Substantia
An International Journal of the History of Chemistry

Firenze University Press
www.fupress.com/substantia

Feature Article

The Strange Case of Professor Promezio: A Cold Case in the Chemistry Museum

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Abstract. Promezio is a famous Italian chemistry professor who is searching for missing element n. 61. In 1924 his laboratory is partially destroyed by a fire and he disappears. Almost one hundred years later high school students are recruited to investigate this strange case. "The strange case of Professor Promezio" represents a unicum in the panorama of laboratory activities for high school students: it is a cold case in which students are asked to investigate a fact that took place almost a century ago. Through the chemical analysis of different findings, the connection with historical events of that period, the study of the suspects' interrogation reports, the reproduction of the experiments conducted by Professor Promezio, the students will identify the possible culprit. A complex scientific problem is solved exploring different areas of chemistry and, in addition, interconnections with history, geography, ethics and other school subjects are deepened.

Keywords: high school introductory chemistry, inquiry-based learing, problem solving, forensic chemistry, history of chemistry.

OPEN ACCESS

Citation: M. Alloisio, A. Basso, M.M. Carnasciali, M. Grotti, S. Vicini (2020) *The Strange Case of Professor Promezio*: A Cold Case in the Chemistry Museum. *Substantia* 4(2): 119-123. doi: 10.13128/Substantia-813

Received: Jan 13, 2020

Revised: Mar 25, 2020

Just Accepted Online: Apr 21, 2020

Published: Sep 12, 2020

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

INTRODUCTION

In the last few decades, a significant decrease in the interest and attitudes in science of high-school students was observed, with strong differences between gender and across countries.[1,2] The awareness of the impact of science on society and economy in an increasingly complex technological world, stimulated several initiatives to improve science education, at both national and European scale. In particular, a large number of projects have been set up to motivate students to study science more efficiently by stimulating their interest.[3] In Italy, the ministerial program ASL, an acronym of "Alternanza Scuola-Lavoro" (school-work alternation), is an innovative teaching method which, through practical experiences, helps to consolidate the knowledge acquired at school and tests the attitudes of students, enriching their education and orienting their study path.[4] School-work alternation, compulsory for students in the last three years of high school, is one of the most significant innovations of the Italian law 107 of 2015 (*La Buona Scu-*

ola) in line with the principle of open school. A cultural change for the construction of an Italian way to the dual system, which incorporates good European practices, combining them with the specificities of the Italian socio-cultural context. In this frame, "The strange case of Professor Promezio" is a practical experience able to combine laboratory activities with historical events which took place in the 20s of the last century, involving third parties like the chemistry museum of Genova[5] and the forensic police. The link between schools and museums has been recently demonstrated to play an important role in the context of chemical education.[6] According to the tetrahedral model[7] and the "context-based science teaching" approach,[8] learning chemistry can be facilitated if chemistry is not taught in an abstract way, but by connecting it to human beings, everyday life, and society problems. In particular, the promotion of the interest toward chemistry by exploiting the great attraction of teenagers for crime scene investigation has been reported.[9,10,11,12,13,14,15,16] However, most of these activities dealt with specific subjects, offering a narrow view of the chemistry world. In order to overcome this problem, we recently reported a practical activity in which students were involved in various interconnected laboratory experiences, able to provide a general overview of chemistry and its many subdisciplines.[17] A detailed and rigorous evaluation of this activity led to the conclusion that the interest of high-school students towards chemistry could be improved by this multidisciplinary approach.

Now we wish to report a new project, "The strange case of Professor Promezio", that, to the best of our knowledge, represents a *unicum* in the panorama of laboratory activities for high school students. In fact, it does not only lead the students through six interconnected laboratories, but, in order to solve a *cold case*, it induces them to deepen historical aspects such as the discovery of element 61, the advent of nationalisms at the beginning of the last century and the spread of malaria in Italy in those years. The effectiveness of teaching science using case histories dates back to the work of Conant.[18,19] History of science can be used to celebrate landmark discoveries as well as great scientists: by connecting scientific knowledge to names, faces and places, science can reach a "human" dimension and can be perceived by the students as something that can be achieved not only by "geniuses". Historical context, on the other hand, allows to highlight how scientific discoveries are the result of the contribution of many factors, often interconnected.[20] More recently it has been demonstrated that a better comprehension of scientific concepts and methods can be achieved including historical components in science classrooms[21,22] and by highlighting how chemistry knowledge has developed over time.[23] So, scientific, forensic and historical aspects are synergistically involved in capturing and inspiring the students. The activity illustrated below has been organized in 2018 and 2019 and has involved about 100 students every year. The students, equally distributed between males and females, were aged 17-18 years and were coming from high schools of Liguria and Southern Piemonte and had different backgrounds: 72% came from scientific high schools, 18% came from technical institutes and 10% were specializing in classical studies.

DISCUSSION

"The strange case of Professor Promezio" is a *cold case* in which students are asked to investigate an event that took place almost a century ago and that involved a *famous* professor, Promezio in fact, who was looking for the chemical element number 61 and mysteriously disappeared during the fire of his laboratory. The case was closed by the police of that time because no corpse was found and evidence against possible suspects was not strong enough; meanwhile the laboratory has been transformed into a chemistry museum. The case was unexpectedly reopened after a skeleton was brought to light by the collapse of a wall in that museum. Students are involved at this stage of the story, to analyze the findings collected at the time of the facts and others recently found next to the skeleton, to reproduce the experiments described in Prof. Promezio's notebook and identify who, among the possible suspects, could have killed the Professor and set fire to the laboratory.

The history of Professor Promezio is a re-adaptation of an event that really happened around 1920: the dispute between Prof. Rolla and Prof. Noyes on the paternity of the discovery of the element number 61 and on the name, Florentium or Illinium, to be given to it.[24,25] History tells that neither of the two contenders was right, and indeed element 61 was named Promethium, by the researchers of Clinton Laboratories (Oak Ridge, Tennessee, USA) who isolated it by nuclear fission.[26] The students, during their investigations, will discover that Professor Promezio, an imaginative representation of Prof. Rolla, mistakenly attributed experimental evidence to the new element.

Going into the details of the activities, the students are involved in:

1. Visit to the chemistry museum with illustration of the original equipment used to purify and characterize rare earth elements in the 20s.

2. Detection of latent fingerprints on the semi-burned notebook of Prof. Promezio, using the Ninhydrin stain.
3. Detection of genetic material on a metal tube found close to the skeleton, using the Luminol test.
4. Qualitative and quantitative analysis of a white powder, presumably used to set the fire, employing flame and Magneson tests and atomic absorption spectrometry.
5. Replication of the experiments described in the notebook of Prof. Promezio, aimed at the isolation of a lanthanide element and at its recognition.
6. Analysis of some fabrics by visual inspection and solubility tests.
7. Identification of an organic molecule through the determination of physical properties and the comparison of analytical data with those found in a database.

Details on each experiment are available in the Supporting Information.

From a chronological point of view, upon arrival, the students are gathered in a classroom, where a short presentation of objectives and conditions of the activity is given. Then, the students are guided through the chemistry museum and introduced to the work of Stanislao Cannizzaro during his stay in Genova, with focus on his influence on the Mendeleev periodic table of the elements and on how the latter led to the discovery and classification of most of the rare earth elements, between the end of 1800 and the beginning of 1900.

Subsequently, the students are divided into teams of five people and each group participates in six half-day experiments, according to a specific workplan. The order of the activities is not relevant for the case study, as information deriving from each experiment is independent and not conclusive itself. Students are directly involved in the practical work and supervised by young M.Sci or PhD students (tutors) in order to encourage their active participation. Experiments cover the main branches of chemistry and are designed to stimulate the discussion on both specific and general aspects. In detail, preliminary tests on the crime scene lead the students to discover the chemistry behind the routine techniques used by the scientific police, as well as to discuss the general issue of false positives during the analysis. The experience in the analytical chemistry laboratory introduces the students to the concept of qualitative and quantitative analysis, and more in details to sensitivity and reproducibility. Qualitative analysis of fabrics, on the other hand, stimulates the discussion on comparative properties of natural and synthetic tissues, structure-property relationships in polymers and on the evolution of synthetic tissues throughout the last century. The organic chemistry experience is aimed at identifying the nature of an unknown substance, highlighting the relationship between structure and properties of molecules. Finally, the evolution of the procedures in the inorganic/physical chemistry field is experienced by performing the isolation of a rare earth element from the mineral Monazite according to classical procedures (fractional crystallization and calcination), followed by its identification through a modern instrumental technique (X-ray diffraction).

Results from each experiment are relevant for the solution of the murder case, but never conclusive, suggesting one or more suspects or exonerating others. Finally, the activity ends with a presentation of results by the different groups, where students are asked to critically discuss the collected data and the scientific evidences in order to come to a sound conclusion of the murder case. This final task is an opportunity to highlight the remarkable creativity and imagination of the students, as well as their enthusiasm and involvement in the investigation.

During the conclusive day of the activity, some representatives of the forensic police are invited to deliver a lecture on how crime scene surveys really take place. In addition, they assist to the presentations of the students and evaluate them, selecting the best one and assigning to the authors a very coveted prize: a one-day visit to the laboratories of the forensic police.

CONCLUSION

In conclusion, the key features of this activity can be summarized in the following points:

1. *Hands-on*: students are not spectators but actors in performing the laboratory experiences, collecting data and analyzing results.
2. *Tutoring*: students are guided in all activities by young tutors (graduates from the Chemistry Department), able to establish a fruitful and friendly relationship.
3. *Team working*: students are divided into groups of five people ("teams"), selected in order to be heterogeneous in scholastic background and gender.
4. *Multidisciplinary and interdisciplinary*: a complex scientific problem is solved exploiting different areas of chemistry; in addition, interconnections with history, geography, ethics and other school subjects are deepened.
5. *Evaluation*: ASL provides a cross-evaluation of the activity by the students and of the students by the University staff, making it available on-line through the Italian Ministry portal.

According to the student evaluation, the activity was greatly appreciated; in particular, the topic was judged very stimulating, able to efficiently introduce different chemistry disciplines and to involve the students in proficuous team working. Due to the acquisition of technical and practical skills, several students declared interest for the study of chemistry. Besides these qualitative statements of general satisfaction, possible changes in the situational interest raised by the activity have been assessed through an entrance and exit test, performed and elaborated as previously reported.[17] It was confirmed that the activity significantly increased interest and attitude toward chemistry, mainly for students with lower scores in pleasure for the study of chemistry (*e.g.* high-school students compared to students from technical institutes), self-efficacy and self-concept in chemistry. The students also observed that working under the supervision of young tutors, competent and close for age to them, allowed to communicate easily and to carry out the experiments independently but with the correct procedures. The final presentation of the results and of the solution of the case was also considered very useful and captivating.

Moreover, all high-school teachers involved in the ASL project were invited to the final presentation of their students and, through the above mentioned Italian Ministry portal, they inserted a feedback regarding the students' experience. Their evaluation was enthusiastic (showing always five stars as the score) not only for the positive feedback of the students, but also for the scientific content of the project and for the practical activities, able to fill the gap with the more abstract way of teaching that is typical of high school.

SUPPORTING INFORMATION

General organization and detailed experiments for laboratory activities are available as Supplementary Material.

ACKNOWLEDGEMENTS

The project has been financially supported by the Italian National Project "Scientific Degrees Plan".

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