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This is to certify that:

Josep Esteve-Romero

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MONITORING OF STUDENT PROGRESS AND EVALUATION IN THE SUBJECT “CHEMISTRY LABORATORY I”

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Abstract

The subject “Chemistry Laboratory I” is taught in the first academic year of the Degree in Chemistry. Its main objective is for the student to get a first contact with the basic laboratory operations and become aware of the importance of preparing the experimental work, in addition to manage registration, analysis and the presentation of results. It is therefore a basic knowledge which will be in the future of great help in further chemistry laboratory subjects, regardless of the specific topic (analytical, physical, inorganic, organic and general). The course consists of 10 laboratory sessions and 5 seminars. The final score obtained by the student is based on the assessment of laboratory notebook, the resolution of a test prior to the practical (to ensure that the student have prepared this practical) and a written exam. The qualification is calculated by the average of the score obtained at each activity, with the following weighing: laboratory / seminars / notebook / test / exam 30: 10: 20: 10: 30; respectively. In this study, the results of 72 students were analyzed, noticing that the average score was 7.7 (24/9/15/7/22 at each evaluation item, respectively). From these results we deduced: firstly, the attitude of students in the laboratory is excellent (laboratory and seminars scores are very high), and second, we have to focus on the organization of the laboratory notebook, the preparation of the practical, the attention from the teacher explanation and the study of the content of the subject, as the scores of notebook, test and final exam can be ameliorated.

Keywords: Chemistry; Initiation; Laboratory; Student; University.

1 INTRODUCTION

The laboratory work is an essential part in the formation of any chemist. At a teaching level, the assays performed in the laboratory are used to visualize and better understand the concepts studied in the theoretical subjects, while the theory can be used to predict and understand the experimental observations and results. Thus, both theory and practice are complementary. In addition, currently the most professional opportunities require a purely practical or theoretical-practical background. Therefore, it is necessary that students learn to cope successfully in the lab, and acquire a solid background in the various aspects of practical chemistry: knowledge and use of reagents, equipment, apparatus, instruments and installations, to recognize and carry out the different assays, operations and laboratory techniques, experimental skills, safety, waste management, labelling, time management and proper observation, collection, recording, analysis, processing, interpretation and presentation of data, and experimental facts; in both theoretical and practical aspects. They should know how to conduct a chemical assay, be able to execute them and understand the associated theoretical concepts. They also need to learn how to prepare, interpret and execute experimental protocols, but they must also understand each step and have sufficient autonomy to conduct them without definite instructions. Also they have to be able to collaborate and work together because it is a large space shared by multiple users. Teachers must work hard in teaching and continuous reinforcement of the theoretical and practical concepts of laboratory contents from the first to the last academic year.

The student of the Degree in Chemistry gets its first contact with aspects related to the experimentation in Chemistry (described above) in various laboratory subjects during the first academic year. For most of them, it is the first educational environment where they can observe, test and apply the knowledge learned in theory and where they are allowed to manipulate reagents and materials with a certain freedom, which usually results fascinating and shocking. In these subjects, basics about the running of the laboratory and work habits which will be essential to follow and pass the laboratory subjects taught in advanced courses, more oriented to each knowledge area in Chemistry. It is probably the most important laboratory subject. For this reason, it is crucial for students' training a successful introduction in the chemical laboratory. The student who passes this subject should have acquired a solid knowledge, sufficient manual dexterity, proper work habits and a positive disposition towards the chemical laboratory. This is a tasks shared between the teacher, who should teach the subject effectively, in an individualized way, motivating and attractive, and the students, who ought to scrupulously follow the instructions of the teacher, to study theoretical concepts, conscientiously preparing the practical, strongly strive to carry out the experimentation, and maintain a positive attitude throughout the learning process.

In general, the teaching of the subject has several parts: seminars (theoretical matter face-to-face taught) and laboratory sessions (experimental and specific theoretical content). The student must perform and is evaluated on the basis of a variety of activities: learning of theoretical knowledge, practical preparation, quality of experimental work, editing of the laboratory notebook, and the preparation of reports. The teaching and evaluation of the subjects presents some difficulties:

- The contents, teaching and assessment of each part are very different, and a student can excel in one (s) and have difficulties in the other one (s).
- Theoretical knowledge is very descriptive and lengthy. Besides, it is arduous to assimilate and retain if not practiced.
- Regarding on the laboratory work and the editing of the laboratory notebook, the teacher ought to continually follow the work of each student to complete instruction and assessment. This does not apply, because that would generate a stressful environment and the high number of students by each teacher.
- Manual dexterity is difficult to transmit and is usually acquired through practice, effort and attention. - The number of practical is conditioned by limitation of equipment and facilities, the cost of reagents and materials, and the number of teachers.

Therefore, positive attitude and willingness of all the participants is essential for an efficient transmission of knowledge. It is also important that the faculty correctly structure the course (number of practical and timetable) and include the relevant content (theoretical content enough but not too long, and nature of each practical). Finally, a greater harmonization between the different teachers and knowledge areas would be desirable, as dissimilar instructions and didactic material may confuse the students. Nevertheless, an advantage for teaching is a relaxed and friendly atmosphere is usually generated that encourages participation and communication.

The aim of this paper is to discuss the experience of students in the first laboratory course taught in the Degree in Chemistry: Laboratory in Chemistry I. We inquired about student opinion on the subject (content, activities, difficulty, utility, programming, structure and organization), the atmosphere in the laboratory, evaluation, and academic results (of each activity and globally). It is also expected to determine the degree of success in the process of teaching and learning, and which areas need reinforcement. From these data, we will try to establish their level of motivation and attitude.

2 METHODOLOGY

2.1 Description of the subject

The subject "Chemistry Laboratory I" is taught at the first semester of the first academic year of the Degree in Chemistry. It is a mandatory laboratory subject with a teaching load of 6.0 ECTS. It has altogether four groups divided into 4 subgroups, each one taught by a teacher and a maximum capacity of 12 students. The subject is taught by professors from the four departments of the Faculty of Chemistry (Analytical, Physical, Inorganic and Organic).

The course aims students learn the operation of a chemical laboratory and basic laboratory operations, the safety and waste management, labelling reagents, equipment, reagents, instruments and

equipment, common, analysis, and collection, recording, processing and interpretation of experimental measurements, as well as the preparation, organization, execution and presentation of the results of laboratory work. Therefore, the essential basic skills are established so that the student can successfully address further laboratory subjects from different areas of knowledge of chemistry. We propose experiments in which the students have to use the different basic techniques so that they acquire skills in them and be able to apply to more complex problems.

When they enrol in the course, students are supposed to know and know how to apply basic and clear the concepts taught in the final year of the subject "Chemistry" at the High School.

The development of the subject is divided into two areas: the practical (in the laboratory with 3.5 h duration) and seminars (taught in classrooms, 0.5-2.5 h duration). In the first ten laboratory sessions, we offer an overview of the basics of working in a chemical laboratory. It is intended students acquire skills in performing basic laboratory operations as well as knowledge about the needed requirements, both pre and post. They have to get familiar with the security mechanisms and management, handling equipment and supplies, treatment and presentation of data, both pre- and post-assay, decision-making and selection of the most appropriate procedure. To reach these objectives, the laboratory sessions will be reinforced with five independent seminars, in addition to those taught at the beginning of each session, which dealt with more specific issues.

The timetable of the subject is structured as follows:

- Seminar 1: Prevention.
- Seminar 2: Introduction to laboratory work.
- Practical 1: Security and laboratory equipment.
- Practical 2: Dissolution, precipitation and crystallization.
- Practical 3: Characterization of liquids and solids.
- Seminar 3: Presentation of results.
- Practical 4: Liquid-liquid extraction.
- Practical 5: Crystallization and identification of samples.
- Seminar 4: Analysis and discussion of the results of the practical P1 to P5.
- Practical 6: Preparation of solutions and pH measurement.
- Practical 7: Acid-basic titration.
- Practical 8: absorbance spectrum of solutions.
- Practical 9. Distillation of mixtures of immiscible liquids.
- Practical 10. Stoichiometry.
- Seminar 5: Analysis and discussion of the results of the P6 to P10 practical.

Attendance at all sessions is mandatory. Students should edit a laboratory notebook where previous calculations, an outline of practical, experimental work, observations and experimental measurements and treatment are indicated. Before each laboratory session, students complete a test to check that they have properly prepared it. Students must resolve and hand in some questions and problems on the topics covered in the seminars and practical (in both cases after its completion), as homework tasks.

The didactic material consists of notes of the topics covered in the seminars and in the scripts of each practical. These includes, for each practical, basic theoretical concepts, aim, material and reagents required, some safety tips, the experimental protocol, and a section indicating the information that students must register, with the associated processing and interpretation. Students must review this material before the corresponding session. A bibliography is also provided, with documents on different themes related to the introduction to the chemical laboratory.

The evaluation consists of two blocks: continuous assessment (70%) and written exam (30%), which examines the theoretical knowledge. The student must reach a 4.0/10 in each block and a 5.0/10 in the average of both. Continuous assessment is distributed as follows: quality laboratory work (30%), homework tasks about on seminars and practical (10%), laboratory notebook (20%), and pre-practical tests (10%).

2.2 Description of the subject

The study was conducted on six subgroups (a total of 72 students), randomly selected, after the publication of the final qualifications. Each student was requested to fulfil a questionnaire anonymously and voluntarily, with various questions about the theoretical and practical content (adaptation and learning difficulties), the usefulness of the subject, and the teaching methodology. We inquired about their opinion about the organization, evaluation and logistics of the subject and the ambiance generated in the laboratory. From their responses, we aim to deduce the experience of students in their first contact with the chemical laboratory, and their level of motivation and attitude. The questions are listed in Tables 1-3. Scores have the following meaning, according to the question (superscript indicated in Tables):

- a: 0-Strongly Disagree - 10-totally agree
- b: 0-too little - 5-correct - 10-too much

Finally, we ask them to indicate the qualifications in each part. In all cases, the average scores are shown. All students agreed to participate in the study.

3 RESULTS AND DISCUSSION

3.1 Experience of the students about the subject

We obtained the following scores:

*Table 1. Opinion of students about the contents and teaching methodology^a
(S: seminars; P; practical; G: overall of the subject)*

	S1	S2	P1	P2	P3	P4	P5	S4	P6	P7	P8	P9	P10	S5	G
Taught content is adequate	7.0	6.1	5.4	8.5	7.9	8.5	7.7	5.9	3.5	8.6	8.4	7.8	6.7	6.9	5.0
Theoretical- practical content is useful	9.1	8.6	9.6	8.7	7.1	9.2	7.9	7.5	4.5	9.5	8.9	8.3	7.0	8.6	4.6
Theoretical aspects are easy to learn	4.1	4.8	3.6	7.8	6.9	4.4	6.6	7.9	6.0	7.4	6.7	6.2	7.2	5.3	6.5
Practical are easy to conduct	---	---	5.0	7.2	5.5	---	6.4	6.0	---	7.9	8.5	8.0	5.3	7.5	---
Teacher has successfully explained the contents	6.8	5.4	7.0	7.5	8.4	8.6	8.1	6.3	5.6	9.4	8.3	7.9	6.5	7.7	6.9
Explanations were motivating and attractive	8.1	4.1	3.9	6.8	7.5	8.0	7.2	4.5	4.7	8.6	7.7	7.6	5.9	6.1	5.7
Ambiance was relaxing and friendly	5.6	5.9	6.8	8.9	8.6	5.8	9.0	8.3	5.6	7.8	9.5	9.1	8.3	6.9	5.9

From the results, it is inferred that students consider:

- studied contents will be useful in the future (except seminars on discussion of results). They are aware that they must apply the knowledge learned in subjects in upper academic years and in their professional career.
- the content of the subject fits the learning objectives.
- the theoretical contents about prevention, management laboratory, safety and laboratory equipment are difficult to assimilate, probably because they are very extensive, descriptive and taught in few sessions. The same happens with the presentation of numerical results and stoichiometry, as they involved calculations and require a high level of concentration. In relation to experimentation, they generally know the associated theory and the correct way to perform the practical.
- practical do not require an excessively high manual dexterity for a proper execution, except characterization of liquids and solids (P3) and distillation (P9), which are more delicate.
- the professor correctly taught the subject.

- teachers ought to strive harder to motivate them and make the subject attractive to them.
- In the laboratory, a relaxed ambiance is maintained, encouraging participation and communication between students with mates and the teacher. This happened to a much lesser extent in seminars, perhaps since they look like usual face-to-face classes.

3.2 Organization of the subject

The following scores were obtained:

Table 2. Opinion of the students about the organization of the subject.

<i>Adequacy of</i>	<i>Score</i>	<i>Adequacy of</i>	<i>Score</i>
Number of seminars ^b	3.5	Sequence of practical ^a	8.6
Duration of each seminar ^b	5.3	Laboratory facilities ^a	7.5
Number of practical ^b	3.9	Laboratory material ^a	8.1
Duration of each practical ^b	4.8	Laboratory reagents ^a	6.8
Time between two sessions ^b	5.0	Number of students per group ^b	7.6

From the collected data, it appears that students think:

- The theoretical content is very extensive, so that more seminars are necessary to teach it properly. the duration of the seminars should not be increases, since they would be too tedious.
- increasing the number and topics of the practical would be a good idea, as experimentation reinforces the learning-teaching process of theoretical subjects. This shows they are motivated to take laboratory subjects, and they consider them extremely useful.
- the timetable of the practical (time and sequence) facilitates the acquisition of knowledge.
- They have enough time to prepare the practical and complete their homework tasks.
- The facilities, equipment and reagents available to students are sufficient and in good condition, but the number of student per group should be reduced. This would facilitate communication with the teacher and allow for more individualized teaching.

3.3 Evaluation

The following results about the different evaluation activities were obtained:

Table 3. Opinion of the students about the evaluation and final qualifications.

<i>Activity</i>	<i>I knew the evaluation criteria^a</i>	<i>Ponderation in the final qualification was adequate^b</i>	<i>Teacher evaluated correctly and objectively^a</i>	<i>Obtained qualification</i>
Quality of laboratory work	3.8	3.9	2.8	24/30
Homework tasks about seminars/practical	8.5	5.2	7.6	9/10
Laboratory notebook	5.7	3.8	4.5	15/20
Pre-practical tests	9.5	4.7	9.8	7/10
Written final exam	7.7	7.6	8.6	22/30
Overall				77/100

We found the students consider:

- they have not been properly informed how the quality of their work and laboratory notebook is going to be evaluated.

- the teacher was unable to monitor their work throughout the practical time, so that they believe the score might not be fair.
- the teacher has not read in detail the lab notebook, perhaps being too extensive.
- they already knew how written exams and problems will be evaluated, because this type of evaluation is already performed in theoretical subjects. In addition, they are more objective.
- the written test has too much weight, considering it is practical subject. More importance should be given to work in the laboratory, where dexterity to conduct the chemical assays and knowledge about laboratory functioning is demonstrated, and the notebook, where the student's ability to describe the work and observations / measurements registered in during the laboratory session is shown. The weight of homework tasks and tests is correct, as it is very low.

All students passed the subject, with high average qualifications in all parts (> 70%). It is worth noting the excellent qualifications of the homework tasks, indicating that students understand the content of each practical and seminar, after attending them, and they studied them hard at home. The laboratory work was satisfactory, showing they acquired manual dexterity and learned to properly handle reagents and materials, and to adequately conduct the experimental protocols. Although an effort to prepare the practical has been noticed, they had better improve this aspect. The laboratory notebook was correct, although improvable, so that students should work harder on the description of the work performed and the observations at the laboratory. The result obtained in the written test shows that they have assimilated most theoretical concepts, but they have some lacks of knowledge they had better solve because to avoid problems in further laboratory subjects. Overall, students properly performed all activities, indicating attitude, interest and motivation, as well as effort and learning capacity at both theoretical and practical level.

4 CONCLUSIONS

Students reached the main learning objectives: manual dexterity in performing basic chemical operations, assimilation of theoretical and practical knowledge about the functioning of the laboratory, preparation of a practical, detailed description of the tasks performed in the laboratory, and the correct recording and processing of data and experimental observations. They consider the subject is properly structured and scheduled, and the most important content has been included. Moreover, they are aware of the usefulness of the subject for training, for both competition of the Grade and their future careers. A relaxed ambiance that encouraged participation was also generated, and probably stimulated learning. Finally, they considered the subject was motivating, attractive, and even fun, since they could visualize the knowledge and manipulate chemicals and materials studied at the theoretical subjects, where they find them a bit abstract. However, to improve the teaching-learning process, the evaluation criteria of the laboratory work and notebook ought to be better explained, and the seminars should be taught as a more attractive way. We must focus on the preparation of practical, the editing of the laboratory notebook and the study of the associated theoretical contents.

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