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ANALYZING DRUG COMPOSITIONS IN A PROBLEM-BASED LEARNING EXPERIMENT TO STIMULATE UNDERGRADUATE STUDENTS´ AUTONOMY

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Abstract

The oversimplification of higher education experimental practices may provoke a lack of confidence among graduates, who do not feel fully prepared to face the situations that they will find when entering the labour market. Our Educational Innovation Group TR4BIOCHEM (PIE22-067) is interested in the implementation of new Problem-Based Learning-laboratory experiences to bring students closer to real situations that they may encounter in their potential job opportunities in an immediate future. Herein, we present a didactic experience carried out with fourth year-biochemistry undergraduate students, within the subject “Advanced Instrumental Techniques” at the University of Malaga. Students, working in groups of five people, adopted the role of analytical chemistry companies, which had to find a solution for a driving question, set in a letter from a pharmaceutical company, interested in the quantitative analysis of a newly developed drug. In this letter, the problem (the quantitative composition of the drug) was issued and the main required specifications for the analysis (sensitivity, accuracy, price, etc.) established. Groups had to search bibliography in order to select the most suitable analytical technique for the analysis, design and optimization of the experimental protocol, including cost estimation and safety considerations. Following the practical implementation in the laboratory, results were presented in a session that simulated a work meeting where the group members assumed a different role in the company organigram. Students, who perceived having gained skills in designing laboratory experiments, felt strongly involved in this project, considering that this experience could be useful for their future careers.

Keywords: *Problem-based learning, biochemistry, analytical chemistry, autonomous work, undergraduate.*

1. Introduction

A rapid social transformation has brought to the table the need for a revision of the educational system. Indeed, a clear disconnection between the educational training provided by universities and the demanding skills required by the labour market has been perceived by students, educators and employers. The introduction of degrees in European universities has catalyzed the development of an education system that is increasingly becoming focused on the development of competences. The term competence is complex and implies a combination of skills such as attitude, motivation, knowledge, teamwork, communication, emotional intelligence, among other factors, to achieve an integrated set of knowledge, skills and abilities (Moliner et al., 2019). Competences development requires an active, student-centred learning methodology that limits the role of teachers to that of mere guides in the process (Almulla, 2020). The active participation of learners usually leads to an increased retention of knowledge as well as a greater involvement and motivation in their learning process. Consequently, better academical outcomes are achieved. Many methodologies, such as design-based learning or inquiry-based learning, have been postulated to bring the labour environment closer to students (Kolmos et al., 2021). Problem-based learning (PBL), firstly used in medical sciences education (Barrows and Tamblyn, 1980) is one of the most promising strategies. It focuses the learning process solving a problem in a real-life situation, which facilitates the development of multiple skills required by employers. In addition, it is often implemented in small groups, which also prepares students for an environment in which they must work in multi-disciplinary groups to solve complex problems (Moliner et al., 2019).

Stemmed from the concern that the laboratory teaching at our university demands a change, our Educational Innovation Group (PIE22-067 TR4BIOCHEM) is interested in the implementation of new inquiry-based laboratory experiences that could make students become protagonists of their own learning process (García Ponce et al., 2019 and 2021; García Caballero et al., 2022). In this chapter we describe a PBL experience within the subject "Advanced Instrumental Techniques", offered to 4th year-biochemistry undergraduate students at the University of Malaga. In this PBL students had to design, analyse and optimise an analytical method to quantify the components of different pharmaceutical preparations as well as present their results to an audience. Encouraging results have been obtained both in terms of students' academic grades and satisfaction.

2. Design

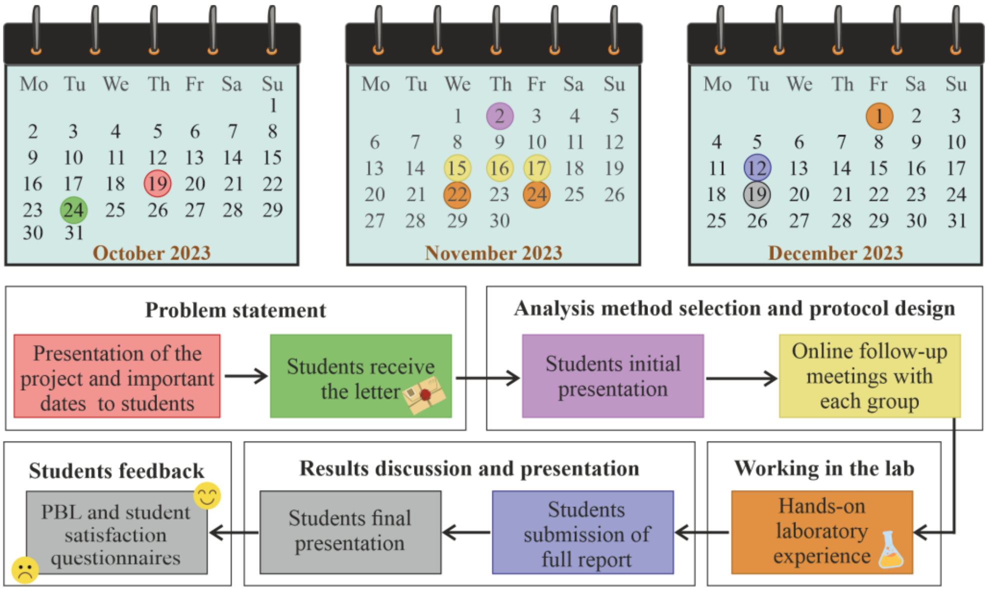
2.1. Context of the study

The target population of this study was fifteen undergraduate students attending the elective course "Advanced Instrumental Techniques" in the final year of the Biochemistry degree at the University of Málaga. These students acknowledged having had a previous poor experience in PBL activities.

2.2. Timeline and data collection tools

The PBL experience was carried out during the first term of the 2023-24 academic year, between mid-October and the end of December 2023 as it is shown in Figure 1.

Figure 1. Timeline, main stages and tasks carried out during the development of the PBL experience at University of Málaga.

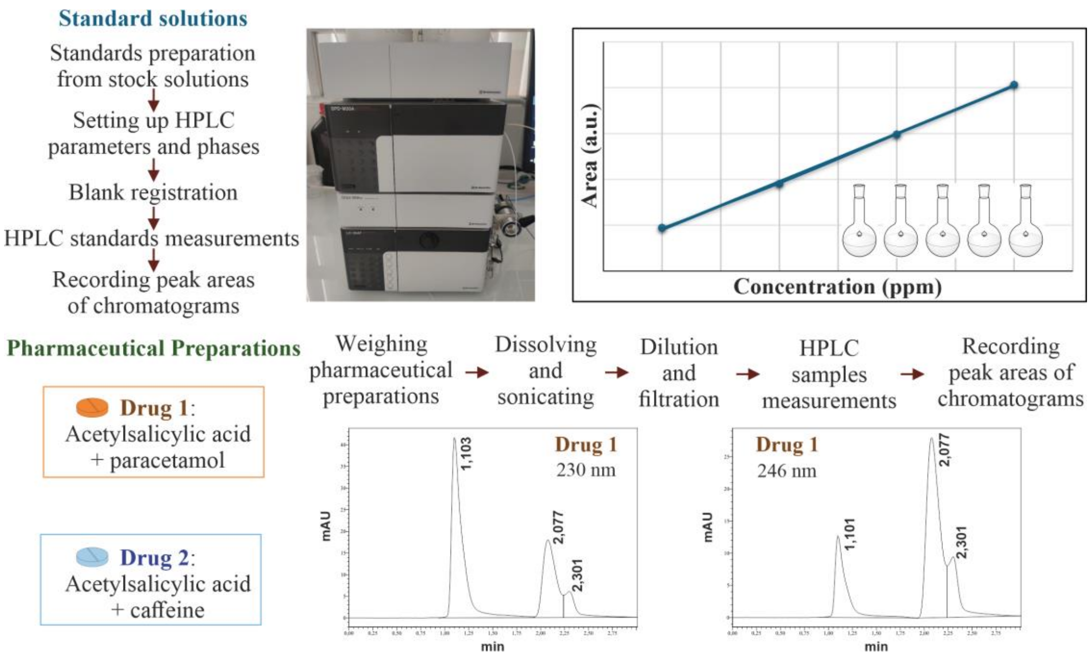


The main steps of the implementation of the PBL strategy are summarized in Figure 1. In the first session, the teachers presented the PBL activity to the students, its stages and chronology. The experience consisted of a role-playing game in which students would work in groups of 5 people. Groups should choose a name and design a logo and an organigram, so that each student should play a different role within the company throughout the whole process. Some days later, they received a letter on behalf of a fictitious pharmaceutical corporation stating the objective "to find a method for the quantitative analysis of two novel pharmaceuticals". In that letter, the main requirements related to the quantitative analytical technique were indicated (fast, economical, reproducible, accurate, sensitive in the ppm concentration range and robust). Then, students carried out a thorough literature review of the different analytical techniques that have been used in similar scenarios to the one requested in the letter. They compared the different analytical techniques, taking into account several parameters such as the method accuracy, robustness, reproducibility and simplicity, the safety considerations, the investment required, or the adaptability to different types of samples, among others. The following week, groups made a short presentation in which they introduced their company to a putative customer and discussed their findings, proposing a method for the drug quality control. At this point, teachers sent students a list of available materials, reactants and equipment to perform the practical experience in the laboratory, in relation to the analytical method proposed in their presentations.

The next step was to design the experimental protocol, carry out calculations for standards and sample preparation, make a cost estimate and establish the necessary safety considerations. An online meeting between teachers and each group of students was set to clarify any doubts the students might have and to ensure the viability of the students proposed protocols. As a result of this process, each group designed a protocol based in the use of High-Performance Liquid Chromatography (HPLC) coupled with an UV detector to selectively quantify the amount of acetylsalicylic acid (ASA), paracetamol and caffeine present in the different medicines. The protocols proposed by the groups converged in a similar protocol, summarized in Figure 2, which they further and independently performed in the laboratory.

A few weeks later (see Figure 1), the companies submitted a final report in which the summarized the reasons for the selection of a given method, the protocol design and the results they had obtained in the laboratory, calculated from the chromatograms, ending with a final general discussion. All this information was also included in a short presentation to an audience that replicated a work corporate meeting.

Figure 2. Schematic representation of the protocol designed by the students for the quantitative determination of two drug components. As an example, the chromatogram of drug 1 at the wavelength of maximum absorption of each of its components (230 nm for acetylsalicylic acid and 246 nm for paracetamol) is shown.



The instruments used to assess the competences acquired by the students were the final report and the initial and the final presentations, all of which were rated using rubrics. Finally, two tests were provided to the students: one to analyse their previous experience and familiarity with PBL and another to evaluate the students' satisfaction with the methodology and the organisation of the exercise in general.

3. Results and discussion

One key parameter to evaluate the impact of this PBL experience was the students' academic grades, since the ultimate objective of any educational experience would be to promote their acquisition of knowledge, skills and competences. This activity aims to develop some practical skills in students who would enter the labour market as biochemistry graduates the following year. It should be mentioned that the mark for this PBL experience was a twenty percent of the final mark for the "Advanced Instrumental Techniques" subject, representing an relevant percentage of the assessment process. The scores obtained in this PBL exercise by the three groups were 9.1, 9.4 and 9.6 out of 10, what implies an average group score of 9.37 ± 0.25 (mean ± S.D.). These marks are a first indication of the positive impact of this activity on the students learning process.

In any educational project, students' satisfaction is an aspect to be considered. Excessive workloads, as well as the use of teaching methods that students could find boring and/or unremarkable, generally generate feelings of stress, anxiety and apathy, leading to a loss of interest and a disengagement from the subject and its content. Therefore, the analysis of the students' responses to the practice satisfaction test is essential to make improvements and adjustments in future implementations. Students' perception of the teaching methodology used in this PBL experience was evaluated by means of a post-course mixed questionnaire, using some 1 to 5 Likert-type scale questions, complemented with some open-answered questions. Main answers are summarized in Table 1.

Table 1. Student responses to the PBL satisfaction test. Each statement in the test could be rated between 1 (strongly disagree) and 5 (strongly agree).

Statement	Mean	SD
The learning methodology (PBL) used in this activity is innovative with respect to that used in other subjects of the degree	4.33	0.98
I think the dynamics of working in the group has been efficient and satisfactory	3.80	1.08
I did not like working autonomously, without the teacher being directly responsible for my learning	1.93	1.10
Sometimes we have been disoriented about how we should approach the resolution of the problem posed	2.33	1.18
With this methodology (PBL) I felt especially involved in my learning	4.00	1.07
With this methodology (PBL) I did not learn more than through the traditional way of studying	2.20	1.26
I would have preferred to work individually, or at most in pairs, not in a group	2.80	1.42
I think we managed to work well in the group in order to solve the proposed case	3.79	0.97
This working methodology (PBL) did not require more work and preparation on my part than in others of the same or other subjects	3.27	1.44
The solution of the PBL case took me too much time, sometimes incompatible with the workload I had to devote to other subjects and assignments	2.73	1.33
I think that not all members of the group worked with the same intensity and that some took advantage of the effort of others	2.87	1.30
In my opinion, the weight of the PBL activity in the evaluation of the course grade was too low for the time I spent on the task	1.87	1.13
In this PBL I was confronted with situations similar to those I may encounter in my future professional development	3.87	1.36
In this PBL I learned how to plan my own laboratory experiments	3.80	1.37
Global perception of this experience	4.07	0.80

An average global perception rating 4.07 over 5 indicates that the experience was in general terms well received by students. They particularly appreciated the fact that the activity was innovative, effective, satisfying and that they had felt involved and autonomous in their learning process. In addition, students mostly considered useful the experience for having developed some skills that could be useful for their future professional activity. The weight of the activity in the final mark of the subject was considered to be appropriate. Teamwork was an issue on which the students' opinions disagreed. Although most of the students felt that they had managed to work well in a group, the preference for individual work and the feeling of uneven effort among group members emerged from some of their responses. The time that students had invested in this experience, compared to that spent on activities from other subjects was the most criticised question. Indeed, some students found that in some occasions it had been challenging for them to combine it with the workload from other assignments. This question should be considered in possible future implementations.

In the final test, students were also asked about their previous experiences and their perception regarding the PBL educational tool. Around 28% had never heard of PBL and more than 85% expressed they had never used it (Table 2). The experience statements that received the lowest were those related to active learning, autonomous working, and planning and receiving instruction in unconventional formats (Table 2). Students rated the acquisition of integrated knowledge, far from the traditional compartmentalisation of subjects, as the most important issue. In this sense, analytical chemistry, pharmacology and biochemistry concepts are all part of our daily experience.

Table 2. Students' responses in the test on their PBL experience and some perceptions of learning. Each statement in the test could be rated between 1 (low experience or relevance) and 5 (high experience or relevance).

Statement	Experience		Importance	
	Mean	SD	Mean	SD
Solving a problem or question autonomously, without the explicit help of the teacher	3.71	1.27	4.67	0.90
Learning, working in a group, in a collaborative environment	4.07	0.92	4.40	0.91
Being the main protagonist or responsible for my learning	3.57	1.09	3.73	0.96
Receiving a non-conventional lesson in which the teacher acts only as a facilitator of the task	3.79	1.05	3.47	1.19
Using an active learning methodology that could be used for different subjects or disciplines	3.86	0.95	4.67	0.90
Diagnose what I need to know or learn to solve a problem or issue	4.07	1.07	4.60	0.83
Planning my learning process and the actions needed to solve a problem	3.86	1.10	4.73	0.80
Integrating knowledge from different subjects or disciplines	4.14	0.66	4.93	0.26
Making decisions about what to learn and how to learn	4.14	1.10	4.67	0.82
Question	**Number of students**			
	Yes		No	
Prior to this course, did you know or have you heard of Problem Based Learning (PBL)?	4		10	
Have you ever used this methodology?	12		2	

4. Conclusions

Our research suggests that the PBL approach was well received by the biochemistry undergraduate students, although it required more effort on their part than traditional teaching. Student grades and satisfaction tests support this hypothesis. Students felt involved in the project and acknowledged it as useful as a training for their immediate professional future. Moreover, the multidisciplinary nature of this exercise was in line with the importance attached by the students to the acquisition of a comprehensive knowledge.

Acknowledgments

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