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The museum of chemistry, from the past to the future through the laboratory

El museo de la química, desde el pasado hasta el futuro mediante el laboratorio

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Abstract

During the last several years, the Chemistry and Industrial Chemistry Department of the University of Genova (DCCI) has developed a few projects with the specific target of helping younger generations approach science in a correct and fascinating way, to contribute fostering the future scientific and technological development of society. In this paper the project, we describe a visit to the Museum of Chemistry of the DCCI followed by a laboratory activity, where the students are provided an opportunity to appreciate chemistry from a more complete point of view. At the end of the activities, a questionnaire is distributed to the teachers, to evaluate their appreciation of both the museum and how the laboratory contributes to the project. An analysis of the results is also reported.

Key words: *education, scientific museum, school laboratory activities*

Resumen

Durante los últimos años, el Departamento de Química y de Química Industrial de la Universidad de Génova (DCCI en el siguiente), ha desarrollado algunos proyectos con el objetivo específico de hacer que las generaciones jóvenes se acerquen a la ciencia de una manera correcta y fascinante, con el fin de contribuir fomentando el futuro desarrollo científico y tecnológico de la sociedad. En este trabajo el proyecto "EL MUSEO DE QUÍMICA: DEL PASADO AL FUTURO A TRAVÉS DEL LAB" consiste en una visita al Museo de Química de la DCCI seguida de una actividad de laboratorio, donde los estudiantes visitantes puedan apreciar la química desde un punto de vista más completo. Al final de las actividades se distribuye un cuestionario a los profesores, para evaluar su apreciacion, por tanto el museo como laboratorio contribuye al proyecto. También se presenta un análisis de los resultados.

Palabras clave*: educación, museo científico, actividades de laboratorio de la escuela*

INTRODUCTION

This article illustrates the aims and the communication strategy adopted in the project "THE MUSEUM OF CHEMISTRY: FROM THE PAST TO THE FUTURE THROUGH THE LAB", a scientific culture dissemination project dedicated to consolidate collaboration and exchanges among schools, general community and the museum of chemistry of the Genoa University. The project began from a collaboration between the DCCI, engaged for years in scientific activities for the schools (from the primary to the high school level) and Green Modeling Italia (GMI), a cooperative society, spin-off of the Genoa University, whose members have many years of experience in training, and scientific research. The project aims at developing new forms of scientific presentation and new methodologies to achieve a more effective exchange between the scientific research world and the community. Specific attention has been devoted to the schools of all levels, providing teachers with effective tools for their work, offering a wide range of educational services (laboratory activities and scientific visits within the museum of chemistry) with a rigorous but appealing scientific approach, stimulating the interest to chemical sciences and biotechnology through a direct involvement of the participants. The belief that scientific museums represent an opportunity to offer culture and education is now widely shared but, especially in our country, this practice is usually underdeveloped. The impact of chemistry museums on the general public in Italy is quite low, mainly because of the relatively small number of visitors **(**Domenici, 2008**).** One of the immediate challenges of these museums is to change their image to get more in touch with the society (O'Brien, 1999) (Gupta, et at, 2010) and to demonstrate (rather than obscuring) the role and impact of chemistry in everyday life, in both its negative and positive outcomes (Morris, 2006).

Recently, several initiatives have been developed that link a visit to a museum of chemistry (or more generally a scientific museum) to laboratory activities, but often without the characteristic of continuity that allows museums to become part of the educational experience. In Italy, the Museo di Chimica of the Università la Sapienza, Rome proposes a numbers of laboratory activities related to specific museum itineraries for schools (http://www.officineapogeo.com). In Widnes, Great Britain the scientific museum "Catalyst" (http://www.catalyst.org.uk), visited by over 40,000 visitors every year, can be summarized by the words of its director, Christine Allison, "Catalyst is a place where science fuses with fun, and of course, chemistry is most fun when it is hands-on."

METHODOLOGY

The guided visit to the Museum of Chemistry of DCCI - University of Genoa

The museum is located in the old Chemistry Institute premises, as a typical example of the chemical laboratory of the early twentieth century with original furniture and tools. It contains hundreds of objects, most of which dating back to the second half of '800 and the first half of '900. Inside the museum, the visitors can appreciate numerous apparatuses and instruments pertaining to different scientific fields (thermodynamics, mechanics, metrology, electromagnetism, electrochemistry, optics and spectroscopy). Two groups of tools are of specific interest, the first includes items from the age of Stanislao Cannizzaro (fig.1).

Fig.1. S. Cannizzaro portrait (http://www.chimica. unige.it/museo/Canizzaro.htm)

Cannizzaro, the son of a magistrate, studied medicine at the universities in Palermo and Naples and then proceeded to Pisa to study organic chemistry with Raffaele Piria, the finest chemist then working in Italy. In 1849 Cannizzaro traveled to Paris, where he joined Michel Chevreul in his laboratory at the Muséum National d'Histoire Naturelle. Two years later, Cannizzaro was appointed professor of physics and chemistry at the Collegio Nazionale in Alessandria, Piemonte (now part of Italy). Then, in 1855, he was called to a professorship in Genoa, where he taught chemistry from 1855 to 1861. During that time he published the "Summary of a course of chemical philosophy" that was presented in Karlsruhe in September 1860 at a conference of the major chemical existing at the time; they are still debating issues such as the distinction between the concepts of atom and molecule. Cannizzaro, developed a method to measure the atomic weight of the elements contained in a compound, clarified these two concepts with irrefutable arguments accompanied by experimental confirmation. Mendeleev, who was in attendance at the convention, took advantage of his views in order to proceed to the drafting of the periodic classification of the elements, completed in 1869. The second group of tools, dating back to the 1930's consists of equipment and tools used to process and characterize the rare earths. The museum also preserves equipments and teaching boards of historical value, and has a store of historical material and numerous paper items yet to be restored. In figure 2 the main room of the museum is shown, while figure 3 shows three images related to three of the main topics accessible at the museum.

Fig.2. The main room of the Museo di Chimica

a) b) c)

Fig.3. Three reports pertaining to the museum: a) filtering apparatus for the separation and crystallization of the rare earth elements. b) original ancient pigments and the Chevreuil chromatic circle. c) eudiometer: tool used to analyze the gas and to measure the purity of air. The instrument shown is an evolution of the one invented by Alessandro Volta in the 1770s.

To make science museums more proactive in school education new communication strategies need to be developed. Visitors need to be directly involved in the scientific phenomena inducing curiosity, wonder, motivation, understanding and interest in learning more. This can be achieved by highlighting the human aspects of chemistry, while exhibits can stimulate memories linked to biographies of scientists, to their human stories and to famous scientific discoveries.

An effective communication strategy should allow the visitors to identify the objects accessing easy information as name, function and historical origins. People should be encouraged to ask questions about the subject involved, receiving answers that enable a deeper understanding about why a tool was constructed, in which cultural and economic context, and what other tool it can be compared with now.

The visit to the museum of chemistry of DCCI directly involves the participants. The guides keep the visitors interest high through the description of the tools and the narration of some anecdotes, related to illustrious personalities of the past who made a strong contribution to the development of chemistry. The visits offered to the schools consist in selected museum routes, each related to a specific laboratory activity, which takes place in a scientific laboratory, located next to the museum. The visit starts with a brief description of the main pieces of laboratory glassware and of their specific uses. School children are encouraged by the guide with a series of questions related to the purpose of use of the different tools, sharing examples from daily life or knowledge arising from their study pathways. The second step of the visit accompanies the visitors into the "room of the gases", where are stored the devices that allowed the determination of the chemical composition of air, and where is available a reconstruction of the system used by Lavoisier to discover the composition of water. In this room, there are also Dewar vessels and several pieces of Kipp equipment, the latter usually collecting a lot of success and admiration by the younger participants. The tour ends in the main room of the museum, which collects most of the scientific instruments of the past. Here, particular emphasis is put on the color theory of Chevreuil, showing the tables created by the researcher to explain the genesis of the different hues and shades of colors, as well as on the discovery history of the colors, both of natural and synthetic origin.

Laboratory activities

Hands-on experiences in laboratories have long been recognized for their importance in science education (Krajcic, 2001). Laboratory investigations offer important learning opportunities for students to link theory and science concepts with concrete events.

The educational goals of the scientific experimentations proposed are a phenomenological–inductive approach to the scientific topic proposed, the introduction of elements for a critical approach to the results, the successful achievement of the learning objectives planned and the creation of new situations that are more open and dynamic, but having a greater emphasis on individual formation pathways. Science educators increasingly perceive the science laboratory as a learning environment in which students have the opportunities to observe scientific phenomena. A privileged place to verify the scientific laws, to build experimental and reasoning skills by learning to apply the theoretical knowledge to practical experimentation by means of hands-on activities. Furthermore, the laboratory is a source of experiences, highlighting the social dimension of the school, improving the ability to work in a team to achieve shared results; through a critical approach to their work, the students develop awareness of their own potential and learn to grow their self-esteem.

A series of thematic labs is offered, in order to develop the interdisciplinary nature of chemistry, whose themes are represented by the biogeochemical cycle of one element (C, N and P). The periodic table is thus the starting point of all the labs and from there the participants discover by significant experiments the path that the chosen chemical element follows within the biosphere and the continuous interactions between living (biotic) and nonliving (abiotic) environments. The proposed experiences, set up ad hoc on the age of students, are listed in the following with the related literature references. During the activities the students are supervised by PhDs who guide them during the experimentation.

A. For classes III, IV and V of the primary school and the lower secondary school level

- Element carbon: The experimental activities involving the element carbon cover such topics as photosynthesis and cellular respiration, alcoholic fermentation carried out by yeast and the production of CO_2, the research of sugars in foods and beverages, using a colorimetric reaction, and the determination of fats. (Reinking, at al, 1994; Yurkiewicz, et al, 1989; Tatina, 1989) (Detecting starch in food, Practical chemistry www.practicalchemistry.org/experiments/detecting-starch-infood.223.EX.html - Science and Plants).
- Element phosphorus: The experiments focus on the structure and function of DNA with its extraction from an array of vegetal origin.
- (Curtis, 1989) (Genetic Science Learning Center, University of Utah; http://gslc.genetics.utah.edu/units/activities/extraction/)
- Element nitrogen: The workshops focus on experiences relevant to the nitrogen-fixing organisms such as microalgae, emphasizing the properties and functions of proteins with enzymatic action and understanding the mechanism of action and the importance of these molecules with particular reference to metabolic processes. (Marini 2005, Inhelder, et al, 1958; Voet , 2004; Van der Maarel, et al, 2002).

B. For the high school students the laboratory activities proposed are:

- Fantastic plastic (in Italian this title sounds like a joke)

  The goal of the laboratory is to accompany the students in a short but significant journey into the world of plastic, to learn more about this material, appreciating its great versatility and assessing its strengths and weaknesses. The journey into the world of plastic starts with its birth, experiencing the synthesis of macromolecules such as special

Nylon® and 'foam' and showing how their properties can be different from those of the starting materials, mostly coming from petrol. At the end, the students are introduced to environmental education, talking about recycling, energy recovery and experiencing the possibility or not to transform an artifact in another according to the type of plastic of which it is composed.

- The natural pigments: extraction and analysis

The activity focuses on extraction, isolation, and spectroscopic analysis of natural pigments. Pigments are initially extracted (from spinaches) into an organic solvent. The extracted mixture, essentially consisting of chlorophyll (green) and carotene (yellow-orange), is then subjected to a separation process using silica. The formation of two "bands" differently colored fully justifies the name given to the technique used: "chromatography", or "write the color". Finally, the two pigments are separately subjected to spectroscopic analysis in the visible, leading to a discussion about the interaction between matter and light.

- Synthesis of colored glasses

The glassy state is that of a solid stuck in the disordered structure of a liquid, the main glass component being the silica of sand. It is possible to impart a color to the glass by adding secondary constituents such as Cu^{2+} (light bleu), Co^{3+} (bleu), Ce^{2+} (yellow), Nd^{3+} (violet); the combined addition of Fe^{2+} and Fe^{3+}, bleu and yellow respectively, cause the well known green color of bottles. Students weigh and mix the powders of the reagents and introduce them in crucibles for heat treatment, which will take place in an oven at high temperature (1000 C). After treatment, the crucible is extracted from the oven and the liquid is poured onto a sheet of aluminum or graphite molds to favor a rapid cooling.

- Properties of the elements: metals

This laboratory experience aims at defining a metal through a series of experimental observations. Students are initially stimulated to make some sensorial remarks on various elements, more or less known; then they compare the behavior of the same elements with respect to certain properties, such as heat and electricity conduction, melting temperature, the chemical behavior in water, air, and solutions of acids and bases. From the observation and processing of the experimental results the students try to define the concept of metallic element and will also be able to order the different elements analyzed according to the degree of metallic behavior.

RESULTS AND DISCUSSION

One of the main goals of the project is to use the Museum as a special resource to address the historical dimension of chemistry, its evolution and the scientific and technical ideas that have been established over time, enabling the discovery of the "current" version of the "historical" equipments displayed in the Museum of Chemistry. This approach also provides a starting point for a series of practical laboratory activities that link different scientific areas with current issues, such as health, environment, food safety and biotechnology. This approach allows to create interdisciplinary experiences through practical laboratory activities, relying on the "hands–on" method. The project would also provide a new tool for science teaching in general and chemistry in particular. In this way, it will be possible to communicate the importance of interdisciplinary science through a trail that includes the use of the Museum of Chemistry as a place of acquiring knowledge not only of the past but also of the present.

The communication strategy used was chosen to provide concrete tools for making up an objective opinion on chemistry and other disciplines often demonized, such as biotechnology. During the experimental work, teachers are supplied with material (Power Point presentations) to deepen the study of topics that can be analyzed in an interdisciplinary way. In Table 1 the activities selected vs the different classes are reported.

The children learn about their own abilities to perform scientific experiments, and have the opportunity to compare their approach with that of a 'real' scientist. In addition, the inquiry-based approach allows children to enjoy teamwork as well as the experimental activities themselves: this is a real source of motivation and shared joy. The opportunity for schools to have free access to interactive educational experiences, that might not otherwise be made use of, favored a copious participation of students and teachers to the proposed activities. This report includes the three school years, 2012-2013, 2013-2014 and 2014-2015 during which 116 classes (almost 3,500 students and over 250 teachers) joined the project. Figure 4 reports the distribution of the students as mirrored by the school level.

Table1. Laboratory activity selected by the different classes.

Laboratory activity	primary school	lower secondary school	high school	TOTAL
The plants and the chlorophyll	8	-	-	8
water: marvelous solvent	4	3	-	7
How much colors with the vegetable!	3	2	-	5
The gases and their properties: the air	1	-	-	1
The carbon pathway	4	-	-	4
phisycal and chemical transformations	-	10	-	10
solid, liquid or gas?	-	3	-	3
Capillarity and surface tension	-	1	-	1
The carbohydrates and the lipids	-	3	-	3
nitrogengetter organisms	-	3	-	3
The proteins:buikldíng block of life	-	1	-	1
The Dna: the molecule of life	-	1	-	1
Metals	-	-	11	11
Glasses	-	-	26	26

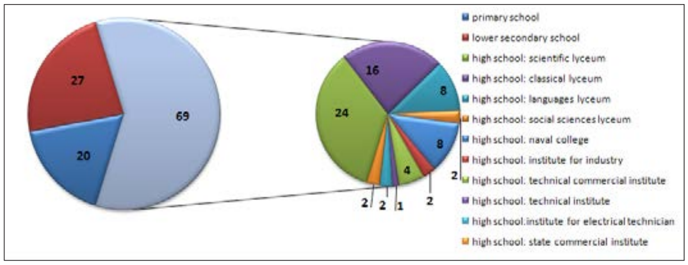

Fig.4. Distribution of the students as the school level (elementary: primary school, media: lower secondary school, superior: high school)

A questionnaire was distributed to the teachers of each group of students to evaluate the effectiveness of the communication strategy both for the visit at the museum and for the lab activities. The first two questions addressed the general satisfaction of the teachers and of the students. The results indicated a favorable attitude towards the project (4.9/5 and 4.7/5, respectively). Additional specific questions were reported, regarding the quality of communication skills and teaching approach of the "guides" during the visits and of the "tutors" during the laboratory activities (more than 95% of the teachers considered both of them "very effective") and the duration of visits and activities and the space available to students (all of the teachers judged both of them adequate). The final questions were related to the materials and equipments used in the laboratory activities and the possibility to reproduce the experiments at school.

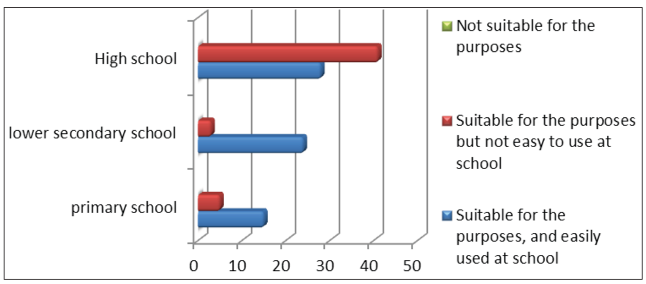

Fig.5: Results related to the two questions: a) the materials used, in your opinion, have proved to be suitable for the purposes and easily used at school, suitable for the purposes but not easy to use at school, not suitable for the purposes; b) in your opinion the teaching approach has been: successful, quite successful or not successful.

In figure 5, results are reported related to the two questions: A) the materials used, in your opinion, have proved to be a) suitable for the purposes and of easy use at school, b) suitable for the purposes but not easy to use at school, c) not suitable for the purposes; B) in your opinion the teaching approach has been a) successful, b) quite successful or c) not successful. The teaching approach was consistently considered successful and interesting, as it was for the materials and equipments used in the laboratory activities. Different opinions were gathered about the possibility to repeat, continue or implement the attended experiments at school. On this point, different answers are probably due to the different complexity of the activities proposed depending on the school level. Thus, Primary school: more than 75% of the teachers thought that the lab activity could be repeated at school. Lower secondary school: practically all of the teachers found the experiments (and related materials) suitable to be proposed again at school by themselves. High school: here the opinions overturn, the teachers found the lab activities not easy to reproduce at school on their own forces.

CONCLUSIONS

The communicative approach used during visits to the museum, based on the engagement of the visitors in the construction of an interactive contest, has proved very satisfactory, particularly for young audiences. This is probably due to their natural curiosity and to their power of observation thanks to an age at which the acquisition of new knowledge is done with enthusiasm and active participation. On the other hand, it proves to be somehow more difficult to raise interest and curiosity about scientific historical exhibitions when the audience consists of high-school students, who usually better appreciate practical laboratory activities. That is why, altogether, a degree of satisfaction even higher has occurred in the evaluation of laboratory activities.

Nevertheless, it remains an important goal, the possibility for students of attending some experimental activities they usually do not have the opportunity to do at school, though in the context of the so-called informal science education (Orlik, 2003).

In summary, we can say that the strengths of this project, which will be further improved in the future, are essentially the following:

-*Adapting to a young audience the exhibition routes*, making them more attractive and interactive.

-*Making easily accessible the interesting collections* in the Museum, conveying concepts of high scientific and historical value to a wide audience.

-*Linking each selected museal tour to specific activities* to be carried out in a real scientific laboratory.

-*Increasing the development of multimedia resources*, such as online renew database, virtual interactive visits to the museum.

- *Developing an application that allows to play online with the "museum memory game"* with which students can enjoy in the recognition of objects and tools seen at the museum, associating the photo of the instrument to its name and to its description.

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Learning in a community of practice: the case of pre-service chemistry teachers

El aprendizaje en una comunidad de práctica: el caso de los profesores de química en formación

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Abstract

What makes the teaching of chemistry a challenge for teachers. In this paper, we have explored communities of practice (CoP) as a viable alternative for teacher training of chemistry. The power of CoPs is through the interactions within the group, and the opportunity to share experiences, so that teachers can learn about new trends in chemistry education and practice in class. This work shows the contributions of a CoPs designed in the project PIBID of the University of São Paulo for the learning of pre-service chemistry teachers. The results show that, in the CoP, the pre-service chemistry teachers have learned about the teaching practice and working effectively in groups; the connection of the practice of teaching; and group engagement on sharing experiences as main factors that favored learning.

Key words: *community of practice, teaching knowledge, pre-service teachers training.*

Resumen

La química es una asignatura difícil de aprender, lo que hace que la enseñanza de la química un reto para los profesores. En este contexto, las comunidades de práctica podría ser un buen ambiente para la formación de profesores. Intercambiando la experiencia en las comunidades de práctica, los profesores pueden aprender acerca de las nuevas tendencias en la enseñanza de la química y practicar clase. Este trabajo muestra las contribuciones de una comunidad de práctica diseñada en el PIBID, proyecto de la Universidad de São Paulo para el aprendizaje de los profesores de química en formación. Los resultados muestran que, en la comunidad de práctica, los estudiantes de licenciatura de química aprenden sobre la práctica docente y el trabajo en grupo, la conexión con la práctica de la enseñanza. El intercambio de experiencias fue el principal factor que favoreció su aprendizaje.

Palabras clave*: comunidad de práctica, enseñanza de química , formación de profesores en formación.*