Promoting science outdoor activities for elementary school children: Contributions from a research laboratory

Diana Boaventura[1,2], Cláudia Faria[3], Isabel Chagas[3], Cecília Galvão[3]

[1] Escola Superior de Educação João de Deus Lisboa, Portugal. E-mail: d.boaventura@netcabo.pt

[2] Laboratório Marítimo da Guia, Centro de Oceanografia da Faculdade de Ciências da Universidade de Lisboa, Cascais, Portugal.

[3] Centro de Investigação em Educação, Instituto de Educação, Universidade de Lisboa, Portugal.

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Abstract

The purposes of the study were to analyse the promotion of scientific literacy through practical research activities, and to identify children's conceptions about scientists and how they do science. Elementary school children were engaged in two scientific experiments in a marine biology research laboratory. A total of 136 students answered a questionnaire about their previous habits towards science and carried out the following actions: i) a guided visit to the laboratory; ii) a brief presentation of the research theme; iii) the development of two experiments; iv) a questionnaire about the experiments and science conceptions. The research methods included observation, document analysis and content analysis of the answers to the questionnaires. Additionally, each visit was video recorded in order to design learning materials. The results revealed that most of the pupils were able to follow every stage of experimentation. However, some of them misinterpreted results and conclusions. One implication of the study is that this type of outdoor activity is extremely important to promote meaningful science learning in children, but more care should be taken in practical science activities so that children can overcome some common difficulties when performing scientific inquiry.

1. Introduction

A number of recent studies have enhanced students' awareness about scientific activity and science processes as a central aim of science education (e.g. Hume & Coll, 2008; Mant, Wilson & Coates, 2007).

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To achieve this goal, some collaboration programs were developed between schools and research laboratories, with the intention of providing students with opportunities to do real science (e.g. Barab & Hay, 2001; Richmond & Kurth, 1999). Given the procedural nature of inquiry-based activities they are more likely to encourage relationships between the stakeholders of both formal and informal education, like the research laboratories, creating opportunities to involve both scientists and educators in science education (Rocard et al., 2007). Moreover, this type of collaboration creates an opportunity for students to engage in practical activities that are different from what is possible to take place in a school setting.

Skills which relate to scientific procedures, such as posing a research problem, formulating hypotheses, designing experiments, collecting and recording data, and drawing conclusions, have been recognised as essential components of any science curriculum (e.g. Atkin & Black, 2003; Rocard et al., 2007). Nowadays, many science curricula, namely the Portuguese one, require students to differentiate between theory and evidence, to collect and record data, and to describe experimental observations and results, as well as to draw conclusions (Galvão, 2001). In order to be effective these skills must be developed at all school levels (Rocard et al., 2007).

There is, however, some debate about what students can learn with this kind of scientific experimentation. The dependency of reasoning skills upon specific contexts makes it impossible to predict how children will be able to perform on such occasions (Zohar, 1998). One direction for research is to examine what students at different grade

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levels can do in an experimental setting without a recipe to follow (Mayer & Carlisle, 1996).

At an elementary school level, it is usually assumed that children are intrinsically interested in science and curious about the scientific phenomena that surround them (Brown, 1997); and that it is necessary to develop children's scientific literacy using inquiry-based activities in a real-world context, as early as possible (e.g. Galvão, 2001; Rocard et al., 2007). However, little time is generally allocated to learning science in the early school years (e.g. Weiss, Pasley, Smith, Banilower & Heck, 2003) and most of research studies performed in real context are done with elder students (e.g. Feldman, Divoll & Rogan-Klyve, 2009; but see Ritchie and Rigano, 1996).

The major purpose of the present study was to investigate how young students understand scientific inquiry when they are involved in activities performed in a real science research context, i.e., under a scientific research project, with scientists and in a marine research laboratory. The novelty of this study is the engagement of very young students (9 or 10 years old) in experiments, contributing to fill the gap of studies in real contexts in early school years. Additionally, we also aimed at making this inquiry-based activity accessible to a large amount of students, which is important to detect their most common difficulties.

The study had three specific aims:

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i) To document and analyse children's ability to differentiate between the different scientific stages, while they are engaged in two scientific experiments, and discuss possible sources of children's difficulties;

ii) To analyse children's conceptions about scientists and scientific work;

iii) To analyse previous habits of students towards science and to evaluate possible implications in their science understanding and conceptions.

2. Theoretical background

One of the major goals of science education is the development of scientific literate citizens (Millar & Osborne, 1998). Scientific literacy is commonly portrayed as the ability to make informed decisions on science and technology–based issues and is linked to deep understandings of scientific concepts, the processes of scientific inquiry, and the nature of science (Bell, Blair, Crawford & Lederman, 2003). Recent reforms in science education stress the need of science curricula leading to a more authentic picture of science (e.g. Anderson 2007; Duggan & Gott, 2002; Ryder, 2001; Schreiner & Sjøberg, 2004; Singer, Hilton & Scwiengruber, 2005). Consequently, scientific inquiry that enables students to apply both substantive and procedural knowledge in order to perform investigations in a way that mirrors actual practices of scientific communities, has re-emerged as the emphasis of new curriculum approaches (Atkin & Black, 2003; Rocard et al., 2007). According to Hofstein and Lunetta (2003), through such an authentic inquiry "learners can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science." (p. 30).

However, while most of the science education community agrees with the fact that pedagogical practices based on inquiry methods are more effective, numerous studies have already shown that school practices do not follow this approach (e.g. Lederman, 1992; Matthews, 1994; Meichtry, 1992; Rocard et al., 2007). In fact, the practical work usually developed in schools seems to bear little resemblance to inquiry as practiced by scientists (e.g. Chin & Kayalivizhi, 2002; Hipkins et al., 2001; Nakhlel, Polles & Malina, 2002). According to Mant et al. (2007), much of the practical work students engage in, even at secondary level, focuses on recipe-style laboratory exercises and a ‘control of variables’ model of science investigation, which involves closed problem-solving and produces learning outcomes that are predominantly content and skill-based. Apparently, little pedagogical attention is given to problem solving, design and critical evaluation of data (Haigh, France & Forret, 2005).

Present teaching approaches need significant rethinking and development if achievement of scientific literacy goals through inquiry-based learning strategies is to be accomplished (Mant et al., 2007; Rocard et al., 2007). To help teachers in this task, some programs and curriculum materials that involve students in real science research activities have already been developed (e.g. NRC, 2000; Rock & Lauten, 1996). These programs, supported by both scientists and educators, intend to provide students with opportunities to do science through either in-class science projects or out-of-school work, with scientists in research laboratories (Barab & Hay, 2001; Bleicher, 1996; Richmond & Kurth, 1999; Ritchie & Rigano, 1996).

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It is generally believed that the more authentic a research experience is, such as an apprenticeship guided by a science professional, the more likely students will learn about aspects of scientific inquiry. Science educators have assumed that working on authentic science research projects facilitates the development of scientific literacy by enhancing students' understandings of science content, the processes and logic of scientific inquiry, and the nature of science (Bell et al., 2003). Opportunities to experience science-in-the-making and engaging in discourse with professional scientists could possibly lead to a broader and more complete understanding of the processes and nature of science (Barab & Hay, 2001; Cohen, 1997; Moss et al., 1998; Ritchie & Rigano, 1996). Such work projects have the potential to motivate students' interest in learning science (Hughes, 2004), to promote the development of autonomy and self-motivation to learn (Reid & Yang, 2002) and, simultaneously, to improve students' thinking and learning capabilities (Duggan & Gott, 2002; Haigh, 2003).

Recently, many primary science reform documents advocate the need to develop children's views about scientific activity, through the use of an inquiry-based approach which emphasizes problem solving and critical thinking in a real-world context, as early as possible (e.g. Galvão, 2001; Rocard et al., 2007). Young children are intrinsically interested in science. They are curious about the world around them and about the causes, processes, and mechanisms that underlie biological and physical phenomena (Brown, 1997). However, despite their well-documented natural interest in science, little time is typically allocated to learning science during the early school years (e.g. Weiss, et al., 2003), and so they have few opportunities to learn, not only science concepts, but

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also the functions and structure of scientific language, discourse, and processes (Mantzicoupolos, Patrick & Samarapungavan, 2008).

Many researchers have shown that participation in real-world activities and events inspires the construction of schemas about the nature of these events (DeMarie, Norman & Abshier, 2000; Hudson, Shapiro & Sosa, 1995). There is, however, some debate about what students of different grade levels can do with scientific experiments (Mayer & Carlisle, 1996). Whereas some researchers claim that children often become confused while recording data and making inferences based on those data, unable to construct a coherent scientific explanation (e,g, Kuhn, 1989; Solomon, Duveen & Hall, 1994), others advocate that children can perfectly understand the task to produce evidence in support of an argument, being able to distinguish between hypotheses and evidence (e.g. Klahr & Fay, 1993; Sodian, Zaitchik & Carey, 1991). Although developing a mature understanding and necessary skills of data collection and interpretation is an essential component of scientific literacy, relatively little attention has been paid to investigating students' conceptions and related skills involved in the collection and interpretation of data (e.g. Gott & Duggan, 1996; Lehrer & Schauble, 2002; NRC, 2000; Ryder & Leach, 2000).

3. Methods

3.1. Context of the study

The outdoor action was performed in a marine biology research laboratory (Guia Marine Laboratory of the Oceanographic Centre of Faculty of Sciences from Lisbon University) and was integrated in a research project funded by the Foundation for

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Science and Technology: “The role of predation in organising rocky intertidal communities” (PDCT/MAR/58544/2004). The project involved scientific research work and science education actions with children. The scientific component of the project aimed to describe and evaluate predation as a structuring force on intertidal communities, and the purposes of the educational component were to promote scientific literacy through practical science experiments, and to identify children’s conceptions about scientists and how they do science.

The activity in the laboratory included the following actions: i) a short-guided visit to the laboratory installations; ii) a brief introductory presentation of the project research theme (predation); iii) the development of two experiments about predator and prey interactions, and; iv) students’ answers to a questionnaire about the experiments and conceptions.

3.2. Description of the experiments

The two experiments regarding predator prey interactions were conducted in aquarium tanks at the laboratory. The starfish *Marthasterias glacialis* (Linnaeus, 1758) was used as a potential rocky shore predator and the prosobranch limpet *Patella vulgata* L. as prey.

The first experiment involved two aquarium tanks. In the first aquarium (procedural control) the starfish and limpets coexisted but were kept apart, whilst in the second aquarium (experimental treatment) the starfish was held next to limpets so that students could see the interactions between the two species. Adult limpets raise their shell, stick

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out their pallial tentacles, ‘mushroom’ and ‘stomp’ on the arms and tube feet of the starfish, often driving them away (Hawkins & Jones, 1992).

The second experiment tested if the observed interaction, i.e. the limpet defence strategy in the experiment 1, was due to chemicals in the water (chemoreception) or to the contact plus chemical cues (contact chemoreception). The experimental design involved a control tank, with a limpet placed in seawater, and an experimental treatment with a limpet placed in a tank with water where a starfish had previously been.

3.3. Participants

The participants were 136 students from three different elementary private schools, two classes per school. All students were at the 4th grade, with 9 (57%) or 10 (43%) years old. The fourth grade was selected because it corresponds to the last year of the first cycle of basic education (in Portugal) and we wanted to access how children can understand scientific inquiry when they are involved in science research activities, before entering in a new cycle of education, where they will be engaged in more complex science activities. In Portugal, during this first cycle of education, science issues are studied as a multidisciplinary subject (including history and geography). After this cycle, natural sciences constitute a distinct curricular subject. The gender balance of students was 55% males and 45% females. The work performed in the laboratory was supervised by marine biology researchers. Although the experiments were previously designed and all the material and equipment was assembled by marine researchers, the activity was open to students’ participation. Throughout the activity students had the opportunity to make observations, to draw conclusions, to generate new hypotheses, and to design an experiment in order to test those new hypotheses (experiment 2). Additionally, they discussed the characteristics of scientific experiments such as the role of control procedures. By the end of the activity, students reached a certain level of understanding not only about the diversity of anti-predator behaviours, but also about scientific procedures, such as formulating a research problem, stating hypotheses, designing experiments, collecting and recording data, and drawing conclusions based on evidence.

3.4 Methods of Data Collection

Several methods were used for collecting data, such as, direct and indirect observations and enquiry by questionnaire. During all the activity, whereas one of the researchers oriented the presentation and experiments, the other observed children's behaviour and recorded their questions and oral answers. Additionally, each visit was video recorded in order to design learning materials, such as a hyper video.

Participants answered three questionnaires. The first one was administered before the laboratory activity to 136 students at school in their classrooms, and the other two were applied at the end of the activity, in the laboratory to 100 students.

The first questionnaire, with the purpose to identify children's *previous habits towards science*, included questions about their habits of visiting science museums, exhibitions and fairs. Students were also asked about the regular use of the Internet and TV. Finally, they were asked about their interest in science and how often and with whom they do experiments.

The second questionnaire, with the purpose to identify *children's ability to differentiate between the different scientific stages,* included open-ended questions related to both experiments. Concerning the first experiment, children were asked about the purpose of the experiment ('what they want to see with the experiment') and to state hypotheses ('what they expected that would happen'). They were also asked about what they observed ('what did they see') while the interaction between the starfish and limpet took place. Finally they were invited to draw a conclusion ('how did they explain what happened in the experiment') and to explain why they used a control aquarium tank in the experiment. In the second experiment, children were also asked about the purpose of the experiment, and invited to state hypotheses, make observations and draw conclusions. Finally children were invited to draw a general conclusion about both experiments ('what conclusion can you reach based on both experiments').

The third questionnaire, with the purpose to identify *children's conceptions about scientists and scientific work,* included two open-ended questions, namely 'why do scientists make experiments' and ' what must a scientist think to make an experiment.'

3.5. Data analysis

For the analysis of answers to both open-ended questionnaires, content analysis was performed. Concerning the questionnaire related to the differentiation of scientific stages, the answers were grouped according to six categories previously defined: i) Purpose of the study; ii) Hypotheses (only for experience 1); iii) Observations; iv) Explanations; v) Control; vi) General conclusions of both experiments. Concerning the

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conceptions about scientists and scientific work, analysis procedures involved organising categories for the different types and meanings of students' answers.

In order to analyse if there was any influence of students' habits towards science (obtained in questionnaire 1) on children's ability to differentiate between the different scientific stages (results of the second questionnaire) and on children's conceptions about scientists and scientific work (results of the third questionnaire), a Multiple Correspondence Analysis (n=97) was performed to define the participants' profile, i.e. their habits of visiting science museums, exhibitions, fairs and of TV and the Internet use. The purpose of this analysis was to characterise the habits of each student in relation to all the different indicators used in the questionnaire (see Table 1). Based on this analysis two dimensions were extracted (Cronbach's alpha coefficient: α_1=0,785; α_2=0,472) (see Table 2). The participants' scores on each resulting dimension was computed and, based on these scores all participants were subsequently clustered on three groups by a Cluster Analysis (K-means cluster analysis). The following groups were considered (each group includes only children that did all the actions simultaneously):

- Group 1: children who regularly go to museums, exhibitions and fairs related to science; they also see documentaries, science programs and use the Internet for school work (n=33);
- Group 2: children who regularly go to museums, exhibitions, and fairs in general, but not to science events; they do not usually see documentaries nor science programs (n=46);

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- Group 3: children who usually don't go to museums, exhibitions, and fairs; they also don't usually use the Internet for school work and don't read science information (n=18).

Finally, each of these groups were compared according to children's answers in each category considered for the analysis of the second questionnaire, and according to the number of different domains considered for the analysis of the third questionnaire (see Results section). The comparison between the three groups was made through a Kruskal-Wallis Analysis Test. Statistical analysis was performed using the computer program SPSS for Windows (Ver.16.0, SPSS Inc.).

- Insert Table 1 and Table 2 –

4. Results

During the oral introductory presentation of the research theme at the laboratory, students were asked about several aspects of predation and they revealed a good previous knowledge on the predator-prey relation, giving a large number of examples. In addition, the majority of them also revealed that predators weren't always successful in catching their prey, namely because of prey fleeing or prey defence.

4.1. Differentiation of scientific stages

The student's answers concerning the differentiation of scientific stages (second questionnaire), organized according to the 6 categories considered, are presented in Table 3:

- Insert table 3 –

In general, children showed a good comprehension of the purpose of the activities (66 or 53% for experience 1 and experience 2 respectively) (Table 3). They understood the problem that they were dealing with, and gave a well defined objective for each of the experiments, based on the background knowledge given in the introductory presentation.

Concerning the second stage, almost all of them (95%) knew what was going to be tested. For example, in the first experiment, the hypotheses advanced by the children mentioned that predation will occur (e.g. '*The starfish will eat the limpet*') or that the limpet will have a defence strategy (e.g. '*The limpet runs away*', '*The limpet will protect itself inside the shell*') (Table 3).

The major problem revealed by children in the observation category, was the incapacity to distinguish observations from interpretation, giving even anthropomorphic explanations (e.g. *'The starfish wanted to eat the limpet but could not do it'*). Children's capacity to describe observations varied also on both experiments. In the first one, only 29% described correctly what they had observed, whereas in the second experiment 60% of the students gave good descriptions of what they had observed during the activity (Table 3).

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As for the explanation category, the majority of children seemed capable of giving an adequate explanation of what happened in each experiment (60 and 55% for experiment 1 and 2 respectively). In this case, the main difficulty showed by students was again the confusion between explanations and observations (e.g. '*The limpet clamped down the starfish arm*'). A minority of students gave a speculative explanation (7and 6% for experiment 1 and 2 respectively) (Table 3).

In what concerns the control category, the majority of students (69 and 58% for experiment 1 and 2 respectively) seemed to misunderstand the underlying idea of a control aquarium. Most of them were not able to explain the reason of having a second tank in both experiments, with the starfish and limpets kept apart (first experiment) and with only the limpet in seawater (second experiment). However, some students were able to explain the need to evaluate the results by comparing the experimental treatment and the procedural control, and some of them mentioned the control situation as a 'natural behaviour', without making a comparison with the experimental treatment (31 and 17% for experiment 1 and 2 respectively) (Table 3).

Finally, children revealed some difficulty in stating general conclusions. Indeed, 59% of them didn't reach an adequate conclusion after both experiments, giving only a general and some times a wrong conclusion (e.g. *'There are predators and victims'*; '*The starfish doesn't eat limpets*') (Table 3).

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Another aspect revealed by our direct observations during the development of the experiments was that children, when asked about how the limpet is able to feel the starfish, suggested a variety of possibilities, namely by visual, tactile (direct touch or water vibrations) and chemical (‘smell’) senses. In addition, when asked about what we could do to understand how the limpet feels the starfish (planning of the experimental design of experiment 2) they also suggested a variety of experimental designs adequate to their hypotheses: putting the starfish and the limpet together in the same tank, but without touching each other, to test if the limpet feels the starfish by direct touch; make vibrations in the water where the limpet was (without the starfish) to test if the limpet feels the starfish by water vibrations. The main difficulty evidenced by children seemed to be how to differentiate and control separately the different variables.

4.2. Student’s conceptions about scientists and scientific work

Analysis of the answers to the third questionnaire showed that children's conceptions about scientists and scientific work involved several domains, namely: substantive knowledge, procedural knowledge, motivation and scientists’ personality.

When asked about ‘Why do scientists make experiments?’ children's answers fell into 3 major categories (Figure 1.a):

Knowledge (62%): ‘*they want to understand or discover new things’*
Process (23%): ‘*to experiment and see the result...*’
Motivation (14%): ‘*because it is amusing, funny...*’

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The answer to the question ‘What must a scientist think to make an experiment?’ revealed three categories (Figure 1.b):

Process (67%): ‘*The scientist has to think on the materials he is going to use’*

Knowledge (16%): ‘*The scientist has to study and to know things that he is going to experiment...*’

Scientist personality (13%): ‘*The scientist has to be calm, curious,...*’

- Insert figure 1.a and 1.b -

4.3. Students habits towards science and possible implications in science understanding and conceptions

The questionnaire about children habits toward science (first questionnaire) revealed that the majority of them regularly go to museums, exhibitions and fairs (77%, 74% and 55% respectively). History museums (67%), art exhibitions (69%) and art fairs (53%) were the most visited. Concerning science events, 53% of the children visited science exhibitions, 33% science museums and 29% science fairs. In addition, almost all children answered that they use the Internet (98%), particularly for school research (62%). Finally, science programs watched by them on TV were mainly documentaries (46%) and science experiments (41%).

Almost all children showed that they like sciences (96%). The reasons they mentioned for this preference were because: it is amusing (65%); it allows learning new things (53%); it is interesting (24%). Some of them also referred to curiosity about science (7%) and that science is useful for their daily life (1%). Concerning how often and with whom they do experiments all of them were familiar with science experiments because of the weekly science experimental activity in school they mentioned. In addition, they indicate that they also do experiments at home (59%). They do experiments based on teacher indication (90%), but they also do them based on the Internet (62%), books (48%), TV (43%), relatives' suggestions (38%) and friends' suggestions (36%).

The three groups considered concerning children's habits towards science (results of the Correspondence analysis), i.e. children very familiar with cultural and science events (group 1); children familiar with cultural events in general but unfamiliar with science events in particular (group 3); and children unfamiliar with cultural and science events (group 2), revealed no statistical significant differences in the understanding of the activities performed, nor abilities to differentiate between the different scientific stages while they were engaged in scientific investigations (answers to the second questionnaire) (Kruskal-Wallis analysis: χ^2=1.10, dl=2, p>0.05).

Children's responses also didn't reveal any statistical significant differences concerning their conceptions about scientists and scientific work (answers to the third questionnaire), independently of their previous familiarity towards science (Kruskal-Wallis analysis: χ^2=1.70, dl=2, p>0.05 for the first question; χ^2=0.06, dl=2, p>0.05 for the second question).

5. Discussion

These results revealed that young children are perfectly able to engage in scientific activities involving prediction, observation, and explanation. Most of the students were able to state hypotheses, make observations, and interpretations of the conducted experiments. However, some students misinterpreted results and conclusions of the experiments, i.e., when asked about observations they gave an explanation and when asked to explain the experiment they described what happened. These results indicated that students have more difficulties in distinguishing between the description of an event, and looking for the causal mechanisms that would enable them to give an explanation. These findings corroborate the work of Solomon et al. (1994).

According to Bell et al. (2003) it is generally assumed that students will learn not only how to do science, but also learn essential aspects of science, by doing science, as if implicit instruction on these topics would in fact lead to desired educational outcomes. However, some researchers have suggested that desired understandings may only be achieved through a combination of implicit and explicit messages, with the "expert–apprentice" relationship serving as an effective source of these messages (e.g. Bell et al., 2003; Ryder & Leach, 1999).

Thus, real scientific experiments may be necessary but not sufficient to elicit changes in students' conceptions about science and scientific inquiry. It is important to encourage students to connect the scientific activities they are developing, in the classroom with the actual scientific enterprise, if we want them to develop understandings of the

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abstract and complex nature of science and scientific inquiry (Bell et al., 2003). The connection to research laboratories plays a major role here.

Several studies have already analysed the impact of the participation of precollege (e.g. Barab & Hay, 2001; Charney et al., 2007; Etkina, Matilsky, & Lawrence, 2003; Ritchie & Rigano, 1996) and undergraduate (e.g. Hunter, Laursen, & Seymour, 2007; Kardash, 2000; Lopatto, 2004; Rauckhorst, Czaja, & Baxter Magolda, 2001) students in laboratory or field research activities supervised by scientists. Most of these studies have highlighted the real nature of the experiments as a crucial aspect for the development of a deep understanding about scientific activity and science processes.

According to Feldman et al. (2009), whereas traditional apprenticeships, which only requires peripheral participation from students only develops expert practitioners, cognitive apprenticeships, where students are really engaged in authentic activities seems to help students to effectively learn about how science is done, and to gain deep conceptual understanding about science. For example, the study of Ritchie and Rigano (1996) highlighted the unique facilities and the authentic context of the experiences as a crucial factor to make students developing desirable scientific practices, despite the fact of the planning and the set-up were made by the supervisor rather than by students.

The present study was conducted within a marine research institution context where expert scientists provided students' supervision. This study differed in several aspects from previous works. Firstly, the students involved were from the first cycle of basic education (9 or 10 years old). Despite the acknowledge necessity of science education in

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early ears, this is often overlooked in real context studies. Secondly, in this study the activity was open to students' participation. Although there was a previous framework done by the scientists (e.g. material and equipment), the students had the opportunity to to participate in every stage of the experimental activity. Additionally, they were encouraged to reflect and discuss about all stages of the experiments, trying to make students aware about the different scientific processes involved. Some authors (e.g. Roth, 1994) consider that open-ended laboratory sessions are best for all students. Thirdly, our study had great number of participants in the inquiry-based activity. According to Ritchie and Rigano (1996) caution needs to be taken before advocating open-ended inquiry for all. The investigation of McRobbie and Fraser (1993, in Ritchie & Rigano, 1996) has demonstrated that, while it was possible for students in classes with a structured environment to have positive attitudes toward science, it was also possible for students in open-ended classrooms to have negative attitudes toward science. The fact of working with a larger sample of students in the present study enabled us to detect their major difficulties while engaged in scientific experimental work. Finally, this activity was designed so that it could be implemented both in marine research institutes and in school classrooms. Several authors (e.g. Bereiter, 1994; Ritchie & Rigano, 1996) have addressed the question of the effectiveness of apprenticeship models in schools, since many teachers could have some difficulties in guiding students' scientific experiments. As we are aware of this limitation, the present study, apart from bringing students to science, promoting the collaboration between schools and research laboratories, proposes one activity that can effectively be implemented in the school context. In fact, these experiments were already proposed as

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a hands-on activity to be used as a pedagogical resource, able to be developed by any science teacher in a classroom (Faria et al., in press).

One implication of the present study is that, despite the great importance of this type of outdoor action for children's education to promote effective learning, more care should be taken so that children can overcome difficulties. Clearly, this type of activities has the potential for students to receive both implicit and explicit messages about scientific inquiry. However, as suggested by Bell et al. (2003) science educators must have an important role in this respect, either in providing orientation for scientists that collaborate in these research experiences, or to alert them to the common nature of children's scientific inquiry misconceptions and to the importance of explicit instruction in overcoming these misconceptions.

A possible way to overcome these difficulties would be to develop a follow-up learning activity in the classroom, if possible with both the science educator and the scientist, to promote and consolidate these learning outcomes. In what concerns the differentiation of scientific stages, teachers could overcome difficulties by assigning to several groups of students a different task or scientific stage of the experiment. At the end of the experiment, all stages should be completed getting the results of each group. The cooperation of the class and the discussion of results obtained by each group could help children to improve and overcome difficulties. In another activity the teacher would change the group task.

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According to Hodson (1992) the promotion of a large variety of opportunities to perform investigations in a different range of scientific contexts probably will encourage students to develop the sort of tacit, intuitive knowledge in their science investigative abilities that results from experience and understanding. As already stated by some authors (e.g. Peterson & French, 2008; Tytler & Peterson, 2003), in this work it was clear that these opportunities could, and probably should, begin from the earliest age, taking advantage of children's curiosity and willingness to understand the natural world around them. As suggested by Tytler and Peterson (2003), first grade teachers need to listen to children's questions and ideas, and must learn how to challenge and support these with recourse to evidence. This needs to be done through a combination of active investigation, pursuing significant ideas and undertaking interesting and productive explorations that involve coordinating ideas and evidence, and scientific reasoning and argumentation.

Another outcome of the present work was that students' conceptions about scientists and scientific work revealed that substantive knowledge seems to be more important when children are asked about 'Why do scientists make experiments?' and procedural knowledge seems to be more important when children are asked about 'What must a scientist think when he is going to make an experiment?'. It is possible that the students' conceptions mirror the opportunity they had in this study to explore and reflect about the need of both substantive and procedural knowledge in doing science. Indeed, to completely understand and perform this activity students had to get some previous knowledge about the marine organisms involved namely their habitat and feeding relations. Additionally, having to discuss all experimental procedurals involved and

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planning how to test their own hypothesis, they also had to reflect about scientific procedural aspects.

Finally, this study showed no relation between students with different attitudes toward science, (i.e. students very familiar with cultural and science events, students unfamiliar with cultural and science events, and students familiar with cultural events in general but unfamiliar with science events in particular) and the understanding about scientific experiments, the different ability to differentiate between scientific stages, or conceptions about the scientists and scientific work. The fact that child's prior attitudes did not seem to affect their abilities to differentiate between science stages, nor scientist work, is an interesting outcome of the present study. It is possible that the high social level of the students and the fact that the schools were in an urban area accounted for this result. This issue should be further investigated in the future to provide further insights into how to promote the best scientific literacy in young children.

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Table 1. Attitudes toward science indicators.

Indicator		*n*	*no answer*
Museums	Yes	75	
	No	22	0
Science museums	Yes	24	
	No	51	22
Exhibitions	Yes	75	
	No	22	0
Science exhibitions	Yes	41	
	No	34	22
Fairs	Yes	52	
	No	45	0
Science fairs	Yes	22	
	No	30	45
Use of Internet for school	Yes	57	
	No	39	1
Use of science books	Yes	30	
	No	66	1
Use of TV to see science programs	Yes	49	
	No	48	1
Use of TV to see science experiences	Yes	45	
	No	52	1

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Table 2 – Differentiation of scientific stages by students of the first cycle of basic education (n=100).

Categories	*Sub-Category*	*Examples*	*Frequency (%)* *Exp. 1*	 *Exp. 2*
Purpose	Adequate	*'We wanted to see the starfish eating the limpet', 'We wanted to see the limpet reaction'*	66	53
	Inadequate	*'We wanted to see and observe things', 'We wanted to see predators and prey', 'We wanted to see that the shell felt the starfish'*	36	46
	No answer		---	1
Hypotheses	Testable hypotheses	*'The starfish will eat the limpet' 'The limpet runs away', 'The limpet will protect itself inside the shell'*	95	---
	No answer		5	---
Observations	Complete	*'The limpet moved up and down and tried to clamp down the starfish'*	29	64
	Incomplete	*'The limpet moved up and down', 'The limpet twisted', 'The limpet stepped on the starfish arm'*	38	5
	Interpretations instead of observations	*'The starfish tried to attack the limpet and the limpet defended itself', 'The limpet defend itself', 'The starfish wanted to eat the limpet but could not do it'*	39	22
	Incorrect observations	*'The limpet was pulling'*	9	10
	No answer		---	3
Explanations	Adequate explanation	*'The starfish ran away because the limpet tried to catch it'*	60	55
	Observations instead of explanation	*'The limpet clamped down the starfish arm'*	42	16
	Speculation	*'The limpet was scared and tried to defend itself'*	7	6
	No answer		7	24
Control	Adequate answer	*'The aquarium with the starfish and limpet apart was used as a control', 'The control was used to compare the natural limpet behaviour with the behaviour in the experimental treatment'*	31	17
	Inadequate answer	*'The aquarium with the starfish and limpet apart was used so that there were no more wars'*	70	78
	No answer		---	5
General Conclusion	Adequate	*'How the limpet perceives and defends itself from the starfish'*	36	
	Inadequate	*'The starfish doesn't eat limpets', 'There are predators and victims'*	59	
	No answer		5	

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Figure 1.a. Percentage of answers to the questionnaire item ‘Why do scientists make experiments?’ in the four categories (knowledge, process, motivation, no answer).

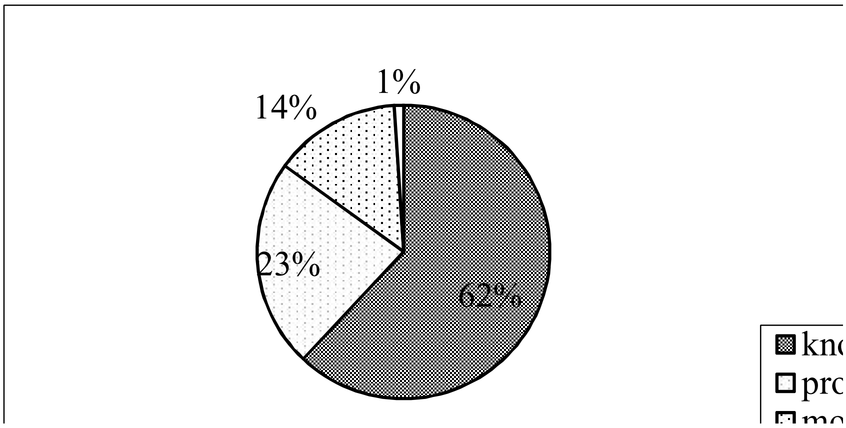
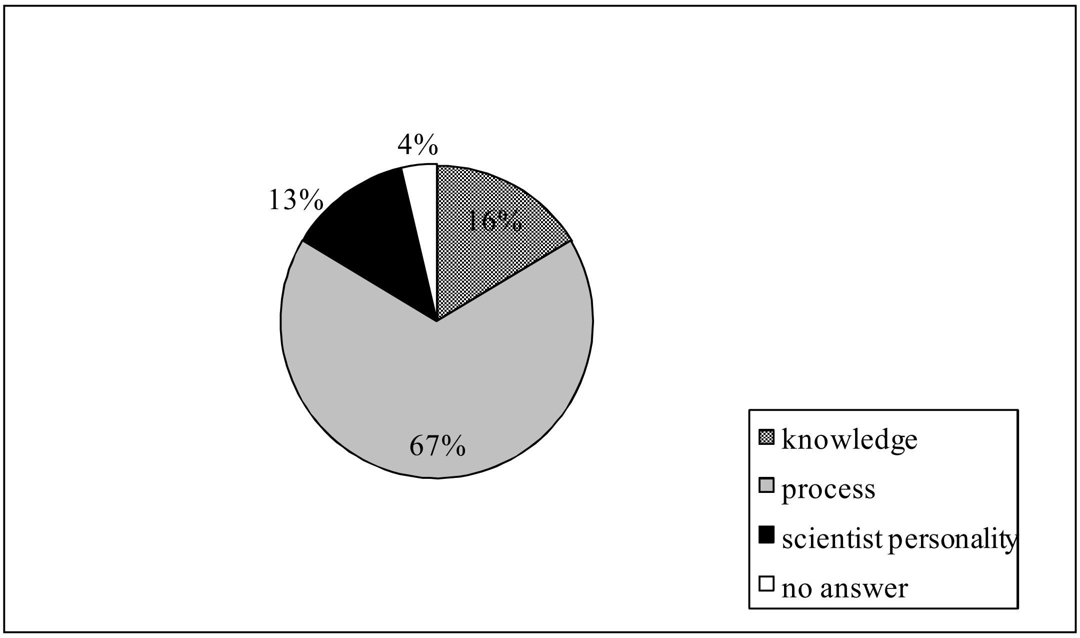


Figure 1.b. Percentage of answers to the questionnaire item ‘What must a scientist think when he is going to make an experiment?’ in the four categories (knowledge, process, scientist personality, no answer).



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