EVALUATION OF THE IMPACT OF A DAY LONG GENERAL CHEMISTRY LABORATORY ON 4TH YEAR HIGH SCHOOL STUDENTS

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Abstract

Despite the recent new ministerial dispositions on the high school's teaching of Chemistry introducing the cross correlation of chemistry concepts and their distribution on the five years long course, the chemistry teaching still remains disjointed from both practise and contacts with real life in specific high schools (Scientific Licei), even though these latter are strictly devoted to the study of all the branches of Natural Sciences, and hence also of Chemical Sciences. As an example, while most of these schools possess a Physics lab, the Chemistry lab is generally absent. This discrimination can be attributed to many factors: 1) the Chemistry laboratory requires specific and very expensive safety structures, 2) the Chemistry laboratory can produce waste substances needing special disposal, 3) in this context the teachers do not possess specific skills, as they are generally graduated in different scientific disciplines. All these facts limit the Chemistry lab implementation and, even when present in the school, its practical use. The lack of a chemistry teaching method based on / or supported by practical experiences can be a serious lack in the learning process leading to students having poor motivations on the study of Chemistry and scarce attitude to acquire a correct understanding of matter composition and related transformations. As a consequence, according to National Scientific Project (Piano Lauree Scientifiche), the UNICAM Chemistry degree course has promoted and evaluated the impact of a 6-8 hours long General Chemistry laboratory [1] to 11 selected Licei of the Marche region and relative Science teachers, to be attended in UNICAM by students of 3rd to 5th year high school. In these experiences, key concepts and chemical reactions themes of the General and Organic Chemistry have been proposed and shown by mean of practical experiences directly performed by the students or small groups of them. In the 2015/2016 academic year, about 400 students have been evaluated at the beginning and at the end of the daylong lab by a multi-answers questionnaire strictly related to the experienced reactions. The analysis of results shows an increase of about 20% of the correct answers after the laboratory experiences.

1. Introduction

Since 2006, the University of Camerino and the chemistry degree teachers have been involved in a national ministerial program (Piano Nazionale Lauree Scientifiche) designed to increase the number of vocations on the study and the enrolment to the academic course of Chemistry, Industrial Chemistry and Material Science. To carry out this project UNICAM chose to work with many licei of Marche Region purposing many experimental activities furnished with the double aim to educate students and to build a connection with teachers for double way interactive activities. In these years we experienced that the study of general, inorganic and organic chemistry in scientific licei, leaving apart the applied science subtype, was confined to one year long training till 2010 and currently, as a consequence of a new ministerial disposition, spread in five years long. Of course, all the licei were involved in the elaboration of new chemistry spread planning and the regime course was achieved with variable timing. As a consequence, the sampled 3-5 years of licei students taken under study in this work are quite non homogeneous in their baseline chemical education. In this dynamic and heterogeneous context we applied the title activity which consists of a day long practical laboratory concerning chemical reactions with recalls of basilar chemistry law and concepts. In previous years, questionnaires were addressed to students and teachers. As a general evaluation we got a full success and a high liking score, denoting the strong attitude to practise and enjoy chemistry labs of these students and a general appreciation of the teachers. From this background, we planned in 2016 to start a preliminary study on the impact of this laboratory on the knowledge improvements of the students attending the experience; the obtained data were used for an analytical discussion on this teaching method promoting the "learning by doing".[2]

2. Results and discussion

2.1 Presentation of the day long activities

The laboratory was performed in a wide Unicam laboratory and the students were located in front of a laboratory bench where the glassware, the reactants and the paper sheets of the procedures were available. The experiences consisted of a brief oral theoretical recall and 1-5 experience description, verification tests, competitions and short games to lighten the practical work and to arouse interest through the stimulation of competitiveness and of the practical skill.

Experience 1: a sample of solid Calcium was let to react with water, the evolving gas was collected in a graduated cylinder. For this experience verification test/competition were supplied.

Experience 2: Double exchange reactions were made with solutions of alkaline and earth alkaline chloride and nitrate, or lead(II) nitrate and sodium sulfate, potassium iodide. An unknown solution was identified by comparison with the results of the preliminary study. Warming/cooling crystallization of golden leaves from PbI_2 was also performed. For this experience verification test/competition were supplied.

Experience 3: The spontaneous redox process of reduction of copper(II) chloride by aluminium foil pieces was observed.

Experience 4: Gaseous NO_2 in sealed quartz tube was cooled in liquid nitrogen bath, in an ice bath and warmed in boiling water. [3]

Experience 5: A blu colored solution of $[CoCl_4]^{2-}$ was treated with water and furtherly with HCl again to get a visive evaluation of the impact of reactants/products concentration on the chemical equilibrium position. A gaming experience was associated to this study.[4]

2.2 Method of analysis of the data

In order to assess the impact of the laboratory experience on students' knowledge, the same test was administered twice, prior to (pre-test) and after (post-test) the execution of the activities. The test consisted of 10 questions, related to the five experiments performed by the students. In particular, five multiple-choice questions were related to the reaction of calcium with water generating hydrogen and the relative Ideal gas law (1-5); two questions, one of which with multiple choice and the other with two options (soluble / insoluble involving three different salts), concerned the reactions of precipitation and recognition of metal ions(7,8); a two-option question (oxidation /reduction referred to aluminum and copper) concerned the redox reaction between aluminum and copper chloride (6); a multiple choice question regarded the balance between nitrogen dioxide and dinitrogen tetroxide and a multiple-choice question was on the equilibrium between $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$ (9,10). All multiple-choice questions had three options.

In the test, most of the questions assessed the students' knowledge which was reinforced or directly acquired during the execution and observation of the experimental procedure, while a limited number of questions concerned essentially theoretical knowledge, predictably already attained during the curricular course.

The tests were administered to a heterogeneous sample of 436 students coming from different Licei and attending different courses of study (classical, linguistic, traditional scientific and scientific with applied sciences option) and grades (third, fourth and fifth). The results have been included in a spreadsheet and analyzed by applying the logic function (if),[5] to compare the pre-test with the post-test responses, in relation to the total average of all the responses and, analytically, to each single response.

2.3 Analysis of the data

With regard to all of the test responses, the following indicators have been applied: 1) R + total, indicating the average percentage of correct answers in the post-test that were incorrect in the pre-test, 2) Total R-, concerning incorrect answers in the post-test which had been correct in the pre-test, 3) RS + total, concerning correct answers in both the pre-test and the post-test, 4) Total RS-, concerning incorrect responses before and after the experimental activity.

The following values expressed as a percentage have been obtained:

R + = 26.38%

R- = 5.48%

RS + = 49,17%

RS- = 18.88%

The R + value shows the essentially positive impact of the experimental work on increasing the students' knowledge of different aspects of chemical reactions; likewise, the RS + value implies the stabilization of already acquired knowledge. Furthermore, the low value of R- provides evidence that the execution of the experiments had a limited impact as a factor contributing to incorrect knowledge. Finally, the RS- value can be considered as acceptable and, to some degree, to be expected, given the heterogeneity of the sample.

From the analysis of individual responses, it appears that the best results, in terms of R +, refer to the questions 1-5, related to the experience of calcium in water which is the longest and articulated experience, and to question 8 on the precipitation of lead iodide and the relative striking crystallization to “golden leaves”. Positive results are surprisingly related to questions 9 and 10 on the two high visive impact experiments related to the difficult concepts of chemical equilibrium (RS +). The worst results, in terms of RS-, are instead related to question number 7, on the experiment concerning the precipitation of various salts, and to question number 6, on the identification of the species which oxidize and reduce during the reaction of aluminum and copper chloride.

3. Conclusions

On the whole, the analysis of the data shows a significant increase in the number of correct answers to the various questions of the test and therefore it appears to confirm, in educational terms, the validity of the procedure that directly exposes the students to an experimental context, minimizing the acquisition of theoretical information load right prior to the experiment while emphasizing learning by doing. The planned laboratory activities motivate the students and encourage them to test their prior knowledge, at the same time creating an ideal learning environment for the acquisition and integration of new knowledge.

From the analysis of individual questions, it emerges that for some of them the best performances are closely related to the compliance and implementation of the experimental protocol (evidence of calcium hydroxide precipitation and hydrogen gas evolution, of lead iodide precipitation, evident color change in the equilibrium reaction of dimerization of NO_2 and the pink/blue forms equilibrium between $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, calculating the volume of hydrogen released in the reaction between calcium and water), and, obviously, to the students' prior knowledge, even though, this latter was extremely heterogeneous in the tested sample of students.

An explanation to the findings connected to question 7, on the solubility in water of different salts, resulting in a high value of RS-, can be attributed to insufficient knowledge or previous misconceptions about the concept of solubility. In the absence of strong experimental evidence or procedural error, this gap in knowledge was not filled. The critical issue posed by question 6 on the redox reaction, could be explained with an insufficient understanding of specific language and of the concepts of oxidation and reduction.

The results of this survey thus confirm the validity of the study conducted in terms of motivation and orientation to the study of Chemistry for high school students while suggesting areas of possible implementation of the experience, both in the planning of the University activities and as part of the school curriculum.

References

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