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IMPLEMENTATION OF THE INVERTED CLASSROOM IN ORGANIC CHEMISTRY LABORATORY PRACTICES

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Abstract: This work presents the application of the flipped classroom methodology in the subject Organic Chemistry, taught in the second year of the degree in Chemical Engineering, at the School of Industrial and Civil Engineering of ``Universidad de Las Palmas de Gran Canaria``. To this end, the student was assigned the task of preparing the laboratory practices as autonomous work, making available the custom-designed academic materials (a practice manual with the theoretical foundations and the experimental procedure, and a collection of explanatory videos on the management of the basic instrumental techniques required in each practice). Before carrying out each practical experience, the student will complete a questionnaire that will allow him or her to know his or her level of preparation to face the experience, and once this is completed in the laboratory, he or she will complete a final report. Following this approach, the results have been very positive in relation to the learning of laboratory techniques and theoretical foundations of the experiments developed, as well as the critical thinking capacity that students develop. They were very satisfied with what they learned in the laboratory practices and with the methodology used.
Keywords: Learning, Flipped Classroom, Evaluation, Innovation. Organic Chemistry.

INTRODUCTION

In recent decades it has been proven that the expository teaching method is ineffective for the understanding and assimilation of concepts if it is not accompanied by activities in which students interact and become protagonists of their learning [1]. The presentation of content through interactive methodologies such as problem-based learning, collaborative work, case studies, among others, can promote and facilitate student learning [2,3]. In this sense, since the implementation of the European Higher Education Area, a change in the roles of teachers and students has been required. The former must become guides and facilitators instead of transmitters of knowledge, and students must be more active in the construction of their own knowledge. However, strategies and actions at the national and institutional level have been limited to implement these changes, which require, first of all, the training of teachers in more flexible, effective and active teaching methodologies4,5. The flipped classroom methodology has been pointed out as one of the models to make this transition6. During the COVID-19 pandemic, this challenge was faced by many teachers, who were forced to prepare the necessary resources to facilitate the active and autonomous learning of the student, obtaining very good results, among which the very positive perception of the students stands out. students about the flipped classroom in relation to increasing their autonomy in learning (Campillo-Ferrer)[7].

The subject Organic Chemistry is often considered a difficult discipline to teach and learn, mainly because students prefer to rely solely on memorization rather than reasoning using models of chemical reactivity. Most students reproduce sequences of stages that they have memorized when solving problems, but they are not able to explain or interpret each stage[8]. To all this, we must add the difficulty of a new language of chemical symbols and schemes or mechanisms that can represent a barrier to understanding and learning [9-11]. Isomers of 1,2- and 1,3-dimethylcyclohexane are shown in Figure 1 as an example.

Although the formulas are drawn in two dimensions, the student must understand their three-dimensional arrangement and be able to identify that the top two molecules are different conformations of the same compound, while the bottom two are different compounds, and that each vertex is an atom of carbon with enough hydrogens to complete its 4 valences.

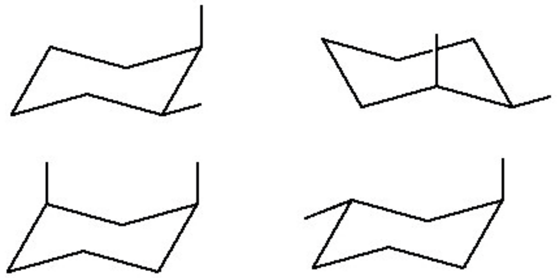

Figure 1. Isomers of 1,2- and 1,3-dimethylcyclohexane

The present work is based on the application of the inverted classroom in learning basic concepts of Organic Chemistry through laboratory experiences. According to Arnold-Garza (2014)[12], the flipped classroom is a teaching method in which material is delivered to students (lectures, comments, etc.) through electronic means so that they can work on them at home, and Use class time to apply what you have learned. It will only be beneficial with proper monitoring and instruction from the teacher. Abeysekera and Dawson (2015)[13] have given a more precise definition of the flipped classroom, in which (1) the greatest transmission of information takes place outside the classroom; (2) class time is used for active and social learning activities; (3) requires students to complete pre- and post-class activities/assignments to fully benefit from class work. In short, students receive the content in advance, through educational videos or documents that they prepare at home, and then they are asked to carry out higher-order learning activities in class with the teacher's advice[14,15].

The benefits of the flipped classroom are multiple: i) Students are familiar with what they are going to learn; ii) they can manage the time spent reading the documents, watching the videos and learning at their own pace, without limitation of time and place, in an autonomous climate. They can repeat watching videos and reading documents, so it is likely that everyone will be able to keep up with the same pace, which is not the case in a live class, where they can fall behind; iii) students take active roles in their learning process and receive feedback from teachers immediately, improving their self-awareness and confidence[14,16].

This work presents the experience of applying the "flipped classroom" methodology in the subject Organic Chemistry, taught in the second year of the degree in Chemical Engineering, analyzing the academic results achieved by the students, as well as the considerations they have expressed through a questionnaire. satisfaction using a 5-point Likert scale. This work was structured as follows:

- Appropriate practical experiments were selected;

- The prior preparation of these laboratory practices was assigned as an autonomous task of the student based on the academic materials prepared to measure (a practice manual with the theoretical foundations and the experimental procedure, and a collection of explanatory videos on the management of the basic instrumental techniques required in each practice).

- Before carrying out each practical experience, (i) the student had to complete an online questionnaire that would allow him to know his degree of preparation to face the experience; (ii) a debate takes place with the teacher to clarify unresolved aspects.

- Once the practical experience has been completed, you would have to prepare a final report and answer a satisfaction survey.

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METHODOLOGY

PARTICIPANTS

The participants in this study (8 women and 4 men) are students in the second year of a degree in Chemical Engineering (n = 12) taught at the School of Industrial and Civil Engineers of ``Universidad de Las Palmas de Gran Canaria`` in the 2021 academic year. 2022. This is the first in-person course after the COVID-19 pandemic, in open and airy classrooms and laboratories, and maintaining social distance. The number of students enrolled in the subject was very low (15) if we compare it with the 37 enrolled in the same subject in the previous year. This was due to the fact that many students of the 83 new students in the first year (2020-2021) abandoned the degree due to the special circumstances of not being present. Furthermore, in accordance with university regulations, students who have completed laboratory practices in the first year they enroll in a subject are exempt from repeating them in the two subsequent courses (3 students), therefore, only 12 students enrolled participated in the project.

MATERIALS AND PROCEDURE

This work is based on the analysis of the academic results obtained by the students, as well as the analysis of their perceptions about different aspects of the practices carried out. The practical course was divided into three parts with two different evaluation tasks: a non-face-to-face part of the student's previous work that includes an online evaluation questionnaire, a second in-person part for carrying out the experiment, and a third non-face-to-face part that It consisted of completing a practice report with a questionnaire.

The first part consisted of the study and preparation of the concepts and theoretical foundations of the practical experiences that they would later develop in the laboratory. The pedagogical structure for this part included independent reading of the practice manuals that describe the theoretical foundation on which the experience is based, the stages of the procedure, as well as the instruments, the necessary reagents and their technical safety sheets with precautions. to consider.

The laboratory practices are: Practice 1. Separation of substances based on the acidity constant; Practice 2. Extraction of caffeine (use of soxhlet); Practice 3. Synthesis and identification of propanone (oxidation of alcohol to ketone and purification by distillation); Practice 4. Synthesis of AAS and obtaining soap (esterification and saponification reactions); Practice 5. Preparation of polymers. All documents were made available to students through the Moodle platform, in the virtual space of the subject. A consultation forum was set up for supervision. In addition, students had the possibility of making inquiries via email.

To learn the correct operation of the instruments necessary for each experience, a series of videos were included in which basic laboratory operations and how to use these instruments were explained: i) how to make a filter; ii) how to filter with a Buchner funnel; iii) use of rotary evaporator; iv) extraction with a soxhlet equipment; v) how to perform thin layer chromatography; vi) distillation and assembly of distillation equipment; vii) video on nylon manufacturing.

In addition, both the recorded theory classes and the collections of solved problems were placed in the virtual space of the subject. These videos explain the theoretical foundations of the reactions used in the practice sessions.

A preliminary questionnaire was designed that the student had to answer online through the Moodle platform during the days prior to the laboratory session, and after reading the manuals and watching the corresponding videos. These questionnaires were part of the student's evaluation.

The second part of the work includes the face-to-face practice session, which begins with a debate about what is going to be done, with the active participation of the students, who share what they have learned with others and express their doubts. At this moment, formative feedback is produced by the teacher, who has analyzed the questionnaires solved by the students before carrying out the practical experiment, knows their weaknesses and resolves their doubts. Subsequently, each student carries out the practical experience individually, following the guide and being responsible for the material, the equipment they use and the results of their experience.

Once the practice is finished, the student must complete a report with a questionnaire about the laboratory experience carried out, its theoretical foundation and the results obtained. It has a long period of time, since it is delivered at the end of the semester, it is done during independent work time at home, and it is part of the evaluation of the subject.

Additionally, students complete a satisfaction survey on a 5-point Likert scale, with the following ratings (very satisfied (5); satisfied (4); neutral (3); dissatisfied (2) and very dissatisfied (1)). Includes the following questions:

- Are you satisfied with the laboratory practices of the Organic Chemistry subject?

- Are you satisfied with the methodology used to understand the laboratory practices of the Organic Chemistry subject?

- Did you read the practice scripts? Check the options that fit your experience and add the last one.

• I read them at home, before going to the corresponding session, to fully understand them.

• I only read them during the practices and there were aspects left for me to understand.

• I only read them during the practices and followed the script as if it were a cooking recipe.

• I understood the mixing process, but I didn't stop to understand the chemical fundamentals.

- What method or tool would you have needed to understand the laboratory practices?

- How do you rate the videos to support practices?

RESULTS AND DISCUSSION

The academic results obtained in the 2021-2022 academic year are shown in Table 1. As can be seen, of the twelve students who completed the internship, 10 passed with good grades. No student passed the laboratory practices with a grade lower than 6 (out of 10 points).

Two students failed the internship: one incorporated through the "Erasmus" program did not master the language, so he was not able to follow the classes or take the questionnaires. He also did not respond to the satisfaction questionnaire. The other suspended student took the previous questionnaires, passing 3 of the 6 questionnaires, and did not complete the final reports. This student stated in the final survey that "*I only read the practice scripts during the practice and followed the script like a cooking recipe*"; "*In some practices I have used them as a cooking recipe, but in others I have understood how to do it*". However, he was satisfied with the laboratory practices of the subject, with a rating of 4 out of 5, and with the methodology used to understand them with the same rating. In addition, he gave the following answers to the questions: What method or tool would you have needed

Course	Enrolled students	Interns	Approved students	Students with grades (%)			
				≥ 8	8 > x ≥ 7	7 >x ≥6	6 > x ≥ 5
2021-2022	15	12	10	60	30	10	0

Table 1. Percentage of students who pass laboratory practices with different grades

to understand the laboratory practices? *"None, all the material that we have used for the practices has been fair and necessary"* and *Have the questionnaires about the practices been useful to you? Yes, they have helped me to guide myself.*

Of the 10 approved students, only 9 responded to the satisfaction survey. All of them stated that they read the practice scripts at home, before going to the corresponding session, giving a score of 5 (very satisfied) to the laboratory practices of the Organic Chemistry subject; In relation to the methodology used to understand the practices, 6 indicated they were very satisfied (5), and three rated this item with a (4). Among these students, 5 indicated that no additional tools are required, and the remaining 4 indicated that "more videos of all practices", "more videos with the explanation of each step" are required. All students fully agreed to positively value the videos and previous questionnaires, answering the following questions:

- How do you rate the videos to support practices?

" *are of great importance*";

"*very positively when it comes to visualizing some procedures that are not clear in the practice scripts*";

"*they help to understand how they have to be done*";

"*they have been very didactic, clear and highly recommended*";

"*They are well explained*";

"*useful on all occasions since they resolved the doubts I had*"

"*favors the fact that some aspects of it are visually seen*";

" *very good, they are a way to better understand the procedures*".

"*I value them a lot, and quite well*"

- To have the practice questionnaires been useful to you? The students answer yes, and in some cases they complete the answer by indicating the following:

"*They have been fundamental since they force the student to, at least, read the script. With this, the knowledge acquired for internships can be promoted*";

"*they were a key point to further deepen the contents of the practice*";

"*serve to highlight the most important aspects of the practice*";

"*since this way he attended the practice with knowledge about carrying out the practice*";

"*because it allows us to understand and understand the practice to be carried out*";

"*more or less*"

In general, during the course of the practical sessions, it could be observed that the students were less dependent than they have traditionally been during those laboratory sessions. They do not require the attention that they required through the traditional teaching method, which consisted of explaining the practice using the expository method moments before its performance, as well as the operation of the instruments. With the traditional method, the students showed less self-confidence, needing the teacher's approval at each stage of the experiment to be sure that they were developing it correctly, and constantly asking questions about the operation of the instruments. This meant that, in some cases, they were delayed and were not able to finish the experience in the scheduled time. With the flipped classroom method, students show greater autonomy and security in their work. Previewing the videos allows them to know, for example, how to trim filters, assemble equipment, use separatory funnels, etc. The use of the flipped classroom showed an increase in motivation, confidence and learning.

In summary, and according to Fautch (2015)[3], the flipped classroom seems to be the appropriate methodology for teaching experimental chemistry in small groups of students, taking into account their performance (measured by their grades) and their positive attitude towards chemistry. flipped class.

AUTHORS' CONTRIBUTION

Milagros Rico: Study design, laboratory implementation, data acquisition, analysis and interpretation. Review of the bibliography and writing of the article.

Paula Santiago-Díaz and Elsa Rodríguez Pérez: implementation in the laboratory, analysis and interpretation of data and review of the article.

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