

DESIGN OF THE LABORATORY SCRIPT BY THE STUDENTS IN CHEMISTRY PRACTICALS: ANALYSIS OF WATER

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Abstract

The laboratory practices during the Degree in Chemistry are currently designed so that the student must learn and execute a fully developed experimental protocol, previously written up by the professor, which contains all the information and requirements for the correct development of each laboratory session. Under these conditions, students do not need to take any initiative and, consequently, they do not put enough effort in reaching practical abilities with a well-based scientific criterion and do not try to think over the purpose of each lab operation, as well as the reason to use each material and/or each reagent. Thus, with the aim to promote a more active role of the students in their learning process and to improve their autonomy, a new laboratory practices design has been developed in this work, which follows methodologies on project-based cooperative learning: the students have been requested to elaborate themselves the laboratory script by pairs. With this innovative design, we pursue to involve the students in both elaboration and execution steps of the laboratory practicals, and then to increase their attention on them. Besides, the required bibliographic research would improve their knowledge about the studied topic and all aspects about the work at the laboratory. The practicals to-be-developed were related to the study of the physico-chemical quality of natural water, which has a high social relevance.

Keywords: Active participation; Cooperative learning; Initiative; Practical; Water.

1 INTRODUCTION

Traditionally, the teaching of the laboratory practicals in the Degree in Chemistry has been conducted following a strategy fully led by the lecturer, wherein the student has to strictly follow the instructions detailed in the laboratory script. This kind of didactic laboratory practical favors the acquisition by the students of several skills related to the laboratory work. However, this approach does not train the student abilities and competencies like initiative, team work, search, organization and synthesis of information (from books, journals and databases) with a critical sense, interpretation of the results, design of experimental protocols, by selecting the required laboratory operations, reagents, material and instrumentation, and elaboration of laboratory guides.

We consider we must break with this traditional didactic methodology and bring the student the real problematic of the work at the laboratory in a job environment, where the student of the Degree in Chemistry has in charge the selection and/or development of the analytical methods for each project, and who must decide which is the optimal way to carry out a specific analytical determination, using a rigorous scientific criterion. Besides, they are expected to organize the tasks at the laboratory, and to dispose which laboratory facilities, reagents, material and instrumentation must be purchased. It also aims to provide a global overview about the work at the laboratory. The optimal way to reach these objectives was the students elaborate the entire laboratory script for one practical. This represents an important change in the mentality of professors and students, as far as the preparation, execution and evaluation of the practical.

In this sense, project-based learning (PBL) combined to cooperative learning (CL) is an excellent tool to reach the indicated objectives, acquire autonomy, research and interpersonal skills, enhance the cognitive development and the ability to work in group. This would provoke an improvement of the teaching-learning process in the laboratory subject. Besides, their implication in all steps of the laboratory practical (design and execution) must attract their attention and increase their interest, and thus improve the learning process. We aim the students work and learn with their partners, and all

together acquire several essential skills to develop a professional career in a chemistry laboratory, such as the individual and team responsibility, the adequate use of interpersonal skills (negotiation, communication between the members of the teams, etc...), the evaluation of the performed work by the own members of the group, and so on.

The students have been encouraged to use internet and the new information and communication technologies. These are powerful tools to find and publish information worldwide (as articles, electronic book, websites and more) about many topics, as well as for virtual meetings and communicate with partners. They are also stimulated to use the traditional sources of information, like printed journals and scientific books, which can be found in the University library. The project was developed using the Virtual Classroom to store, revise, organize, write up, lead and evaluate the performed work. This would enhance the learning-teaching process. The selected topic was the analysis of water, which quality is currently one of the major concerns in the areas of environment and health science, and then can contribute to the protection and the safety of the local community. The entire project was build up to maximize the motivation of the students. The laboratory scripts developed by the results of the project were directly introduced in the course syllabus of a laboratory subject taught at the Degree in Chemistry, belonging to the area of Analytical Chemistry.

2 OBJECTIVES

The learning-teaching methodology was based on a combination of cooperative learning and project-based learning. The study was related to a real analytical problem which may improve their theoretical knowledge, like the physico-chemical analysis of water. A research work was proposed to the students, to be developed by groups, including the three steps of the analytical process: description of the problem, selection of the required reagents, material, laboratory operation and instrumentation, design and elaboration of the experimental protocol, analytical determination, and application to incurred samples, elaboration of the analytical report and discussion of the results.

The aim of the work was to stimulate the participation to improve the achievement of the general and specific competencies, as well as the learning results, and to enhance the background of the students, considering the following aspects:

- To know how to write, organize, structure, and self-evaluate the performed work.
- To introduce the student to team work, and the development of the related interpersonal skills, by means of the cooperative learning and foster the acquisition of competencies (distribution of the tasks).
- To be familiar with the sources of information (consultation of scientific bibliography about methods for chemical analysis, books, journals or websites, related to methods of chemical analysis; search of official procedures published in the Spanish State Agency Official Gazette, BOE). Organize the search of information, to assemble, discuss the validity and summarize the collected information.
- To get experience about the preparation and exposition of public presentations.
- To learn about the main parameters used to evaluate the quality of water, and the related analytical methods.
- Evaluation the quality of water by means of its chemical composition.
- Organization of the chemical laboratory.
- Elaboration of the different parts of a laboratory script (selection of the title; description of the objectives; introduction; selection of the reagents; material and instrumentation; waste and environmental disposals; detailed experimental protocol considering the preparation of solutions, laboratory operations and measurements; and requirement of the related calculations).
- Writing of the final report of the practical.
- Adequately interpret, expose and discuss the results (those own ones and those from their partners), both written and orally.
- To participate and act in a round-table.

The students have worked on the following competencies: management of the information, team work/planning and organization ability, analysis and synthesis ability, oral and written communication, and critical thinking.

3 METHODOLOGY

The topic was the analysis of water. Each pair of student must elaborate a laboratory script about the determination of one of the physico-chemical parameters normally taken to evaluate the quality of the water. Finally, the procedures were applied from samples provided by the students from any source, except sea water. The Virtual Classroom was used by the students to manage, organize the information, to upload the intermediate and final document, as well as to communicate with the teacher, and by the lectures to provide them bibliographic information and useful indications, and follow and evaluate their work. The development of the project was as follows:

- 1 Meeting between the different teachers of the subject to manage the work with the students, to decide the objectives, competencies and learning results to-be-acquired by the students. Selection and uploading of the relevant bibliographic information (BOE links, journals and books about chemical analysis). Selection of the physico-chemical parameters to-be-determined, which were: pH, conductivity, dry residue, chemical oxygen demand (COD), and concentration of chloride, nitrate, sulphate, carbonate plus bicarbonate, calcium (II), magnesium (II), potassium (I) and sodium (I) [1-7].
- 2 Meeting of each professor with their students to explain the development of the project, and to assign each physico-chemical parameter to each pair of students, and description of the work to-be-done.
- 3 Search and selection of bibliographic information by the students. Special attention must be paid to the official methods of analysis published by the Spanish BOE.
- 4 Proposal of the most adequate method of analysis. The teacher must approve the procedure before continuing. If the students make a wrong choice, the lecturer will indicate the correct one. The applicability was evaluated on the basis of their coincidence with the official method, the previous knowledge of the students and the availability of laboratory reagents, material and instrumentation.
- 5 Elaboration of the laboratory script. The following points must be included:
 - Identification title
 - Brief description of the objectives of the analysis
 - Explanation about the problematic caused by the analyte in water and needing of its determination.
 - A list of the used reagent (including their danger and specification for a safe sue), material and instrumentation.
 - Experimental protocol: detail each solution to-be-prepared, laboratory operations and measurement, in their correct order.
 - Required parameter: concentration \pm confidence interval.
- 6 The procedures were revised by the lecturer, and approved whether correct. Otherwise, the necessary changes needed to be made. The evaluation was performed on the basis of the formal presentation, explanation details, clarity, structure, inclusion of all the required parts and accuracy of the scientific content and the bibliographic sources.
- 7 Public exposition of the analytical method to the other students. The exposition was evaluated by the professor and the other students on the basis of: clarity, structure, organization, mastery and accuracy of the scientific content, time management, and artistic and formal aspects.
- 8 Sampling of the water: the water was provided by the students (one per pair of students). Samples were: drinking, tap, irrigation (gardens and agricultural fields), river, rain, waste (urban, agriculture and industrial), ornamental pond, aquarium and public fountains, from several towns in the area.
- 9 Analysis of the samples of water (two laboratory sessions), provided by the students, following their own laboratory script. Each pair of students must determine the same physico-chemical parameter in all the water samples.

- 10 Elaboration of the laboratory report (similar to those required for the other practicals): including, title, objective, introduction (why the analyte must be monitored), identification of the sample (source and time of sampling, external aspect), experimental, safety and environmental care, adequate calculations, experimental results, calculations, value of the studied parameter and global chemical composition, this last one from the results obtained by the other students. Each pair of students must interpret the value of the parameter in each water sample and the total composition of their own sample: Coherence with their source, possible contamination and hypothetical sources, adherence with the legal regulations, consequence for environment and population, etc...
- 11 Round-table of the students, moderated by the lecturer, to discuss the results.
- 12 Finally, the students were requested to fulfil an anonymous evaluation questionnaire and provide their opinion about the project (organization, usefulness...). The answers were useful to know the strong points and the deficiencies, which should be corrected for the following years.

At the end of the project, the lecturer must assess whether the students have acquired the competencies and learning outcomes of the subject, like the critical thinking, the work-team skill, the ability to search and manage the information, and to deal with legal and regulatory aspects.

4 RESULTS AND DISCUSSION

Project-based learning combined to cooperative learning about the elaboration of the didactic material by the students has been proven as an exciting and satisfactory innovative way to taught laboratory subjects. Different practical activities have been carried out. Students participated and were evaluated in more aspects than solely the execution of a practical, and which have been poorly studied during the Degree: bibliographic research about legal regulation and analytical method, management of the information, elaboration and evaluation of didactic material, elaborate and expose a public presentation, deep discussions of the results by round-table, participation in a work-team, and development of a chemical analysis project about a topic with a high social, economic and environmental relevance (water quality).

The development of the project has reached its objectives. The involvement and the motivation of the students towards the project were positive from the beginning. The quality of the laboratory scripts, the public presentations, and the adequacy of the bibliographic sources were satisfactory. The sampling was adequate, as a large variety of sources were taken and analyzed. Even the work at the laboratory and the laboratory reports were better than for other practicals. Finally, they actively participated in the discussion of the results. Their conclusions were, in general, correct. The students positively evaluated the project especially the following points: opportunity to participate in elaboration the didactic material, instead of being simply receptors; stimulation of the autonomous and team work; to be familiar with bibliographic sources; to acquire experience in the elaboration and exposition of public presentations: management with legal and regulatory aspects; evaluation of their partners; and the possibility to discuss the quality of the sample on the basis of the physico-chemical characteristics, which they have determined themselves, instead of only indicate the final result or discuss the results of other, and the importance of the selected topic. However, they indicated the project was time-consuming and represented a high workload. Finally, they recommended the application of this didactic methodology in another laboratory subject, but enlarging the lecture time dedicated to it.

The development of the project has positively contributed to an improvement of the teaching of Analytical Chemistry Laboratory subjects, as it enhances the teaching-learning process, the motivation and the participation of the students, the ability to communicate and to work in groups, as well as their autonomy to face new challenges.

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