VIRTUAL LABORATORY PRACTICES AS ALTERNATIVE OF TEACHING CHEMICAL EXPERIMENTS

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ABSTRACT

The performance of virtual laboratory practice in the Metallurgy Engineering of the Technological University José Antonio Echevarría, Havana, Cuba, is described. The experience presented was developed in a second-year group, and two laboratory practices were done with satisfactory results. With this activity, the students achieved the skills they need through virtual experimentation. In addition, it was possible to motivate the students to consider the importance of physical-chemical analysis showing the link with computing. *[African Journal of Chemical Education—AJCE 11(1), January 2021]*

INTRODUCTION

Virtual laboratories are an essential complement to those performed in traditional facilities and contribute to better development of individual skills, typical of this type of academic instruction. They should not replace real practices. It is necessary to search for an adequate pedagogical balance between both modalities, making a better formation of the students [1].

There are some experiences in this area. Woodfield et al. [2 and 3] described and evaluated Virtual ChemLab with 1 400 students enrolled in freshmen level chemistry courses. They found that if effectively used it provides practical experience by connecting the theory taught in the classroom with the real world of the laboratory, provides a realistic learning environment for different learning styles, and teaches the cognitive processes (or analytical skills) that form the foundation of chemistry and other laboratory sciences. Later, Tatli and Ayas [4] examined the effect of a virtual chemistry laboratory student achievement among 90 students from three different ninth-grade classrooms and established that the developed virtual chemistry laboratory software is at least as useful as the real laboratory, both in terms of student achievement in the unit and students' ability to recognize laboratory equipment. While, Davenport [5] describe ChemVLab+, a set of online chemistry activities. This study, with more than 1400 high school students, in California, found that students using online activities demonstrated increased learning. On the other hand, Blackburn et al. [6] integrated into a first-year laboratory module at the University of Leicester, a series of laboratory themed simulations. They observed high student engagement and very positive results to prepare the students before doing real experiments.

Model ChemLab is a chemistry lab simulation software mainly created for an educational purpose that has been mentioned by its utility [7, 8, 9, 10, 11, 12, 13, 14 and 15]. Luque et al. [16]

classify it as excellent, and González et al. [17] catalog it as one of the most complete. Rodríguez et al. [18] clarify that it can be easily integrated into a General Chemistry course at the university. Vidal and González [19] evaluated the potential of the Model ChemLab simulator pedagogically. They concluded that although it does not promote the development of general cognitive skills and does not promote the active learning of chemistry, it can be advantageous if it is used in the university in the framework of a teaching-learning process conceived as directed research, fundamentally in the execution of experiments that replace the real laboratory. Currently, there are some positive testimonials about the utility of ChemLab inclusion in the courses of some universities [20].

In the experience of Cabrera de Vera [21], 11 simulated analytical techniques practices of the Analytical Chemistry course were carried out with students from Chemical Engineering and Food Engineering. The compilation of the results was made through surveys and interviews between the periods 2014 to 2017, giving positive results to both teachers and students.

On the other hand, the second semester of the second year of the Metallurgy and Materials Engineering (Metallurgy) of the Technological University of Havana has eleven subjects. One of them, the Physical-Chemical Analysis [22], has no final exam, which means that students, often overwhelmed by a large number of subjects in the semester, do not prioritize it with the consequent lack of motivation for the subject [23].

The 54 total hours of Physical-Chemical Analysis semester are distributed in 12 hours of lectures, 6 hours of practical classes, 12 hours of seminars, and 24 hours of laboratory practices. The lab practices are arranged in 4-hours sessions per week of experiments of gravimetry, volumetry, potentiometry, two of spectrophotometry and one of analytical chromatography.

The physical-chemical analysis requires a high number of laboratory practices and needs to exercise different parameters that are not possible or feasible to use in real laboratory conditions [24]. One alternative solution to cover this need could be to conduct virtual laboratories that are an easily handled educational tool for universities and help to develop quick and effective decision-making [9]. Moreover, the subject of physical-chemical analysis has as a proposal, within its educational objectives, to develop habits and skills in the use of computing [20].

This paper aims to describe the experience of implementing the training requirements of the subject Physical-chemical Analysis of Metallurgy through virtual laboratories using ChemLab as an alternative to the lack of own teaching laboratory.

METHODOLOGY

In order to comply with the formative requirements of the subject Physics-Chemical Analysis of Metallurgy and so that the students could acquire the proper knowledge of the methods and techniques of analytical chemistry, to extend, deepen, consolidate, generalize and verify the theoretical foundations of the subject through the simulation, it was proposed the execution of two virtual laboratory practices with the use of the ChemLab simulator, as a didactic strategy. Also, students carry out an extra-class work. Students received a random mass of the compound to work on the simulator. With it, they had to carry out the two virtual experiments and then compare their results.

Organized laboratory practices are shown in Table No.1. In the laboratory practices, the content of the Physical-Chemical Analysis of two of the six subjects studied in the course was taken into account. The method to be used was the bibliographic search and the experimentation, and the documentation to be reviewed was ChemLab's user guide. As there were only two pertinent practices available in the simulator, gravimetry and volumetry were selected. That was the reason why the extra-class work was indicated after the execution of these two real practices in the course.

The first experiment, gravimetric analysis of chloride, shows how to determine the composition of an unknown chloride salt by reacting chloride and silver ions to produce a silver chloride precipitate. This precipitate should be filtered out and weighed. Based on stoichiometric ratios, the students should determine the amount of chloride initially present in the test sample.

The other experiment, volumetric analysis of chloride, tries to determine the composition of an unknown chloride solution by measuring the volume of required reacting silver ions that produce a silver chloride precipitate. Potassium chromate serves as an indicator of the reactions end-point, changing the solution to a yellow color. Using the equivalence law, the students should determine the chloride composition initially present in a test solution.

The group was divided into two semigroups, one practice per each one. Students should develop the labs independently on their personal computers. After opening the software, they should select their experiment, its apparatus, chemicals, and required amounts through menus and dialogues following the correspondent ChemLab test procedures. ChemLab lets the students distribute the apparatus in the work area and locate them in suitable positions.

Table 1. Laboratory practices performed

	Subject	Tests	Bibliography
2	Gravimetric	Gravimetric analysis of chloride	ChemLab test procedure
3	Volumetric	Volumetric analysis of chloride	

The report of the practice with the results of the determination had to be sent by email or delivered printed. For evaluating the practice, we take into account the content, consistency, degree of fulfillment of the objectives, and the clarity in the communication of results. This experience was carried out during the second semester of the academic year 2015-2016.

In order to receive feedback about the application, we performed an evaluation study. The objective was to evaluate the technical aspects (ease of use) and the pedagogical aspects (facilitated learning). Feedback of the students about the use of the simulator was evaluated through questionnaires. Questions were of two types: How easy was the application to use? Did it help to understand the course and, did the students like it? Answers were based on a 5-point Likert scale [25]. The mean value was calculated in order to obtain a relative ranking of the activities. A total of 20 students used the simulator, and a total of 13 answered the questionnaire. Students were from a mixed-sex group (15 males, six females) with a chemistry background.

RESULTS AND DISCUSSION

The task systems used to expand proximal development zones include tasks of activity and communication [26]. In that sense, selected students performed the exercise individually without the participation of the teachers. Students generally formulated the objectives of the practices, satisfactorily conducted the virtual laboratories, analyzed the results, and presented the conclusions.

Using the virtual laboratory, the students were able to do the experimental operation sequences that lead to the measurement of the physical property that allows the analytical determination. Those experiments had not been possible to perform in real laboratory conditions experimentally.

There were some deficiencies in work with units, and the interpretation of the results. As it was the first time that the students used the simulator, they had to execute a creative use of the time, one of the most distinguished manifestations of the development of the organizational abilities [26]. The skills exercised by the students in this study have the function of generating a generalized efficacy, particularly of learning to learn. Since all the skills cannot be covered, developing the remaining practices in the quality control laboratory of the metallurgic industry must be evaluated.

In general, a simulator was valued as reasonably helpful to understand the course providing evidence of facilitated learning. It was also partially possible to motivate the students to pay attention to the subject's Physical-chemical analysis showing the link with the computing given that the core values of the first answer. The evaluation results are shown in Table 1.

Table 2. Evaluation Results: Likert Values	
1: Not at All - 5: Very Much	
Items	Mean
Simulator helped me to understand the course	3.3
It was difficult to interpret the simulator results	2.3
It was difficult to work with the simulator	2.1
I found the simulator stimulating	3.8

There was, as well, a clear consensus that it was not difficult to interpret the simulator results or to use the simulator. The simulator was also considered moderately stimulating since these values are only slightly higher than the median of 3.

CONCLUSIONS

The training requirements of the subject Physico-chemical Analysis of Metallurgy were covered through two virtual laboratories with the use of ChemLab as an alternative solution to overcome the limitations in real laboratory testing conditions. During this experience, laboratory practices had satisfactory results. This activity also helped students to get the required knowledge and abilities through virtual experimentation. Through this work, it was possible to link to the subject of Physical-chemical analysis with the subject of computation. He also contributed to the development of three of the personality development skills: understanding and seeking information, communication, and the temporary organization of life. In all cases, the groups submitted their reports and clearly showed that they had acquired the working knowledge in the chemical laboratory.

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