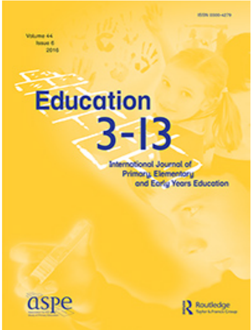


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# Exploring marine ecosystems with elementary school Portuguese children: inquiry-based project activities focused on 'real-life' contexts

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The purpose of the study was to investigate how young students engage in an inquiry-based project driven by real-life contexts. Elementary school children were engaged in a small inquiry project centred on marine biodiversity and species adaptations. All activities included the exploration of an out-of-school setting as a learning context. A total of 49 students and 2 teachers were involved in the activities. The research methods included observation, document analysis and content analysis of the answers to a questionnaire and an interview. The results revealed that most of the students acquired scientific knowledge related to biological diversity and adaptations to habitat. Moreover, students progressively demonstrate greater autonomy, argumentative ability and decision-making. One implication of the present study is that elementary science curriculum could be better managed with inquiry project-based activities that explore different types of resources and out-of-school settings.

**Keywords:** elementary school education; science education; project approach; inquiry activities; out-of-school activities

## Introduction

Nowadays technological and scientific knowledge assumes a leading role in societies. It is important to form enlightened citizens, who are able to reflect critically about the world and to make both responsible and informed decisions concerning issues related to their lives (Holbrook and Rannikmae 2007; Osborne and Dillon 2008). The skills needed for a citizen of the twenty-first century are based on critical thinking and problem-solving, on effective communication, on collaboration and on creativity and innovation (AMA 2010; EP&C 2006).

Being scientifically literate requires the confidence, interest and/or disposition to use or put into action a blend of knowledge dimensions for engaging with science. As such, it requires the ability to use science: as a tool for inquiry or discovery, for learning, informing or contributing to problem-solving, and to critically reflect on its use or role in society (Murcia 2007; National Research Council [NRC] 2006).

Accordingly, one of the fundamental objectives of science education in elementary schools is to enable students to observe their natural environment and to develop skills

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required to understand and explain both themselves and their environment (Akinoglou 2008). Aligned with these major goals, many science reform documents advocate the need to develop an inquiry-based approach from the first years of schooling for supporting the laying down of strong foundations of scientific literacy (Bell 2001; Bybee 2000; EC 2007; Milne 2008; Osborne and Dillon 2008). In alignment with these international perspectives and recommendations, the Portuguese science curriculum was, also, re-examined and restructured, and nowadays, important goals are developing students' substantive, procedural and epistemological knowledge, along with researching, reasoning, communication and argumentation competencies from the beginning of basic schooling (DEB 2001).

This inquiry approach has been defined as the 'intentional process of diagnosing problems, criticizing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments' (Linn, Davis, and Bell 2004). Through this deeper engagement process, students are presented with more opportunities to foster initiative-taking, creativity and innovation, being able to develop in schools different literacies in an integrated way (Bybee 2000, 2006; Osborne and Dillon 2008).

According to many different studies (e.g. Alkon 2004; Danyi et al. 2002; Dresden and Lee 2007; Elliott 1998; Gallick 2000; Kogan 2003; Scully, Howell, and Corbey-Scullen 2000; Williams 1997), one of the most effective educational strategies allowing learning by doing and inquiry-based active learning in science education is the project approach.

The key characteristic of the project approach is researching real-word problems, which are meaningful for students, and which have been raised by them or/and in collaboration with the teacher and could be further refined during the course of the study (Ladewski, Krajcik, and Harvey 1994; Kelly 2014). For the development of the project, knowledge will be based on experience and experimentation in real/authentic life, and, students' active participation and exploration through collaborative work are of major importance (Driver, Newton, and Osborne 2000; Howe 1997; Minstrell 2000; NRC 2006). Actually, this collaborative work can be seen as the core of the project work (Kaldi, Filippatou, and Govaris 2011).

Through this research around a familiar real-world problem, this approach, when focussed on the elementary education, can highlight opportunities for building onto children's innate curiosity about their natural environment and the world around them. Indeed, it is from everyday experiences and through the exploration of familiar settings that children acquire scientific, technological and practical knowledge (Boorman and Rogers 2000; Martins and Veiga 2001). These everyday experiences could act as meaningful contexts that are fundamental in stimulating children's curiosity and involvement in the learning process (Boorman and Rogers 2000; Blenkin and Kelly 1996; Milne 2010; Murcia 2007).

Project works are centred on planned research, examination and observation. According to Krajcik and Czerniak (2014), the project approach involves the following aspects: asking, and finding solution to questions that are meaningful to students; planning and performing investigations to answer the questions; collaborating with peers and teachers (and/or with other key members of the community) in answering the question and making sense of the data; and having familiarity with learning technologies in accessing information and researching. Through all the implementation process, students are expected to develop their skills of thinking, problem-solving, creativity, access to information, information processing, questioning, making conclusions, presentation and negotiation, as they are engaged in an active inquiry (Rutherford and Ahlgren 1989; Schneider and Lumpe 1996; Wells 1994; Yager 2000).

Nowadays, within the context of student-centred learning, inquiry project-based teaching methods have become increasingly prominent, namely in the first years of schooling, as a response to the challenges of the twenty-first century (Kaldi, Filippatou, and Govaris 2011). But, despite these new demands for elementary teachers to engage students in authentic scientific inquiry projects (Michaels, Shouse, and Schweingruber 2007; Nowicki et al. 2013; Krajcik and Sutherland 2010), it is known that many elementary teachers today do not develop this kind of approach in their classrooms (Dresden and Lee 2007; Geist and Baum 2005; Kaldi, Filippatou, and Govaris 2011; Pearson 2007; Windschitl 2003). This evidence provides a renewed urgency to the long-running debate over how best to support them in changing their practices accordingly. Moreover, and according to Braund and Reiss (2006), there is a need to deeply reflect about the potential for learning science outside the classroom. If we can get it right, there is every chance that the school learning can be complemented and extended by out-of-school learning. If we get it wrong, we continue to lose many of our best students from science.

Through this study, it has been aimed to make a contribution to this discussion, providing some evidence about the potentialities of developing inquiry science project-based activities, focused on out-of-school community resources and 'real-life' situations, for supporting science classroom teaching in elementary school.

## Methods

### *Description of the activities*

This study was integrated in a research project funded by the Foundation for Science and Technology: 'Between land and sea: a proposed integration of literacies' (PTDC/CPE-CED/117923/2010). The project intends to promote an effective science teaching and learning, through the development of multidisciplinary activities that involve an integrated approach of different literacies, focused on marine ecology, to be applied in different learning contexts. These activities are expected to be implemented not only in classrooms but also in non-formal education institutions, such as science centres, and research laboratories. The activities are aimed at increasing students' motivation towards science and are based on the general theme 'Between tide marks', which provided 'real-life' situations as an appealing learning context.

The inquiry project-based activities were developed in the context of the Portuguese National Curriculum for the Elementary Education, and were centred on the exploration of marine biodiversity and species adaptations to habitat and modes of life. The activities included a preparation session, a field trip and a consolidation session back to the classroom. In the preparation session, students' previous ideas about the subject under study were discussed through group debates and exploration of some movies related to the subject, and the research question that will lead all the subsequent work was defined by them.

Depending on the activities, the field trip was made to one of three possible places. The first field trip was conducted in a fish market, a public structure of traditional commerce, and aimed to promote the observation of different fish species, with different morphological characteristics, and also to encourage the dialogue between students and local sellers, in order to obtain information about the habitat of each species observed and to promote an understanding about the relation between the different morphological characteristics of each fish species and its habitat.

The second field trip was conducted at the Vasco da Gama Aquarium, a scientific and didactic Portuguese institution with more than 300 living marine species and thousands in a museum. This field trip aimed to promote the exploration of the main species that live in rocky shores versus sandy shores, in order to understand the differences between them in terms of morphological and behavioural adaptations.

The third field trip was conducted on a rocky intertidal platform. In this field trip, students had the chance to observe the diversity of organisms that live in this type of habitat and describe the main morphological characteristics of the specimens observed. During the visit, students should also collect some physical and chemical data (air and water temperature, type of microhabitat) to characterise the habitat of each specimen (crevices, tide-pools and exposed platform).

In the consolidation session, held in the classroom, students, working in groups, initiate a research about one of the species observed in the field trip (fish market/aquarium/intertidal platform). Each group created a species identification card, focused on species morphological characteristics, habitat and modes of life. At the end, through the comparison of the similarities and differences between the different species analysed, students should develop a deep understanding about marine biodiversity and species adaptations.

Students could still perform other tasks, such as creating a story about the species selected, building a new design of a fish (with the SCRATCH software) and dissecting a fish brought from the fish market to observe their internal organs.

The strategies used for these activities include collaborative work, discussion of ideas, research in book and on Internet sites, direct observation and description of living organisms, and the use of new technologies for presentating information. During all the activities, students assume a leading role, choosing their own path to get an answer to the research question previously defined. In the preparation session, after defining the research question, each group should identify the type of information they will need to collect during the field trip. Based on these suggestions, and after a class discussion, a worksheet was created to guide the observations in the field. In the out-of-school contexts, although the visit was guided by the teacher or the monitor (in the case of the aquarium), each group had to decide how they could collect the information needed, according to the worksheets created. Finally, in the consolidation session, all the decisions needed for the completion of the tasks were the students' responsibility.

### *Participants*

Each project activity was developed during the period of one month. The study involved three classes, from two different public schools. All students were 7–9 years old. The activity that involved a visit to the fish market was developed with a group of 25 students (class A1). This same group of students developed a second activity, which involved a visit to the aquarium (class A2), in the beginning of the subsequent school year (with the same teacher). The activity that involved a visit to the intertidal platform was developed with a group of 24 students (class B), from a different school.

According to both teachers involved, all students regularly develop practical work in their daily classroom activities, being familiarised with Internet search and computer use. All students often use books and encyclopaedias in search of information, and are used to work in groups.

### *Data collection*

The main objectives of this study were to evaluate the impact of the inquiry-based project activities on student's learning, namely on the acquisition of scientific knowledge and on the development of scientific skills, and to understand how the different participants, both students and teachers, evaluated the activities concerning their potentialities and the difficulties they felt.

Several methods were used for collecting data, such as direct and indirect observations, written documents and enquiry by questionnaire, which was complemented by a group interview with a few students and an interview with each teacher. All sessions were observed by a member of the research team. The observer gave support to students or to the teacher whenever requested (participant observation). The observation was centred on the following aspects: teachers' attitude and students' attitude during the activity, type of resources used and students' and teachers' difficulties. The majority of the tasks were audio- and video-recorded. All written documents produced by the students were analysed in order to assess students' understanding of the scientific concepts under study.

A questionnaire was applied to all participating students at the end of each activity and an interview was carried out with a group of five to six students (randomly selected) from each class. A total of 74 students answered the questionnaire and a total of 16 students were interviewed. The questionnaire was focused on the evaluation of the developed activity, taking into account the following dimensions: aspects they liked most, difficulties experienced and aspects that facilitated their learning. In order to deepen our understanding concerning the perspectives of both participants about the activities, both students and teachers were interviewed. All interviews were audio-recorded. These interviews were subjected to content analysis, based on categories that emerged from the responses given by participants (inductive analysis) (Milles and Huberman 1994).

Notes made by the teachers were also collected and analysed, in order to characterise how each activity was implemented, to identify teachers' main difficulties and to understand the type and quality of student learning from the point of view of the teacher. This resource was essential as it allowed us to understand the aspects that worked better and worked worse, and to reflect about the activities.

The triangulation of all the information gathered by the various collection methods used enabled to confront the perspective of the different participants, thus increasing the reliability of the study.

## Results

### *Impact on students' learning*

Concerning the acquisition of scientific knowledge, the analysis of the questionnaires ($n = 74$) revealed that the majority of students agreed that through the activities they developed a greater understanding of science concepts (65%) and that the activity promoted the learning of scientific knowledge useful for daily life (50%), helping them to understand the need to study science (54%).

The analysis of the students' written work and of their interactions during the tasks performed indicates that all groups achieved the proposed objectives and science concepts, acquiring knowledge about species diversity and some of the adaptations that allow them to survive in their environments, as illustrated by the following excerpts of a dialogue between the teacher and some of the students:

Teacher – If I tell you some characteristics of a fish, what could you know about its life?

Student A – We could know its habitat!

Teacher – If it is flat with eyes up ...

Student B – The fish lives in the bottom!

Professor – If it is fusiform, one eye on each side ...

Student C – The fish doesn't live in the bottom and must live in the water column.

(Dialogue in classroom; class A)

Teacher – What have we learned about the behavior of this organism (anemone)?

Student D – That the anemone can live out of the water for some time, but it must be closed to conserve the water until the tide comes again.

Student E – When she has to eat, she launches a stinging liquid into the other fish ... so she can eat.

Student F – It's more or less like that. She uses the tentacles, and the tentacles are poisonous.

Teacher – and what about crabs and limpets?

Student G – That they are invertebrates because they have no internal skeleton. Crabs use their clamps to attack and defend themselves.

Student H – The clamps were not used only to attack and defend, but also to dig.

Student I – During low tide, crabs go for more closed places to keep humidity.

Student J – The limpets when they want to feed, they move up through the rocks.

Student L – Normally, when the tide is low the limpets cling to the rocks so that it is almost impossible to take them of, but when the tide is high they move up a little to eat.

(Dialogue in classroom; class B)

In interviews ($n = 16$), students highlighted different aspects about what they have learned, according to the different field trips in which they were involved, as illustrated by the following answers:

- Those involved in the visit to the fish market highlighted aspects related to fish morphological adaptations (class A1):

I learned the word fusiform, and the morphology of the fish.

I learned that fish exhibit different physical characteristics according to their habitat.

These students also became more aware about species and habitat conservation issues.

It changed my behavior towards fish … to respect them and not to eat the smaller ones.

We cannot eat the little fish because one day they can disappear, became extinct.

Certain fish live in places that humans can destroy ... and we should not destroy or alter fish habitat, because they became extinct.

- Students involved in the visit to the Aquarium emphasised aspects related to species morphological and behavioural adaptations (class A2):

During the low-tide, the star-fish remain quiet, clinging to the rocks, but at high-tide they move.

Flounders camouflage in sand. Because they have the same color of the sand, they can't be seen by their enemies.

I learned that marine worms build tubes into the rocks, in which they take refuge during low-tide.

I din't know that the anemone shrug his arms to hold water, and that the mussels close their valves to retain water, and also that the star-fish make the gas exchange through their feet.

• Finally, students involved in the visit to the intertidal platform referred aspects related to marine biodiversity and adaptations (class B):

> I did not know that there are marine organisms that could stay out of water for a long time.
> I did not know sea cucumbers, nor knew that there are brown and red algae!
> I learned about animals that I did not know, how they live, what they eat ...

Both teachers also agreed that students developed an understanding about species adaptations, as illustrated in the following extract: ' … [the activity allow students to] *realize the adjustment of the organisms to the different environmental conditions, making them to realize about the various survival strategies of marine animals*' (Teacher, class A1 and A2).

Concerning the development of scientific skills, according to both teachers, students improved some competencies, such as the use of scientific language, the ability to use diverse information sources and technologies for research and to communicate the information collected, and also observation and discussion skills. The observations made during the implementation of the activities also revealed that students, in all classes, progressively demonstrate greater autonomy, argumentative ability and decision-making during their team work.

As aspects that could have facilitated their learning, most students referred the importance of working in group (87%) and the help they received from their colleagues (81%) and the teacher (57%). Moreover, they pointed out different aspects as being important for their learning, depending on the activities they were involved. Those who performed the visits to the fish market and to the aquarium emphasised the importance of having to research in books and other sources of information (76% each) and the use of real data during the activity (68% and 60%, respectively). Students who performed the visit to the intertidal platform focused on the importance of having to conduct direct observations (54%) and the need to make decisions about how they should organise their work (54%).

### *Activities evaluation*

#### *Students' perspective*

The overall results of the students' questionnaire ($n = 74$) revealed a very positive appreciation of the activities. Ninety-nine per cent of students enjoyed the activities, considering they were easy (95%). The main aspects highlighted by students were working in groups (91%), presenting the results to colleagues (66%) and the use of real data (61%). These results were corroborated by the interviews, in which all students ($n = 16$) referred they enjoyed the activities: nine of them highlighted the out-of-school activities, five preferred the research tasks (especially the Internet research) for the creation of the specimen identity card and two students did not highlight any particular aspect of the activity. Considering group work, only one of the students interviewed admitted to dislike working in group, stating that '... I like to do things for myself (...) in my way, but as a group we must all come to an agreement' (student from class B).

With regard to their main difficulties, students referred the need to do research in books (47%), the need to make decisions on how to organise the work (41%) and the need to to draw conclusions (34%). Concerning the research task, some students referred some difficulties with the selection of the relevant information (36%), as illustrated in the following excerpts:

> To guide the research (...), to decide what information was really important from the data collected in the internet (student from class C)
>
> To search and select the characteristics we need to describe species (student from class B)

Students who developed the activity on the intertidal platform (class C) also referred to the difficulty they had in making direct observations in the field (46%) and in defining the research problem to guide the data collection in the field (46%).

### *Teachers' perspective*

Teachers considered that the activities were appropriate both to the curriculum and to the age range of their students: 'all proposed tasks are well adjusted to the students' since 'they are focused on concepts and knowledge already explored, and that will be applied and investigated more deeply' (Teacher, class A1 and A2). According to them, students showed interest and commitment in performing all the tasks.

Teachers also highlighted as the value added of the activity the use of direct observation for collecting data, and also its contribution to the increase in students' motivation for science.

> I think the direct observation allowed the corroboration of some scientific concepts and its better assimilation. (Teacher, class A1 and A2)
>
> All the activity was very positive for students: they developed a large set of skills, and meaningful learning about the intertidal organisms. It also promotes in students not only the motivation to investigate further the observed organisms, but also for investigate other living beings who aroused their interest. The activity also served to work in an interdicsciplinary way all curricular areas. (Teacher, class B)

The major difficulty addressed by the teachers was the lack of scientific knowledge on the specific topics proposed, making it difficult to deepen and clarify students' doubts, which could be minimised by improving bibliographic information and websites to be used by students. Time was also a limiting factor, since some of the tasks, including writing and correction of texts, entailed a large expenditure of time. However, one of the teachers referred that the acceptance and students' interest in the activity greatly facilitated the development of the activity, favouring teaching practice.

## Discussion

The activities developed in this study integrate various out-of-school contexts with the work in the classroom, promoting the acquisition of scientific knowledge through different learning experiences involving the exploration of real data. Through this, students had the chance to assume a very active role which seemed to stimulate their sense of autonomy and motivation. Moreover, students felt that the activities allowed them to interact and to share ideas with peers. In fact, and according to their own words, the team work, the need to present their results and the use of real data seemed to facilitate their learning and to contribute to the popularity of the activities, which was further valued by the teachers.

The opportunity for students to work in groups seemed to have favoured the development of their autonomy, and the capacity to deal with their peers. Indeed, according to some authors (e.g. Mercer et al. 2004; Thurston et al. 2007), the cooperation that exists between students in a group allows them to rebuild and to create their own ideas, favouring not only the development of reasoned arguments, but also the joint construction of knowledge. As recognised by students, all these acquisitions may have been facilitated by the collaborative work that was necessary to accomplish the tasks assigned and that represents a significant part of the project-based learning approach (Kaldi, Filippatou, and Govaris 2011). Indeed, a successful team work implies talking and listening, question, argument and sharing, which contribute to co-construction of knowledge (Cross 1998; Jarvis, Holford, and Griffin 1998; Veenman, Kenter, and Post 2000).

Through the inquiry project developed in this work, students were engaged in activities that involved observation, interpretation, justification, discussion, explanation and argumentation. Moreover, because of the use of real data and the need to decide what to do with it, a major difficulty according to their perspective, students had to resort and develop some important skills, such as cooperation, perseverance and creativity, having also the opportunity to develop their reasoning and decision-making skills. By developing all these actions, students were required to think critically, to take deeper looks at issues, and, as a consequence, they were probably also required to develop more complex visions of the science topic explored.

The evidence collected in this study is consistent with the recent literature, concerning the importance of creating different opportunities to perform investigations in a range of educational contexts, from the earliest age, taking advantage of children's curiosity and willingness to understand the natural world around them (e.g. Boaventura et al. 2013; Peterson and French 2008; Tytler and Peterson 2003). As already stated by Murcia (2007), when the relevant content is obtained from children's inquiry into a specific real context, it places them at the centre of the learning and provides opportunities for children to construct ideas and shape prior knowledge and understandings. Real-world investigations and learning driven by contexts of interest to students provide opportunities for developing scientific literacy, as they encourage children to see the various forms of knowledge from different disciplines relating and coming together to form an understanding of the whole (Murcia 2007).

Indeed, years of research indicate that the use of out-of-school resources, such as museums, aquaria or other kind of learning contexts, has the potential to impact both conceptual and affective learning with lasting effects on students (e.g. ASE OSWG 2011; Bybee 2001; Hofstein, Bybee, and Legro 2007; Rickinson et al. 2004). Definitely, school science must extend the walls of the school to the resources of the community (Braund and Reiss 2006; EC 2007; NRC 2006). Moreover, choosing learning contexts that allow children to do things by themselves, to ask questions, to take control and to make decisions seems to be a relevant way to provide opportunities that enable them to use their own intellectual skills (Blenkin and Kelly 1996).

The results obtained in this study highlight the importance of developing new forms of teaching and learning that take into account international recommendations, that stress, among other important points, the introduction of inquiry-based project approaches and exploration of out-of-school settings with elementary students (DeWitt and Osborne 2007; EC 2007; NRC 2006). Indeed, these results contribute to the idea that elementary science curriculum could be better managed with inquiry project-based activities that explore different types of resources and out-of-school settings (Bell 2001; EC 2007; Krajcik and Czerniak 2014; Milne 2008; Osborne and Dillon 2008), and should be seen by the teachers as an indication that the science curriculum has to be understood not only in terms of content knowledge to be assimilated by students, but also in terms of the importance of the creation of situations that facilitate personal and meaningful knowledge construction mediated by social peer interaction, which is the main core of the project approach, namely in elementary school education.

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