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Full Length Research Paper

The impact of experimental activities on the motivation and acquisition of scientific concepts at the basic school level.

***Azevedo M.-M[1,2], Fonseca F[1], Teixeira A[3], Brito C[4], Andrade RP[4], Palmeirim I[5]**

[1]School E.B. 2, 3 D. Maria II, Vila Nova de Famalicão, Portugal;
[2]Department of Microbiology, Faculty of Medicine, University of Porto.
[3] Faculty of Dental Medicine of The University of Porto, Rua Dr. Manuel Pereira da Silva, 4200-393, Porto, Portugal.
[4]Life and Health Sciences Research Institute (ICVS), School of Health Sciences, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
[5]Department of Biomedical Sciences and Medicine. University of Algarve.
Campus de Gambelas, 8005-139 Faro, Portugal.

*Corresponding author E-mail: mariamanuel2001@megamail.pt, Phone: +351 252311365, Fax: +351 253604809

Abstract

Forty students (middle school) participated in the science activity entitled "Scientists for a Day", developed by the Life and Health Science Research Institute/School of Health Science, University of Minho. The activity consisted in a set of laboratory activities. The general objectives of this activity were to stimulate the pleasure of knowledge, encourage critical views, heighten the interest in science, motivate students towards experimental work and demystify the idea of what a Scientist is. To validate this activity and evaluate what they have learned, the students were asked to answer a questionnaire before and after this action. In this study we observed a clear correlation between the use of experimental activities as a learning tool and an increase in scientific knowledge.

Key words: Science communication, Science Education, experimental activities, extra-curricular activities, extension activities.

INTRODUCTION

Communication of Science to the general public plays a major role in today's society. It helps to bridge the gap between Science and Society, promoting access to scientific and technological knowledge. In 2001, the European Commission presented an action plan entitled "Science and Society" EC (2001), which focused on the need to establish a democratic model of science communication and to identify its potential players: the media, researchers, research institutions, universities, and business companies. On the same note, the scientific journal "Nature" organized specific teams to work with online contents and to prepare press releases that build the public understanding of scientific research Moutinho (2006). As a result, scientific culture has acquired both individual and social dimensions Godin et al. (2000).

The "Declaration on Science and the Use of Scientific Knowledge" adopted at the World Conference on Science held in Budapest and organized by UNESCO in 1999, recognizes that Science Education is essential for human development and to create endogenous scientific capacity as well as informed and participant citizens. However, today's communication channels are insufficient. A survey conducted among Portuguese people of different levels of education, showed that only 37% of them related to science with significant proximity Costa et al. (2002). With this in mind, who should be involved in Science Education? It is now up to the universities to develop the so-called "extension activities", which include activities such as "Public Understanding

of Science" or "Science Communication".

Knowledge becomes active, useful and with multiple and connected meanings within different and non-formal contexts. Schools and universities will always have a privileged position on the Education of Societies, if they take upon themselves the role as organizers of this body of knowledge from different origins. The Public Understanding of Science is a way of complementing the education of both students and teachers.

The Portuguese School Curriculum for Basic Cycles 1, 2 and 3 Ministry of Education (2001) describes the skills that students should achieve with great emphasis on the role of Science and Technology for the development of individual skills. Today's ever-changing society, demands an enlightened population with sufficient knowledge to fully understand and follow science and technology debates, and also to consciously get involved with the issues surrounding these matters. Therefore schools must prepare the young people for these transformations, giving them the tools that will allow them to adapt to new situations.

Fully aware of the increasing importance of learning in non-formal contexts, forty students of the school *E.B. 2, 3 D. Maria II* (middle school) participated in the science activity entitled "Scientists for a Day", developed by the *Life and Health Science Research Institute/School of Health Science* (ICVS/ECS), University of Minho, which is the closest public university. The general objectives of this activity were to stimulate the pleasure of knowledge, encourage critical views, heighten the interest in science, motivate students towards experimental work and demystify the idea of what a Scientist is. In an effort to validate this activity and evaluate what they have learned, the students were asked to answer a questionnaire before and after this action.

It is our belief that such activities are essential for students to develop skills that will allow them to apply scientific methodologies, namely, interpretation and critical analysis skills toward new situations.

Material and methods

This study was conducted between 2007 and 2008 and was the first of this kind to ever be conducted in Portugal. With this in mind, a convenience sample was used. The experimental group consisted of 40 students between the ages of 12 and 15, of the 7th grade of the school *E. B. 2, 3 D. Maria II*, located in the municipality of Vila Nova de Famalicão, district of Braga. Data collection was processed through a questionnaire, which included 86% of multiple choice and 14% of open answer questions. This evaluation instrument was developed by the authors of this study and was designed to test the students' knowledge regarding several areas such as: heredity, acid/basic concept, embryonic development and sensory perception. It was conducted within a context of regular classes and was pre-tested on 10 students. Student participation was voluntary and anonymous and had a limit of 45 minutes for its conclusion. The level of participation reached 100%.

The activity was structured in several steps. The first consisted in a questionnaire (pre-test) about the above-mentioned contents. In the second one, the students participated in the action "Scientists for a Day", developed in the ICVS/ECS (University of Minho). The experimental activities were subdivided into 4 stations: 1st station – "Extracting banana DNA"; 2nd station – "Acid/base"; 3rd station – "Observation of chicken embryos"; 4th station – "Five senses". Finally, the same questionnaire was answered 15 days after the field trip (post-test).

The data was converted to percentage values and statistically treated using the statistical software SPSS (Version 14.0 SPSS Inc, Chicago, IL, USA). In order to identify significant statistical differences, the data was analyzed using Pearson's Chi-square test ($\chi 2$), and the values were considered statistically different when $p<0.05$.

TEST DAST was also administered to gather information about the students' images of scientists and the laboratory environment. This part of the study was done as homework and was subjected to a qualitative analysis.

Results

The activity "Scientists for a Day" consisted in a set of laboratory activities subdivided into four experimental stations, namely: 1st Station – "Extracting banana DNA"; 2nd Station – "Acid/Base", 3rd Station – "Observation of chicken embryos" and 4th Station – "Five Senses".

Station I – Extracting Banana DNA

In this station, the students extracted DNA from a banana using a very simple and easy experimental protocol with instruments and/or substances that can be easily found at home, such as a spoon, blender, strainer, filtering paper, banana, salt, water, detergent and alcohol. The main objectives of this station were to learn about DNA function and its cellular location, to know that it is possible to isolate and to see DNA (if in large quantities) and to recognize that all living beings possess DNA.

We observed a significant improvement in all aspects that were explored in this station, when comparing the performance of students' pre- and post-tests, with approximately 40% of the students showing progress (Table 1). Regarding the absence/presence of DNA in different objects/living beings (pen, turtle, microorganisms, tulip, mold, ball, mp3, water, cabbage), the students revealed reasonable subject knowledge in the pre-test (Tables 1 and 2), however significant

Table 1. Correct answers of students (%) concerning stations 1-4 and some general aspects (p≤0.05)

Stations	Questions	% Correct answers		% Increase in correct answers	*p* value
		Pre-test (R.PRE)	Post-test (R.POS)	Δ (R.POS-R.PRE)	
Extracting banana DNA	What is the importance of the nucleus?	33	71	38	p =0.004
	Which contain DNA?				
	mold	48	91	43	p <0.001
	mp3	75	100	25	p =0.002
	cabbage	75	94	19	p =0.026
	Is it possible to visualize DNA?	13	56	43	p<0.001
	Mean	49	82	34	-
Acid/Base	Are you familiar with the acid/base concept?	28	88	60	p<0.001
	Is it possible to use red cabbage as an acid/base indicator?	15	82	67	p<0.001
	pH value of:				
	juice	13	53	40	p<0.001
	coca-cola	35	80	45	p<0.001
	caustic soda	20	62	42	p<0.001
	detergent	30	71	41	p<0.001
	water	40	68	28	p=0.018
	Mean	26	72	46	-
Observation of chicken embryos	Are there similarities between embryos of different species?	35	91	56	p<0.001
	Do 3-day-old chicken embryos have paws?	25	68	43	p<0.001
	Does the heart of a 2-day-old chicken embryo beat?	45	94	49	p<0.001
	Are chicken embryos used as animal models in science?	38	88	50	p<0.001
	Have you observed live chicken embryos?	23	92	69	p<0.001
	Mean	33	87	53	-
Five senses	Are there interactions between sense organs?	10	41	31	p<0.002
	Can there be different perceptions of the same temperature?	43	76	33	*p= 0.010*
	Mean	27	59	32	-
General aspects	What is an experimental protocol?	20	74	54	p<0.001
	Can experimental protocols be simple?	53	91	38	p=0.001
	Mean	37	83	46	-

Table 2. Correct answers of students (%) concerning stations 1-4 and some general aspects (p>0.05)

Stations	Questions	% Correct answers		% Increase in correct answers Δ (R.POS-R.PRE)	*p* value
		Pre-test (R.PRE)	Post-test (R.POS)		
Extracting banana DNA	Which contain DNA: pen	88	91	3	*p*=0.612
	turtle	90	97	7	*p*=0.228
	microorganisms	93	88	<0	*p*=0.532
	tulip	73	88	15	*p*=0.093
	ball	83	97	14	*p*=0.128
	water	30	50	20	*p*=0.079
	Mean	76	85	10	-
Acid/Base	pH value of: vinegar	98	94	<0	*p*=0.462
	lemon	93	97	4	*p*=0.387
	Mean	96	96	2	-
Five senses	What are the five senses?	85	91	6	*p*=0.418
General aspects	Are you able to do simple experiments at home?	35	56	21	*p*=0.150
	What precautions must you take in a laboratory?	68	85	17	*p*=0.075
	Who should conduct experiences?	45	65	20	*p*=0.100
	Mean	49	69	19	-

improvements were still observed in the post-test (Table 1). In the specific case of water, difficulties were evident in both the pre-test and post-test. Very positive results were also obtained in what respects the importance of the nucleus and DNA visibility, where an average of 41% of the students improved their knowledge (Table 1). Globally, this experimental station fully fulfilled the proposed objectives.

Station II – "Acid/Base"

The students tested several foods and day-to-day products regarding their acidic, basic or neutral properties. The acid/base indicator used was the water of boiled red cabbage. It was explained to the students that, whenever in contact with neutral solutions, the indicator maintains its original color, in contact with acidic solutions it turns red and in contact with alkaline solutions it can change to two different colors: blue for weak alkaline solutions and green for strong alkaline solutions. The main objectives of this station were: conveying the message that foods, detergents and other products have acidic, basic or neutral properties; demystifying the idea that base/sweet are synonyms; presenting the concept of pH, which is a measure of the acidity/alkalinity of a substance; explaining what are acid-base scales; understanding that the red cabbage is a pH indicator.

In terms of concepts such as acid/base and using red cabbage as a pH indicator, significant progresses were made after doing this activity. The percentage of correct answers increased 60% and 67%, respectively (Table 1). Regarding the pH value of the tested substances, many difficulties were detected in the pre-test (Table 1) except for vinegar and lemon (Table 2). In the post-test, significant improvements of about 40% were confirmed (Table 1). We believe this experimental activity was very successful regarding all goals proposed, and that its implementation in the classroom would result in great benefits for the students.

Station III – Observation of chicken embryos

This station started by showing the students explicatory panels about the early stages of development of several vertebrate embryos. Student then opened chicken eggs

with the help of a scalpel and a scissor and observed chicken embryos in different developmental stages using a stereomicroscope, with an emphasis on the structures that precede the formation of the eye, ear, brain, vertebral column and limbs. The main objectives of this station were: to acquire the notion that different vertebrate embryos are very similar in the first stages of development; observation of chicken embryos over development; understanding how to gain knowledge about human embryo development.

We point out that in the pre-test the students showed several difficulties in terms of embryo development-related issues, namely, they were unaware of the similarities that exist between vertebrate embryos during the first stages of development, they had no notions regarding the time it takes to develop the structures that precede the eye, ear, brain, vertebral column and the limbs in the chicken embryos, and they also weren't aware of the importance of using chicken embryos as experimental models (Table 1). In fact, the correct answers obtained in the pre-test (mean 33%) may be due solely to pure chance, since these subjects are not dealt with throughout previous school levels. In the post-test, however, the students significantly improved their performance in all of the areas that were explored (Table 1), underlying the great advantage in using hands-on teaching methods to convey information and generate enthusiasm towards a specific subject.

Station IV – Five Senses

In this station the students conducted experiences so that they would understand that the senses work and cooperate with and each other and that it is possible to "deceive the senses". The main objectives of this station were: reminding the notion of the five senses; verifying that the sense of smell and taste work and cooperate together; understanding that what we see (sight) and what we feel (touch) does not always correspond to reality, but to a relative reality.

Concerning the knowledge of the five senses, the majority of the students in the pre-test answered correctly and this situation was maintained in the post-test (Table 2). In the question regarding the interaction between sense organs, 31% of the students improved their performance between the two evaluation moments (Table 1). A similar increase in the number of students who answered correctly was also observed in the experimental situation related to the different perceptions of the same temperature (Table 1).

General Aspects

In addition to fulfilling the above-mentioned specific goals of each station, this study was also conducted so that the students could achieve other objectives, such as: understanding Science as a simple and effective tool for problem solving; meeting and talking with scientists; visiting laboratory environments; conducting simple experimental protocols; encouraging the students to actively participate in the experiences and in result interpretation.

With this in mind, we studied students' knowledge regarding experimental protocols and laboratory environments. Several difficulties were highly visible in the pre-test, however, they were partially resolved after this activity (Table 1 and II). Regarding open answer questions, such as knowing scientists, in the pre-test and in the post-test, 60% and 76%, respectively, declared they knew scientists ($p<0.131$) and 33% (pre-test) and 50% (post-test) showed interest in becoming scientists one day ($p=0.127$). In terms of interest in conducting experimental activities, 93% (pre-test) and 100% (post-test), declared they enjoyed accomplishing them.

In order to research students' alternative conceptions with the TEST DAST Chambres, (1983), students made drawings of scientists in their daily life. Prior to having visited the ICVS/ECS, they represented scientists as individuals, mainly men, according to stereotyped images (crazy hair, round eyeglasses, crazy eyes), working in very simple environments using nothing but test tubes and balloon-flasks (Figure 1). After the field trip, they continued to have a stereotyped image of the scientists, however, they portrayed them working in more complex laboratory environments, surrounded by laboratory materials such as: microscopes, magnifying glasses, computers, biological materials (eggs, microorganisms) and symbols related to research and knowledge, for example: books, archives, formulas, etc (Figure 2). Most representations, before and after the field trip relate scientific activities with findings in the health department, particularly trying to find a cure for certain diseases, namely cancer.

DISCUSSION

The use of active innovation activities which stimulate judgment is essential for the growth and motivation of the students. With this in mind, students of several schools were invited to participate in the activity "Scientists for a Day". Science Education's main objective should be the development of critical judgment/thinking, it should be interdisciplinary, integrated and should understand and connect "Science, Technology and Society".

After the participation in this activity, several improvements were detected regarding the students' understanding and application of concepts, data analysis/ interpretation and critical views. However, some previous misconceptions still prevailed on certain aspects: for instance, the fact that they considered the nucleus of the cell was important because it is located in its centre, or that water contained DNA. In the first case, it is our opinion that they may be influenced by school books and teacher which

often, in an oversimplified manner, represent the nucleus as the centre of the cell. As for the second case, the explanation could come from the fact that they mistakenly confused water with aqueous environment.

When it comes to the contents developed in station "Acid/Base", significant improvements occurred. In addition, another relevant aspect that resulted from this study consisted in the fact that the students started to realize that conducting these experiments is easy and all it requires are simple materials that they can find in their own homes. Scientific processes which involve experimental work, data gathering and its analysis and interpretation, are very important so that they can participate actively in the search for solutions to problems Dibartolomeis et al. (2003). Recent studies have shown that Science teachers' classroom practices reflect an image of Science as a set of factors, terms, concepts and theories that are up to scientists to create, teachers to instruct and students to memorize passively and uncritically Reis et al. (2005).

It is necessary to mention that the students' motivation for eventually becoming researchers increased from the pre-test to the post-test, which demonstrates the relevance of such activities. The observation of chicken embryos was, without a doubt, the activity that the students were more enthusiastic about. The awe and excitement were clearly visible as they observed the chicken embryos and their heart beating. Regarding the image of scientists, in spite of the fact that the students visited the ICVS/ECS and were in contact with scientists, most of the students do not see them as typical scientists, in other words, the stereotyped image of a scientist still prevails. However, after the field trip, they portrayed their work environment in a more realistic way.

According to Sequeira (1996) "Research and discovery should be an ongoing process, a constant attitude in everyday life and not an isolated act. Only in this way we are able to create active citizens who possess scientific literacy, essential to consciously discuss science and technology-related issues raised by today's society, and a key aspect in exercising citizenship". In that sense, these activities should be constant. Since the vast majority of students said they greatly enjoyed performing experimental activities, Science teachers should take this fact into account and increase the number of practical classes. Today's teachers should take upon themselves the role of transforming information into knowledge, and knowledge into experience, so that they can teach students to think for themselves instead of just repeating information Cury (2004). According to Piaget (1996), new stimuli generate new cognitive structures, which lead to intellectual development. One of the most important objectives in learning Science should be the familiarization of students with the characteristics of the scientific work, in order to help them comprehend their paths and their multiple features, making them active citizens who are capable of making their own decisions in interdisciplinary situations, in which Science is one among the many voices of Society Cachapuz et al. (2000).

Notwithstanding some limitations, for example, the fact that we do not possess information regarding possible variables that may have influenced the outcome of this study, such as socio-economic conditions or intellectual levels, we consider this work to original and innovative, since it translated into a positive contribution to different aspects of student learning and socialization. Brown-Acquaye (2001) emphasized the importance of Science Education in developing countries, since it may lead to an improvement in quality of life. Other studies developed a set of Cellular Biology-related activities in places where these initiatives would normally not occur, such as town squares and shanty towns, in order "To Socialize the Scientific Knowledge". Similar experiences were developed in Science Centers and Schools Araújo et al. (1999).

In this study we observed a clear correlation between the use of experimental activities as a learning tool and an increase in scientific knowledge. Such actions performed in an informal atmosphere allow the students to learn effortlessly, while making Science fun! The experimental stations presented in this current work are very easy to perform and economically viable. It is our belief that these kind of activities should be encouraged and their relevance recognized, as they are essential in creating prepared and active citizens who are capable of responding to future challenges.

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