some of their features | Registration of the observations in a table | Answer to the problem question | Presentation of the work developed to the class | Systematization of the learning outcome through the elaboration of a *Venn* diagram (interdisciplinary relationships with Mathematics)
TT3	Elaboration of a "Vocabulary tree" (interdisciplinary relationships with the Portuguese Language subject) | Building of a prototype of the Almourol Castle (interdisciplinary relationships with the Artistic Expressions subject) | Exploration of the module "Rocks in which I stumble" at the CIEC and of the map of the municipality of VNB with the distribution of existing rocks | Observation of rocks and exploration of some of their features in laboratory | Registration of the observations in a table | Presentation of the work developed to the class
TT6	Exploration of the module "Rocks in which I stumble" at the CIEC and of the map of the municipality of VNB with the distribution of existing rocks | Observation of rocks and exploration of some of their features | Registration of the observations in a table
TT9	Walk through the streets of VNB and visit to the Sculpture Park | Exploration of a cartoon in order to formulate the problem question | Exploration of the kits of rocks | Registration of the observations in a table
TT10	Walk through the streets of VNB and visit to the Sculpture Park | Exploration of the module "Rocks in which I stumble" at the CIEC and of the map of the municipality of VNB with the distribution of existing rocks | Research and completion of a registration table | Systematization of the activity by resorting to a game.

All the in-service teachers also presented an instrument for the assessment of the pupils' learning outcomes (in terms of knowledge, competences, attitudes and values).

When comparing the activities developed by the five in-service teachers after the trainig programme to the didactic proposals they presented before the beginning of the programme (initial questionnaire), an evolution in the quality of the thematic exploration can be verified, both in terms of study visit and practical activity.

In what concerns the study visit, while in the initial questionnaire of the TT3, TT6 and TT10 did not make any reference to the pre-visit stage and the TT6 did not mention, in her initial planning, the post-visit stage, after the training programme all teachers refer, at least, one of the parameters of analysis established for the pre-visit, during the visit and post-visit stages.

Through the analysis of the checklist presented below (Table 11), comparing the aspects which the five in-service teachers considered for the development of a practical activity on "Rocks and Minerals" before and after the training programme, we can verify that all the teachers evince considerable improvements.

Table 11 – Comparison between the aspects considered by the five in-service teachers in the development of a practical activity on "Rocks and Minerals", before and after the training programme.

Experimental activity	TT1		TT3		TT6		TT9		TT10	
	Before	After	Before	After	Before	After	Before	After	Before	After
Definition of pupils' learning outcomes		X		X		X		X		X
Contextualization of the activity	X	X	X	X		X		X		X
Formulation of the problem question		X		X				X		X
Identification and register of pupils' ideas		X		X		X		X		X
Planning of the experience		X						X		X
Selection and preparation of adequate resources		X		X				X		X
Experimentation: observation, measuring and systematized registration of data		X	X	X	X	X	X	X	X	X
Analysis and discussion of the data and systematization of conclusions		X		X				X		X
Answer to the problem question		X		X				X		X
Assessment of pupils' learning outcomes		X		X		X		X		X

Three of the in-service teachers (TT1, TT9 and TT10) who initially only referred to one aspect of the development of the practical activity, after the training programme, and when planning and implementing the activity with the pupils, evinced having covered all the foreseen aspects.

TT3, who at the beginning made reference to only two of the aspects (contextualization of the activity and experimentation: observation, measuring and systematized registration of data), after the training

programme, she came to include 7 more aspects; the only item neglected was planning the experience with the pupils.
Compared to other in-service teachers, TT6 was the one that revealed a more modest change in her practice, given that, in spite of having indeed contemplated more aspects after the training programme (at the beginning she only mentioned one aspect and after the programme she referred 5), at the end several items persisted unmentioned: the formulation of / answer to the problem question; the planning of the experience with the pupils; the selection and preparation of adequate resources; and the analysis and discussion of the data and systematization of conclusions.
The planning of the experience with the pupils was the only aspect that was not addressed by two of the in-service teachers (TT3 and TT6).
At the end of the teacher training programme, and notwithstanding the fact that all the in-service teachers covered a greater number of aspects in the development of the practical activity, this does not mean they did it with the same level of performance. After the assessment made by the researchers/teacher trainers on the work developed by the in-service teachers with their pupils, and based on the previously established scale (Table 1), we can observe that TT9 and TT10 presented an excellent level of performance, TT1 and TT3 a very good level of performance and TT6, a sufficient one.

4.3 Assessment of the proposed didactic approach on "Rocks and Minerals" for the Primary School level

Throughout the sessions, the in-service teachers explored the didactic approach on "Rocks and Minerals" for the Primary School level presented by the researchers/teacher trainers, both in terms of disciplinary and didactic content knowledge. At a certain point of the training programme, the in-service teachers carried out the activities as if they were the pupils, given that, according to the results of Rodrigues' study (2011), this process facilitates the implementation of the strategy on their teaching practices of sciences.
During the sessions, the researchers/teacher trainers registered the comments of the 12 in-service teachers on the proposed didactic approach, namely: the adequacy of the approach in relation to Primary School curriculum and to pupils' age; the rock and mineral samples selected for the kits; the type of activities proposed; sites suggested for implementing study visits to formal and non-formal contexts.
The analysis of in-service teachers' comments indicate that they consider the proposed didactic approach as well as the corresponding kits to be adequate to the Primary School level, being useful resources for them to teach this particular theme, as we can see in the following excerpt of TT3:

> *"all activities in this training programme as well as the strategies used were appropriate to the progression of each pupil given the expected learning outcomes".* (our translation)

Additionally, the implementation of the didactic approach regarding the theme "Rocks and Minerals" by the 5 in-service teachers in their classes was also taken into consideration. In their communication posters, they presented pupils' learning outcomes, deriving from the development of the activity, as well as a reflection on the whole process.
Table 12 presents the compilation of in-service teachers' perceptions on pupils' learning outcomes as the result of the development of the activity.

Table 12 – In-service teachers' perceptions on pupils' learning outcomes as the result of the development of the activity.

Pupils' learning outcomes	
Knowledge	He/she knows that the correct designation for the term "stone" is rock
	He/she knows the main rocks that exist in his municipality, region and country
	He/she knows the uses and practical applications of some rocks
	He/she recognises that rocks are not all alike
	He/she knows that rocks are classified, as to their origin, as igneous, sedimentary and metamorphic rocks
Competences	He/she makes predictions
	He/she observes rock samples by using the naked eye or the with the aid of a magnifying lens
	He/she analyses some features of rocks

	He/she compares rocks according to some of their features
	He/she searches information on different sources
	He/she registers data in a double entry table
	He/she answers to the problem question
	He/she reports the outcomes of his/her researches and learning process orally
Attitudes and values	He/she shows respect for other people's ideas
	He/she evinces accuracy and precision in carrying out experiments
	He/she is fond of sciences and of science learning

Thus, in-service teachers consider that the approach implemented made it possible to develop different learning in pupils, both in terms of content, skills, attitudes and values. To illustrate, we present some excerpts from the reflections of the in-service teachers:

- *"pupils' interest and concern regarding the use of correct scientific vocabulary was evident, showing curiosity and fondness for learning about the theme studied"* (TT1);
- *"students present themselves always as highly motivated for the new learning, often being them wanting to develop the theme further"* (TT3);
- *"students showed enthusiasm for learning and raised many questions, and they became very motivated to learn more and more..."* (TT6);
- *"they evinced curiosity and critical thinking as well as fondness for and interest in science"* (TT9). (our translation)

4.4 Assessment of the in-service teacher training strategy

Based on the analysis instrument "Assessment of the in-service teacher training programme" (Table 7), applied to the answers of the in-service teachers in the final questionnaire, it is evident that more than 64% of the teachers evaluate all the assessment parameters of the programme as "very good". All the others in-service teachers consider the analysis parameters as "good", with the exception of a teacher that assesses the "schedule" parameter as "sufficient" (Table 13). Thus, we can conclude that the objectives, contents, time management and the organization and logistics of the trainig programme were adequate to the in-service teachers' expectations and needs.

Table 13 – Assessment of the in-service teacher training programme by in-service teachers.

In-service teacher training programme					
Analysis dimensions	**Analysis parameters**	**Positioning of in-service teachers (%)**			
		Insuf.	**Suf.**	**Good**	**Very Good**
Objectives	Clear, relevant and achieved			16%	84%
Contents	Clear, relevant, fully explored and of practical application			28%	72%
Time management	Adequate duration of the training programme in relation to the objectives set and adequate time for both theory and practice			36%	64%
Organization and logistics	Schedule		9%	27%	64%
	Diversification of teaching resources			13%	87%
Teacher trainers' performance	Clarity in the presentation of the training programme's goals and in the oral presentations made				100%
	Successful motivation of the group, taking into account the expectations and needs of the teachers			9%	91%
	Appropriateness of the teaching methods to the target audience, demonstrating the practical applications of the themes studied				100%

Almost all the TT assessed the researchers/teacher trainers' performance as very good.

The good working atmosphere among the in-service teachers and with the researchers/teacher trainers was also highlighted, as it can be seen in the following excerpt, withdrawn from the individual reflection of the TT9:

> *"Finally, I must point out the good working environment of the group sessions, as well as the leading role played by the teacher trainers responsible for the training programme".* (our translation)

5. Conclusions

Results indicate that the in-service teacher training programme was a positive contribution to the professional development of the in-service teachers, namely by improving their practices with regard to the integration of formal, non-formal and informal sciences education contexts, in particularly in approaching the theme "Rocks and Minerals".

The strategies implemented in this training programme can also be used in pre-service teacher training, provided the necessary adjustments. For example, the implementation of the activities with the students and the respective reflection would have to be different, since pre-service teachers do not have their own class. However, Higher Education Institutions may promote the development of this type of activities and invite schools to come to their science laboratories to participate in these or other activities, such as field trips or study visits, organised, for example, at the institutions' Open Days or during the Science and Technology Open Week. Pre-service teachers may also go to schools that have an agreement with the Higher Education Institutions and develop the activities with the pupils, under the supervision of classroom teachers with proven quality teaching practices.

In relation to the didactic approach of the theme with Primary School children that was presented and explored in this training programme and implemented by some of the in-service teachers in their classes, results suggest an adequacy of the proposal, either in terms of the current official curriculum, or of the pupils' age. Moreover, the didactic approach is appropriate to the development of pupils' learning, concerning the themes/contents explored, as well as to the development of scientific-technological skills, attitudes and values. The fact that this didactic approach used local contexts as a starting point for the exploration of the theme "Rocks and Minerals" was also considered an asset, which is in line with the study of Piranha and Carneiro (2009), where "the use of geological information of local and regional settings is considered to be a strong link to integrative learning. It invites the learners/participants to reflection, because it shows them the reality of the place where they live (…)" (our translation) (p. 135).

In the words of Carneiro, Toledo and Almeida (2004), "Geology provides minimal understanding of how the planet works and it launches the bases of an effective exercise of citizenship" (our translation) (p. 559), i.e., geological knowledge contributes towards the education of conscious citizens, who are able to make informed decisions and to solve problems, particularly those related to anthropic occupation, the exploitation of resources and certain natural disasters.

We therefore consider that a stronger focus on the exploration of themes of Geology in the early years of schooling, by integrating formal, non-formal and informal contexts, is crucial.

The study here presented also provides evidence of the role of research in: (i) the conception and validation of didactic resources supporting the teaching and learning process; (ii) the development of in-service teacher training programmes that, by fostering the consolidation of teachers' disciplinary content and didactic knowledge on a specific theme, may guarantee an adequate exploration of that theme by teachers with their classes. Teachers' professional development, in terms of didactic knowledge, implies these being confronted not only with new guidelines, but also with the possibility of testing/assessing their operational viability. To accomplish this, an atmosphere of trust and openness between in-service teachers and teacher trainers is needed. The practices developed in this in-service teacher training program evince that it is an achievable goal. Teacher education will always be a central issue in what concerns the quality of educational practices.

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