History of science and science museums

An enriching partnership for elementary school science

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Abstract

The activity presented in this article is intended for elementary school students and focus on the pioneering oceanographic work of the Portuguese King Carlos I. This activity involves the exploration of the exhibits belonging to two different science museums, the Aquarium Vasco da Gama and the Maritime Museum. Students were asked to study fish adaptations to deep sea, through the exploration of a fictional story, also based on historical data from the work of the King that served as a guiding script for all the subsequent tasks. In both museums, students had access to observations of: historical collections of organisms, oceanographic biological sampling instruments, fish gears and ships. They could also observe the characteristics and adaptations of diverse deep-sea fish species. The present study aimed to analyse the impact of this activity on students' scientific knowledge, on their understanding of the nature of science and on the development of transversal skills. All students considered the project very interesting. The obtained results suggest that the activity promoted not only the understanding of scientific concepts, but also the development of knowledge about science itself and the construction of scientific knowledge. This emphasizes the relevance of creating activities informed by the history of science. As a final remark we suggest that the partnership between elementary schools and museums should be seen as an educational project approach, in which the teacher has to assume a key, mediating role between the school and the museums.

Key-words: Elementary education; Science education; Science museums; History of science

1. Introduction

Nowadays, it is agreed that scientific literacy in science education not only involves knowledge of scientific key concepts but also understanding of scientific inquiry as a human enterprise (DeBoer 2000; Ryder 2001). One way to accomplish this integrated understanding is the exploration of the history of science in science teaching. Indeed, many science educators have already stressed the crucial role that

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knowledge of scientific history plays in building a foundation for scientific literacy (e.g. Duschl 1997; 2000; Lombardi 1997; Matthews 1990, 1994; Monk and Osborne 1997; Wandersee 1992).

Non-formal[1] science education institutions, like science museums, can be a major contributor to this goal, since they have special resources that are unavailable elsewhere, such as historical collections, that could provide an awareness of the relevance of history and philosophy of science to the progress of scientific knowledge (Faria, Pereira and Chagas 2012; Ramey-Gassert, Walberg and Walberg 1994). Moreover, they generate learning environments based on curiosity and intrinsic motivation, which stimulate active learning through exploration and manipulation of the exhibits (Bamberger and Tal, 2006; Griffin and Symington, 1997; Falk and Dierking 2000). These learning contexts can, as a complement to the work performed in school, foster communication and sharing of ideas among students, the formulation of hypotheses and/or research questions, observation and data collection. Griffin (1998) argues that school visits to museums should be formally included in the school curriculum units.

The activity presented in this article were designed to be done in the classroom and in two different science museums, and were intended for elementary students (eight to nine years old). Students were asked to study fish adaptations to deep sea, through the exploration of a fictional story that was based on historical data and was centred on the work of King Carlos I of Portugal (1889-1908), a pioneer oceanographer who dedicated himself to the study of coastal Portuguese marine fauna.

The purpose of the study is to evaluate a set of science tasks informed by the history of science and to analyse its potential to develop students' understanding of different aspects related to the construction of scientific knowledge, in elementary school.

2. Theoretical background

A main purpose of science education is to introduce students to the concepts and processes of science, together with helping them to learn about science, its changing methods, its forms of organization, and its interrelationships with society (Millar and Osborne 1998). The report, 'Taking Science to School' (National Research Council [NRC] 2011) identified four crucial strands of science proficiency: knowing, using, and interpreting scientific explanations about the natural world; generating and evaluating scientific evidence and explanations; understanding the nature and development of scientific knowledge; participating productively in scientific practices and discourse. To accomplish these major goals, it is accepted that students need to understand basic science concepts, use science process skills, create meaningful connections with science, technology, society and environment, develop values and attitudes toward science and understand the nature of science.

According to international recommendations (Autio, Kaivola and Lavonen 2007; EC 2004; Osborne and Dillon 2008; United Nations Educational, Scientific and Cultural Organization [UNESCO] 1999), in order to assure students' proficiency in science and the development of the key competencies needed for any citizen, science teaching strategies should promote a motivating and stimulating learning environment, develop autonomy, namely through the implementation of inquiry, problem-solving and

[1] In formal education, learning occurs in a planned and hierarchical way, and is generally associated with a school or training institution, usually involving validation and certification; In non-formal education, learning although planned, is extremely flexible, usually occurring outside of school, although sharing with formal one the fact that it is mediated; Informal learning applies to situations in life in which learning occurs spontaneously (adapted from Eshach 2006).

decision-making project activities, which include discussion, argumentation and modelling of information (EC 2007; Osborne and Dillon 2008; Driver, Newton and Osborne 2000; Duschl and Grandy 2008; Osborne, Erduran and Simon 2004; Sadler 2004; Sadler and Zeidler 2005). Through these types of strategies, students are presented with more opportunities to foster initiative taking, creativity and innovation (Bybee 2006; NRC 2000). Moreover, due to its multidisciplinary and multi-causal nature, and because of its strong support in reality and individual experiences of students, the activities of this nature emphasize the moral values, ethics and skills associated with teamwork based on community (Dreyfus 1993; Duschl and Grandy 2008), helping to create positive visions and attitudes towards science.

As already mentioned, in order to promote public engagement with science, students must understand the purposes of scientific activity, its contents, processes and its nature. They should also have a functional understanding of science as a social enterprise (Bell, Lewenstein, Shouse and Feder 2009; Driver, Leach, Millar and Scott 1996; Lederman 2007). However, it is still under discussion how to integrate these issues in science curriculum and how to pedagogically explore them. In the last decades, science educators have repeatedly argued that history of science can play a significant role in helping learners to develop more appropriate conceptions of the scientific enterprise (e.g. Abd-El-Khalick and Lederman 2000; Duschl 2000; Duschl and Grandy 2008; Kafai and Gilliland-Swetland 2001; Klopfer 1969; Wandersee 1992; Mathews 1994; Monk and Osborne 1997; Solomon, Duveen, Scott and McCarthy 1992). According to Allchin (2013), the history of science can have an integrative function in all of these major educational goals. Indeed, reflections on NOS in a historical context, with concrete connections to events in the past, is not restricted to a philosophical discussion, but is connected to specific scientific problems. History of science suggests questions and experiments that promote appropriate conceptual change in students; humanizes scientific contents and reduces formalism; and reveals the integrative and interdependent nature of human achievements.

The development of collaborative actions between schools and museums for educational purposes can contribute greatly to these goals. The importance of learning science in a non-formal context was highlighted in several studies (Chin 2004; Griffin 1998; Jarvis and Pell 2005; Kisiel 2003). According to the National Science Education Standards (NRC 2011) these institutions can contribute greatly to the understanding of science and to encourage students to pursue their interests outside of school.

Indeed, considering that learning derives from experiences in the real world (Dierking, Falk, Rennie, Anderson and Ellenbogen 2003), science museums provide learning environments with unique features, that enhance curiosity, motivation and interest in science (Bybee 2001; Bybee and Legro 1997; CoxPetersen, Marsh, Kisiel and Melber 2003; Falk and Dierking 2000; Faria et al. 2012; King and Glackin 2010; Leinhardt and Crowley 2002; NRC 2011), which may complement the learning developed in formal environments, not only by providing a direct contact with reality, but also as an opportunity to contextualize knowledge and its evolution into a broader cultural and environmental context (Xanthoudaki 2002).

History of science collections are currently employed in some school-museum educational programmes (see Filippoupoliti and Koliopoulos 2014 for a review). The way history of science is used in these educational interventions varies broadly. The simplest one engages history of science in a science museum guiding tour, using stories that include people, ideas and practices from history of science to raise the visitors’ interest or to make sense of an exhibition (e.g. Fadel 2011). There are also educational programmes in which history of science offers the proper educational environment so that students become familiar in a systematic way with scientific and historical knowledge (e.g. Faria et al. 2012; Heering and Muller 2002; Sibum 2000; Teichmann 1999).

A key educational challenge for science museums is to link emotional and sensory responses to science-specific phenomena. Associating scientific thinking, enjoyable events and real-world outcomes can create important connections on a personal level (Bell et al. 2009). In this sense, non-formal settings occupy an important and unique space in science learning, presenting advantages that are unique and complementary to the advantages of schools (Bell et al. 2009; Jarvis and Pell 2005; Pedretti 2002, 2004).

A visit to a museum is currently regarded as an educational tool that promotes visitors' understanding and recognition of their cultural heritage, the acquisition of cognitive and historical knowledge, the development of a sense of aesthetics and the improvement of the understanding of scientific issues (Xanthoudaki 2002). Thus, these institutions may contribute to the development of a school interested and receptive to science learning throughout life, playing an important role in the achievement of the goals envisaged in international documents of science education (Millar and Osborne 1998; Organisation for Economic Co-operation and Development [OECD] 2003, 2006; NRC 2011; Osborne and Dillon 2008).

Inquiry activities, problem solving and decision making, promote the connection between formal and non-formal education and the understanding of science in a global perspective, and constitute the main orientation guidelines provided by the international recommendations for science education reform.

Finally, the use of stories in elementary school science teaching is not something new. The use of stories in science education can and should be considered as a simple and effective point of departure for the introduction of scientific topics and processes (Ellis 2005). Indeed, this is one of the potentially strongest teaching tools used in science education, both as the starting point for critical thinking on a particular scientific concept and for an understanding of ideas or abstract concepts (Roslan 2008). According to Roslan (2008), there are many benefits, including social, emotional, cultural and intellectual ones, associated with using stories in science classes. Stories encourage students to reflect and to formulate questions about particular events. Children are naturally driven by their curiosity and try to use their prior knowledge to understand new ideas and to solve problems. This process can be further enriched through the development of inquiry-based projects that include the exploration of real and unique science museums resources.

The present study aimed to assess the impact of an activity on elementary school children, namely on the acquisition of scientific knowledge related to deep-sea adaptations, on the understanding of scientific knowledge construction, namely the transitory nature of scientific knowledge. Moreover, it was intended to analyse the implementation process and the difficulties felt throughout the entire process.

3. Methodology

3.1. Historical context of the study

King Carlos I of Portugal (1889-1908), was one of the world pioneers in the field of oceanography and father of Portuguese oceanography, leaving an internationally recognized body of work. He sponsored 12 oceanographic campaigns, between 1896 and 1907, with the main goal of inventorying and thoroughly studying the marine fauna of the Portuguese coast. This endeavour proved to be not only of great scientific importance, but also of great economic interest, since it enabled the maximization of the yield of the fisheries industry, an important industry for Portugal. It also allowed the study of the currents and of the topography of the ocean near the Portuguese coast (Saldanha 1996).

Since the beginning of oceanographic investigations in the nineteenth century, the great-depth marine ecosystems have aroused the interest of many researchers. Edward Forbes, a British naturalist who conducted a series of dredging works in the Aegean Sea between 1841 and 1842, developed the azoic theory. This theory postulated the absence of life at depths below 550 m due to the extreme conditions of the environment, in particular the low temperatures, the high atmospheric pressure and the lack of light. The azoic theory dominated the scientific thought of the nineteenth century, despite all the evidence related to the existence of life in the deep sea. As evidence of this stands the work published by Bocage in 1865 in which he refrains from divulging the depth at a sponge had been captured (800m deep), only releasing this information in 1871 (Saldanha 1996).

Forbes' theory persisted as a kind of scientific stubbornness, despite evidence to the contrary. Interestingly, Portuguese fishermen captured sharks at great depths, 1200m deep, while scientists doubted the existence of life below 550m deep. In this regard, King Carlos I wrote in his book (in 1904):

> We all know that in an epoch in which they discussed the non-existence of animal life, especially for the complex organisms, beyond a certain depth, our long-line fishermen systematically captured abyssal sharks, and accidentally brought, stuck to their fishing gears, large sponges (Hyalonema, Askonema). To him [King D Carlos I] we owe the discovery of a lot of new species, some of them that are still only known in our seas. (adapted from Bragança 1957).

Over twelve oceanographic campaigns, King Carlos I created a zoological collection of great historical and scientific value. This collection, that is part of the exhibition of the Aquarium Vasco da Gama, constitutes a valuable contribution to the faunal inventory of the Portuguese coast. This collection has not only the specimens collected during the Kings' campaigns, but also the oceanographic instruments, fishing gear and specimen illustrations made by the King. The aquarium Vasco da Gama also has a large collection of fish collected at great depths, which allows the observation of the different adaptations of these species to the abyssal environment. Moreover, the cabin of one of the yachts used by the King, Amelia IV, and some of the Kings' personal belongings used during the campaigns are exhibited in another museum, the Maritime Museum, in Lisbon. This Museum has a large collection of different models of ships, navigational instruments, fishing gears, maps and other objects of the time. Both institutions were included in the activity described in this article.

3.2 Participants

The activity was implemented in a classroom of a public school, near Lisbon, during the period of two weeks (June 2014), with a class of 25 children, eight to nine years old from the 4th grade of elementary school, by one teacher. According to the teacher, all students were used to working in groups and they regularly developed practical work in the classroom, involving Internet and book research. They were also used to making school visits to different science museums. For the activity presented here, groups of five students were formed, with at least one computer with Internet access per group.

3.3 Description of the activity

This study was developed in the context of a research project 'Between tide marks: Integrating literacies', focused on the development of multidisciplinary research activities, centred on real situations of daily life, that aims to promote the integration of different literacies in science learning. One important aim of this project is to involve teachers in the implementation and further development of any of the produced activities, encouraging them to adapt the activities to the curriculum, to students' interests and characteristics, and to time constraints. All the activities developed within this project were made available for schools so that any teacher could implement them with his/her students. The activity presented in this article aimed to develop students' understanding about how scientific knowledge is constructed, namely to understand the social, scientific and technological issues associated with the construction of scientific knowledge, and at the same time to acquire some scientific knowledge about deep sea life, biological diversity and fish adaptations.

The activity was based on Forbes' azoic theory, which argued that there was no life in deep sea due to the environmental conditions there. This theory was related to the pioneering work of King Carlos I in oceanography, contributing to the discovery of life forms that inhabit the deep sea. The activity involved the exploration of the exhibits belonging to two different institutions, the Aquarium Vasco da Gama and the Maritime Museum. They included a session before the visits, two study visits guided by a curator of the museum, one to the Vasco da Gama Aquarium and the other to the Maritime Museum, and a consolidation session back in the classroom. In the session before the visits, students read and discussed a short story 'The dream of King Carlos I', authored by a Portuguese biologist, Raquel Gaspar (2012), which tells the story of the life of King Carlos I, his naturalist inclinations, and his pioneering work in the discovery of marine creatures that inhabit the deep sea. The action of the story is centred on the work of the King with the fishermen of a Portuguese village. It contains historical data and tells the fictional adventure of three children that discovered some objects on the beach related to the Kings' yacht and tried to discover its story. This story served as a guiding script for all the subsequent tasks, including the visits to Vasco da Gama Aquarium and Maritime Museum.

In the Vasco da Gama Aquarium, students had the opportunity to observe the collection of King Carlos I, namely his naturalistic and artistic inclinations, the research instruments he used, and also to observe the characteristics and adaptations of diverse fish species characteristic of deep sea. In the Maritime Museum students observed some navigation instruments, equipment and research vessels used in oceanography, both from the Kings' epoch and contemporary ones. They also saw the cabin of the yacht Amelia and some personal belongings of the King. For the museum visits, the museum educators created a worksheet for each exhibition, which connected the story of the book 'The dream of King Carlos I' and each museum exhibition. During the visits, students had to search for some artefacts present in the exhibitions related to the story, and answer the questions in the worksheet. For example, they had to find and draw some fish species and some vessels, and they had to find some instruments or some objects used by the King, based on the available information. For this purpose, students had to choose their own path to get an answer to the questions asked at different sections of the exhibition. All decisions required for the completion of the tasks were the students' responsibility.

Back in the classroom, students had a final consolidation task with the objective of integrating all the knowledge acquired and to establish the connection to actual scientific and technological knowledge. In this consolidation session, students had to create a diary of King's life aboard his yacht, where the description of his chambers, meals, collection instruments, and also his findings could be included. The students also conducted research on the characteristics of deep-sea fish species, focusing on their morphological characteristics and environmental adaptations. For this, they were shown some videos about life at great depths, the environmental characteristics of the deep sea, and the evolution of the technology required to explore life at great depths. These consolidation tasks lasted for five class sessions. The strategies used in these tasks included collaborative work, discussion of ideas, internet research, analysis and interpretation of different sources of information, and use of digital technology for research and presentation of information.

3.4 Data collection and analysis

The main objective of this study was the assessment of the impact of the activity on students': 1) acquisition of scientific knowledge related to deep-sea adaptations, and 2) understanding of the development of scientific knowledge. Additionally, we intended to analyse the difficulties that students faced throughout the implementation process.

All tasks performed by the students were audio and video-recorded. All sessions were observed by one of the researchers in the context of a participant-observator, as the researcher supported the students and the teacher when requested. In order to understand the implementation process, the observation took into account the following aspects: the behaviour of the teacher and of the students during the activity, the type of resources used, and the difficulties encountered both by the students and the teacher. Moreover, for the characterization of the implementation process, teacher's and students' documents were analysed. The implementation notes made by the teacher were analysed in order to understand her main difficulties and to see the type and quality of student learning from the teacher's point of view. This document allowed us to gain a greater understanding of the effectiveness of the activity itself, considering the difficulties and constraints of its implementation with elementary school students, which was reflected in further improvement.

All documents produced by the students during the activity were analysed in order to assess students' understanding of the scientific concepts under study. In order to understand students' appreciation of the activity, at its end 18 participating students answered a written questionnaire (multiple choice questions) focused on the following aspects: aspects they liked most, greatest difficulties encountered, and aspects that facilitated their learning (see Appendix 1). Questionnaire data were subjected to a descriptive statistical analysis (frequencies and respective percentages for each question).

In order to better understand the participants' perspectives about the activity, both students and the teacher were interviewed. In the case of students, it was a group interview with five students (one member of each group, selected by the group). Both interviews were centred on the following dimensions: suitability and popularity of the activity; the impact of the activity on students' learning, in a historical and scientific perspective, and its impact on the development of scientific and social skills; difficulties experienced. All interviews were audio-recorded, and were analysed through content analysis, based on categories that emerged from the responses given by the participants. Through an iterative process of reading and re-reading data, we assigned meaningful pieces of text to categories (Miles & Huberman, 1994). The initial categories were based on our starting questions, but by the re-reading process these were being further explored and deepened, as new categories of the data had emerged from the analysis. The inductive analysis of the interviews were performed independently by two researchers, who discussed and reviewed the analysis to assure greater reliability.

All used instruments for data collection were developed by the authors for the evaluation of the activities created under the project ‘Between tide marks: Integrating literacies’. The Questionnaire was previously tested with a different class of students of the same age in order to verify if the questions were suited to the age of the participants. Data obtained through the analysis of the questionnaire was confronted with students’ answers to the interviews, in order to deepen and confirm students’ perspective about the activity. Finally, data collected using different methods (observation, worksheets' answers, questionnaires, teacher and students’ interviews) were crossed to assure the reliability of the analysis and to get a deeper understanding of students' perceptions and learning.

4. Results

4.1. Students’ perspective

4.1.1 Popularity of the activity

Questionnaire analysis revealed that all surveyed students (n=18) liked to participate in the activity, considering that it was easy to perform. The aspects they liked most were: working in groups (17 students), presentation of their results to the class (12 students) and the study visits they made (12 students). Considering the answers given in the interviews by the 5 students, the aspects that had the greatest impact on the development of the activity were the study visits, emphasised by the five students interviewed, and the creation of the Kings’ diary, highlighted by three of them. In general, students reported that the activity was of great importance for their learning and for their understanding of science, as illustrated by the following excerpts[2].

> (,,,) and because learning through field trips and with people that know more and that help us, is easier. And then having to do the diary, and the various tasks of the activity, makes the learning of science more fun. (student 1)

> It was important for me to have more knowledge about (...) the work of King Carlos I. Especially about the abyssal zone…the types of fish and other organisms that live there… and its characteristics. (student 2)

> I think it was important because it strengthened our knowledge and answered to some of our questions. (student 3)

> I really enjoyed this project, and I think that was very important to me. (student 4)

[2] All students and teacher excerpts were translated from Portuguese by the authors of this article.

In the interviews, students also mentioned that one of the aspects they liked least was conducting the literature research (n=3), because of the fact that there are often many distractions from the main theme under research, and also by the difficulty they had in finding the needed information.

> The hardest part was the literature research because sometimes we were in the correct sites but there was no information there. (student 1)

> ... because then I also started to see other things. And also because I'm not very good at searching in the Internet. So I do not like ... [for example] We wanted underwater capsules, and when we wrote only capsules, it appeared coffee capsules and pills! (student 4)

In the questionnaires, this was also stressed by many students, revealing that they had difficulties with researching information in books and other sources (11 students), with analysing and selecting the information (8 students), and having to identify a problem (8 students). However, according to them, these difficulties were overcome with the help of their peers and their teacher.

In the interview, some students also mentioned that they had some difficulties in understanding the language used by the guides during the guided tours to the museums, stating that it was sometimes too complex. However, this difficulty was overcome with the explanations given by the teacher.

> … But I also had trouble in understanding what the guides said... in both visits... I had to ask the teacher a lot of things. (student 4)

4.1.2 Impact of the activity

The analysis of diaries created by students showed that the proposed objectives for this activity were fulfilled. Indeed, the analysis of the diaries revealed that students came to know about the importance of the work done by the King, the navigation instruments and fishing gear employed by him and also about the characteristics and adaptations of the organisms that live in the abyssal zone. This knowledge was constructed during the study visits and with the research of information on the internet.

> … and the first person in Portugal to do studies with animals from the abyssal zone, that started to conserve them and created a collection donated to the Vasco da Gama Aquarium, was King Carlos I. And it was very important because it was one of the very few kings educated. (student 3)

> The research made by the King Carlos I was important because he discovered new fish species. (student 2)

> I learned about the various types of boats, used by the King and used by the fishermen….they were different. How do they fished, the fishing tools they used. (student 1)

> I didn´t know that the characteristics of the deep sea fish were different…. there are less light, higher pressure and low temperatures. (student 5)

This activity also allowed students to understand the importance of the work done by King Carlos I for the scientific knowledge of the time. The notion of the evolution of scientific knowledge, and the influence of the practical fishermen' knowledge can be found in students' comments.

> The scientists said there was no life in the abyssal zone, but King Carlos I and fishermen already knew that yes there was! (student 4)

> Contrary to scientists, fishermen already knew that life existed in the deep sea, because they captured fish there. King Carlos I helped them, and learned from them. He could not know all things about it, but he took their expertise to study them [the species], and to show the world that it was wrong. (student 3)

> Because he helped to transmit to other people, sailors and other scientists, that there was life in the abyssal zone. Because everyone said there was not. The research made by King Carlos I was important because he discovered new fish species. (student 1)

Direct observations made in the classroom not only demonstrated a great ability to work in groups for most students, but also their ability to make decisions and organize their work. However, there were also some complications that hindered the development of the tasks. The decision making among students became sometimes an obstacle in the cases where the groups were formed by an even number, due to one of the elements missing school. This led them to a say, "when we could not decide something, we went to vote. But since we were four, sometimes we vote two in one option and two in another, and then we could not decide" (student 5), and so they often appealed to the teacher for help in the decision. Regarding the development of the remaining tasks, all groups showed autonomy, motivation and commitment to its implementation.

Students also stressed that the aspects that facilitated their learning were the help of the colleagues (16 students), the group work (16 students) and the study visits (15 students).

> With the things we learned in the field trip was easier. (student 1)

> Was easier because we learned different things in field trips, and also because we worked in groups, and working in group makes everything easier. We can divide the tasks. (student 3)

> …But imagine that in the group someone has a question, and then we do not need to ask the teacher because we can ask to our colleagues. (student 5)

4.2. Teacher's perspective

The teacher found that the activity was appropriate both for the curriculum, and for the age of the students. In her words,

> It was an activity that has been fully accomplished, either for students or for the teacher, since it was possible to achieve the desired goals in a constructive way... All tasks arise in articulation and promote a growing interest.

With respect to students' engagement with the activity, teacher revealed that students revealed a great willingness to participate, both in carrying out the study visits, as in the development of the tasks, or in the concretization of the practical work.

> The receptivity of students could not have been better, since from the first moment to the last one, they showed interest and were engaged, whether in analysing the documents, or on observation tasks during the visits, in the development of the tasks in the classroom, in searching information, in performing the synthesis of the acquired knowledge and in the final presentation of the work done.

According to the teacher, the implementation of the activity did not present major difficulties, and the available resources were a major contribution. However, she referred to some time constraints "the schedule for finishing up the work in the classroom was not enough, and so we had to use more time in the class to complete the activity".

Concerning the impact on students' knowledge, the activity allowed them not only to develop diverse scientific expertise, related to scientific knowledge itself, but also about the scientific processes and the evolution of science knowledge, as listed in the following excerpts of the teacher interview:

> .. The acquisition of knowledge about the diversity of marine fauna of great depths and the different instruments used over time, on oceanographic research; the understanding of the adaptations of organisms to the environment where they live; the knowledge gained on the work of King Carlos I as an oceanographer; the perception of the work of different scientists and their importance to scientific knowledge and its evolution; the importance of observation, and of the written record and of drawing as a form of expression and, ultimately, the creativity put into practice for the concretization of the final work.

> ...from a story and the field visits related to it, [the students] acquired, deepen and applied concepts and scientific and technological knowledge, and simultaneously they could understood how scientific knowledge is constructed.

> ...[students could] have the perception of the work of scientists and their importance to scientific knowledge and its evolution...

They also developed some scientific and communication skills, as illustrated by the following teacher comments:

> ... There was a very significant and positive development in students' behaviour... They progressively worked faster and more easily, assimilating the concepts and knowledge, discussing in a committed

way, using appropriate language and scientific concepts previously acquired, becoming involved in the various tasks and practical work.

> ... they reflected, combined knowledge and made inferences in a context in which they had no previous background.

> ...starting from the knowledge already internalized and realizing the relationships between the different variables (environmental factors, external characteristics of the animals, etc.) students proved being capable of finding their own way to knowledge.

Finally, she also highlighted the increased level of motivation and interest in science classes showed by students as a result of the work done,

> Of course that it changed the behaviour of students concerning their vision and perceptions about science classes. Most students will be in the future more eager to know, to learn, to search, to observe, to understand, to discuss and analyse and to apply.

As a final comment, the teacher also felt she learned a lot with the activity, not only about the scientific subject, but also concerning students' needs on the work implemented with him, as illustrated by their own words:

> ...I developed and deepened my knowledge, as my own students, on the subjects under study, particularly on marine fauna of great depths, on fishing tools and on oceanographic research, among others.

> ...I confirmed the need that students have to undertake their own actions to acquire and consolidate knowledge, and this realization is not related only with practical work, it relates also with the need to perform observations, discussions and research.

5. Discussion

Students enthusiastically participated in the activity and the major goals were achieved. Students said that both the visits to the museums and the tasks at school were very important, because their integration not only facilitated learning, but also made it more fun. Motivation plays a key role in the learning process, and according to Zoldosova and Prokop (2006), it increases when learning is associated with problems/situations relevant to the daily life.

The opportunity for students to work in groups seemed to have favoured the development of their reasoning and decision-making skills, and the capacity to deal with their peers. According to Mercer, Dawes, Wegerif and Sams (2004), when students work in groups or in pairs, they are involved in interactions of higher symmetry than those that exist between student and teacher, which will favour the development of reasoned arguments and/or the description of the events observed. Moreover, the cooperation that exists between students through dialogue allows them to rebuild and/or create their own ideas, contributing to the joint construction of knowledge (Thurston et al. 2007). Skills such as cooperation, tenacity, perseverance and autonomy were constant during the development of the activity developed in this study, and promoted its progress and success.

The activity performed in this study allowed students to learn the story of King Carlos I, his findings and the importance they had for the scientific knowledge of his time. The proposed activity had the feature of including two visits, to an Aquarium and a Museum, allowing students access to historical collections of organisms, instruments, and ships. The obtained results suggest that the activity promoted not only the acquisition of scientific concepts, related with biodiversity and species adaptation, but also stimulated the development of knowledge about science practices and the evolution of scientific knowledge. These visits promoted also a great interaction among students, and with the monitors and the teacher, encouraging the formulation of questions, reflection, scientific explanation of phenomena and collaborative work.

The integration of non-formal learning institutions, such as science museums, aquaria and/or zoos in school science education can be considered a major asset for promoting learning and students' interest in science (Faria et al. 2012; Griffin 1998; Rennie and McClafferty 1995). As already highlighted by Faria, Pereira and Chagas (2012), in a study with older students, science museums can be an excellent context to develop activities embedded in the history of science, because of their historical collections and documents that represent unique resources rarely available in schools. The outcomes of this study indicate that the engagement of young students in an activity involving a visit to science museums, and extending it by adding an historical dimension, is an important and successful strategy for creating a compelling context for learning about scientific practices and to develop a deep understanding about the scientific activity. As evidence of this claim, one of the students made the following statement in the interview: "science is fallible…but is still science!"

The results obtained in this study should be considered with same caution because they are based on a small local sample, making it impossible to carry out generalizations. In addition, due to the age of students, the questionnaire used was very simplified. However, the possibility of confronting the different perspectives of both participants (students and teacher) and the possibility to cross all the data obtained by different assessment methods (direct observation, questionnaire, interviews and analysis of students work) contributed to assure the reliability of our results.

Based on the results obtained in this work, we suggest that the partnership between elementary schools and museums should be seen as an educational project, centred on students' active participation and collaborative exploration of a real-world scientific issue. Several authors have already highlighted the need to develop school-museum partnerships and science museums are gradually empowering their science education functions (Chin 2004; MacLeod and Keistead 1990; Stocklmayer, Rennie and Gilbert 2010; Tal and Morag 2007; Tran 2007). Indeed, there are already some successful experiences in engaging teachers to use history of science as a tool in science education school programmes in non-formal settings. Some examples are lectures-demonstrations created by teachers, creatively using collections of scientific instruments of a local museum in Greece (Paparou 2011), educational workshops for teachers related with Galileo's laboratory (Falomo-Bernarduzzi, Albanesi and Bevilacqua 2012) or workshops on the use of historic experiments and old scientific instruments as educating tools (Heering 2011). However, in order to develop this type of partnership as a shared educational project over time, and not only resulting in occasional actions, teachers' education institutions must also rethink their role in this process. Indeed, as already claimed by several authors (e.g. Chin 2004; Faria and Chagas 2013; MacLeod and Keistead 1990), suitable programs for both initial and in-service science teacher training are needed in order to guide teachers to integrate informal resources and events into their practices, and consequently making them able to assume a key mediating role, as knowers of the learning process, in this type of shared projects.

As a final comment, there is a need to clarify and reflect on the possible implications of these shared project approach in the future development of schools and museums partnerships. It would be interesting to investigate if the perception of the different participants, teachers, museum educators and students has changed after being part of this project. Has the perceived relationship between the two museums involved and schools changed? And what about students? Did they change their perception about learning in museums? These issues deserve further and deeper investigation.

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