Application of CBL approach to Chemical Engineering MSc students
Aplicación del ABR a estudiantes del Máster en Ingeniería Química

Araceli Rodríguez[1], Rubén Miranda[1], Eduardo Díez[1], Naby Conte[1], Marcos Tierno[1]
arodri@ucm.es, rmiranda@ucm.es, ediezalc@ucm.es, nconte@ucm.es, mtierno@ucm.es

[1]Departamento de Ingeniería Química y de Materiales
Universidad Complutense de Madrid
Madrid, España

Abstract- The paper presents the challenge-based learning (CBL) methodology that has been implemented in the theoretical part of "Internships in companies and research centers" course, of the Master in Chemical Engineering: Process Engineering at UCM. The methodology involves the establishment of an experts panel to guide the students, the definition of the challenges to be solved, the configuration of the students' working groups, the development of different presential sessions to propose a solution to the challenge and the public presentation and defense of the proposed solutions. The assessment of the methodology has been carried out by a questionnaire answered by the students, which allowed concluding that the methodology used was valuable, despite their perception of the high effort needed. Among the activities carried out, the visit to industrial facilities was considered the most attractive, while the preparation of a CV activity was the least appealing for the students.

Keywords: CBL, Z generation, Chemical Engineering Master, team-working, self-learning.

Resumen- Esta comunicación presenta la metodología basada en el Aprendizaje Basado en Retos (ABR) que se ha empleado en la parte teórica de la asignatura "Estancias en empresas y centros de investigación" del máster en Ingeniería Química: Ingeniería de Procesos en la UCM. La metodología implica el establecimiento de un panel de expertos, la definición de los retos a resolver, la configuración de los grupos de trabajo, la realización de distintas actividades para resolver el reto, y la exposición pública del mismo. La evaluación de la metodología se realizó mediante una encuesta a los alumnos cuyas conclusiones más relevantes son que, a pesar de que consideraban que era necesario mucho esfuerzo, los estudiantes pensaban que la metodología era interesante. Entre las actividades llevadas a cabo, las visitas a plantas industriales fueron las más valoradas, mientras que la preparación de un CV resultó la menos atractiva para los estudiantes.

Palabras clave: ABR, Generación Z, Máster en Ingeniería Química, trabajo colaborativo, autoaprendizaje.

1. Introduction

This paper presents the description of a project for innovation and improvement of teaching quality, which has been carried out during the academic course 2022/2023 in the context of the compulsory subject "Internships in companies and research centers". This course comprises 15 ECTS, distributed as follows: 12 ECTS practical credits (short internship in a company or a research center), along with 3 ECTS theoretical credits. Considering the students that are currently taking the course belong to what is called Z Generation (Z-Gen), the project aims to the application of a Challenge Based Learning (CBL), in a playful environment to develop the 3 ECTS theoretical credits, by proposing three different challenges which 3-student groups must tackle, related to the Sustainable Development Goals (SDGs) and oriented to the job market. Additionally, this approach will permit working with the transversal competences "team working" and "self-learning".

In literature (Nichols & Cator, 2008) CBL is defined as "an engaging multidisciplinary approach to teaching and learning that encourages students to leverage the technology they use in their daily lives to solve real-world problems". According to Johnson & Adams (2011), "by giving students the opportunity to focus on a challenge of global significance and apply themselves to developing local solutions, CBL creates a space where students can direct their own research and think critically about how to apply what they learn". Among the skills the students acquire with this approach Nichols & Cator (2008) mention:

- A multiple entry point strategy and varied and multiple possible solutions.
- A focus on universal challenges with local solutions.
- An authentic connection with multiple disciplines.
- An opportunity to develop 21st century skills.
- The purposeful use of Web 2.0 tools for organizing, collaborating, and publishing.
- The opportunity for students to do something rather than just learn about something.
- The documentation of the learning experience from challenge to solution.
- 24/7.

This approach is particularly interesting when dealing with Z-Gen students due to their specific characteristics. According to literature (Dolot, 2018), Z-Gen members simultaneously move in between real and virtual worlds and, consequently, they can easily seek for the whatever information they need. In fact, they are usually called "digital natives" (Rothman, 2016) or "the online generation" (Dolot, 2018). Another important characteristic of this group is that they are prone to multitasking, mainly because they profusely employ applications that support that way of working. However, this implies that the ability to concentrate, being precise or being able to memorize something in the long term has become difficult for Z-Gen members (Csobanka, 2016). Furthermore, a characteristic that also justifies the convenience of enhancing

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"team working" and "self-learning" approaches is that Z-Gen students are more attracted towards a certain topic or task when they are given autonomy to fulfill a certain task. In fact, they are called "the autonomous generation" (Edward, 2023).

2. Context & description

A. Context

Nowadays the "Master in Chemical Engineering: Process Engineering" at Complutense University is organized in three semesters during two academic years (90 ECTS). The last semester is devoted to the development of the Final Master thesis, as well as the compulsory course entitled "Internships in companies and research centers". This last course involves 15 ECTS credits but its structure is not the classical, as includes theoretical 3 ECTS together with the practical 12 ECTS (the internship itself).

From the beginning of the master (academic course 2013/2014) until today, different strategies have been tried to direct these credits towards the necessities of students and their formation in transversal competences and soft skills. For example, initially the theoretical block includes magistral lessons concerning the scientific method, the evolution of Chemical Engineering, or the development of scientific texts. However, despite the continuous efforts by means of the master coordination commission, the results of the satisfaction surveys carried out for students show that, although the students initially found the activities interesting, they also though that they were clearly directed towards the research field, far for their future professional career. For this reason, during the academic course 2022/2023, we have developed a project aimed to bring the students closer to the job market. The project proposed to approach the students to the job market by the application of a Challenge Based Learning in a playful environment, proposing three different challenges related to the Sustainable Development Goals (SDGs) and oriented to the job market. To follow up the resolution, three different mentors were recruited: industrial (former BSc students who are currently working in private companies), junior (former 1st year Master students), and academic (teachers involved in Master teaching) (Black, 2009).

B. Employed Methodology

The development of the project was tackled following these steps:

1. Configuration of the panel of experts. In the academic course 2022/2023, three industrial experts (a worker form Proquicesa, a worker from ASPAPEL, and a former worker from Técnicas Reunidas), three junior experts (former 1st year Master students), and three academic experts (teachers from different master's courses).

2. Establishment of the challenges to be addressed. In the academic course 2022/2023, the proposed challenges were:
    1. Analysis of the phosphorus recovery from wastewaters (circular economy applied to urban wastewater treatment plants).
    2. Analysis of the sustainability in the papermaking industry (the paper industry is very intensive in water and energy consumption).
    3. Analysis of the energy efficiency in the cement industry (the cement industry contributes around 5% of total greenhouse gases emissions at worldwide level).

   According to CBL methodology, each challenge was characterized by an initial statement and several guiding questions, to help the students face the challenge.

3. Configuration of the students' groups. At this point, the students were asked to organize themselves in 3-person groups. Afterwards each group was randomly assigned a challenge. With the idea of introducing a playful environment, the assignation was performed by distributing metal pins with the symbols of the three chemical elements discovered by Spanish scientists (team Pt for phosphorus recovery, team W for papermaking industry, and team V for cement industry). Additionally, each group was asked to find a name for themselves in consonance with the challenge and, to motivate them, we established a contest in which the students voted the best name.

4. Face the challenge. To compel this step, several presential sessions were programmed along the course:
    1. Lecture about research, development, and innovation in Chemical Engineering.
    2. Lecture on how using the main databases for scientific literature and patents literature. Recommendations for writing scientific or technical reports.
    3. Lecture of the industrial experts: their expertise and their advice.
    4. Lecture from a member of "Oficina de Prácticas y Empleo" on how to talk and present efficiently in public (Complutense University Office devoted to guide students towards their incorporation to the job market).
    5. Lecture from the coordinator of internships of the master on how apply and get curricular and extracurricular internships.

   Additionally, in between lectures 2, 3 and 4, additional sessions in which the experts followed the development of the challenges, were scheduled.

   Furthermore, the following activities the students had to fulfil were scheduled:

    a. Analyze which SDGs are related to the challenge, as well as possible specific indicators of whether an SDG is achieved or not.
    b. Development of a CV for a specific job offer related to the challenge (supplied by the academic experts).
    c. Development of a technical report which describes the proposed solution to the challenge.

   Every activity involved a report the students had to deliver by means of the tool "task" of Moodle.

5. Planned visits to industrial facilities. The aim of this activity was to make the students closer to the industrial reality, and to give them different points of view, which could make the process of facing the challenge easier. During the academic course 2022/2023, the following industrial facilities were visited, one specific for each of the covered challenges by the students:

1. EDAR Sur – Canal de Isabel II. The first urban wastewater treatment plant producing struvite from recovered phosphorous.
2. El Alto, Portland Valderribas cement factory. One of the largest cement factories in Spain.
3. International Paper (papermaking factory). One reference factory in sustainability in the papermaking sector using 100% recovered paper as raw material and 100% recycled water (reclaimed water from a nearby urban wastewater treatment plant).

6. Presentation of the proposed solutions to the challenges. This activity was developed in two ways:

    1. By asking each student group to prepare a power point presentation following the PechaKucha format (20 slides, 20 seconds per slide), to present their solution in front of the crowd.
    2. By asking the students to prepare a 5-min length "informative message", with the aim of transmitting the importance of the challenge to common people. Due to there are many ways of preparing this message (poster, tiktok, video, etc.), the junior experts accorded with the students three alternatives in between all the possibilities. The chosen options were poster, video or practical demonstration, each group selecting one of these.

    The presentations were carried out in a 3-hour length session in which all the groups presented both their power point as well as the diffusion message. Afterwards, the students were asked to assess which three informative messages were the best ones (assigning 3, 2 and 1 point, respectively).

7. Evaluation of the methodology. The evaluation of the methodology was carried out by means of survey distributed to the students, to assess all the aspects of the project (lecture sessions, assigned task, time-schedule, time- effort…). The aspects to assess in the survey (from 1 to 5 being 1 poor and 5 very good) were:

    1. Lectures of the industrial experts.
    2. Lecture of "Oficina de prácticas y empleo" member.
    3. Lecture of the coordinator of internships for the master.
    4. Mentoring sessions.
    5. The activity of preparing a CV.
    6. The technical visits to industrial facilities.
    7. The challenges presentation session.
    8. The interest of the proposed challenges.
    9. The necessary effort to fulfill the challenge.
    10. The achieved learning degree during the process of facing the challenge.
    11. The implication of the academic mentors.
    12. The implication of the junior mentors.
    13. The utility of CBL methodology.
    14. The whole process of facing the challenge.
    15. The whole development of the theoretical part of "Internships in companies and research centers".

3. Results

The impact of the Project was evaluated by means of different indicators. As previously said, at the beginning each group was asked to find a name for themselves. Figure 1 displays the different names the students adopted and, being the numbers inside the pie chart the votes each name received. The names in the chart are grouped according to the challenge. As it can be observed, the most voted name was CRAFT maybe due to it was an acronym intimately related to the word kraft (one of the most popular paper grades). The purpose of this exercise, along with giving them the metal pins, was to engage the students towards the resolution of the challenge.

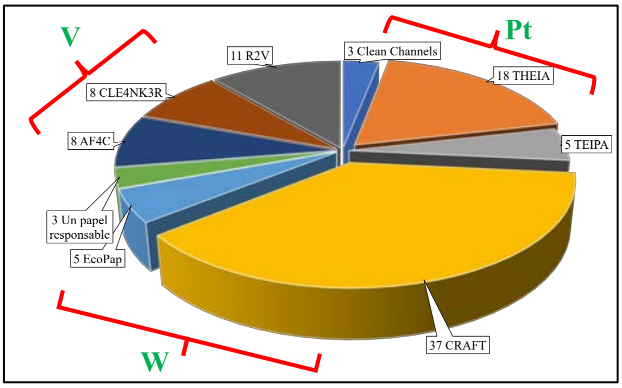

Figure 1. Best name voting results.

The second indicator we employed was the technical report the students had to deliver at the end of the process. The students were asked to deliver a 20-page report with the following structure: introduction, current state of the art, proposed alternatives for improvement to solve the challenge, final remarks. Overall, all the reports were well written, however, the main difference in between groups, lied in the fact that some groups were unable of providing a solution to the challenge, but only described some possible alternatives or approaches. In future editions of the project, this negative aspect maybe could be overcome by giving students a specific session concerning CBL. Another employed indicator was the presentation session. Although all the talks were well-prepared, we could find the same differences in between groups, already commented in the previous paragraph. Concerning the informative message, 4 groups chose a poster, 2 groups chose a video, and 3 groups chose a practical demonstration. After the presentation session, the students voted which informative messages had been the best three ones. The results indicate that the best rated messages were the two videos.

Finally, Figure 2 shows the results of the questionnaire the students answered after the theoretical session. Table 1 summarizes the statistical analysis. As it can be observed in all questions the mode is at least 3 and, except in the case of the 5th and 16th questions, the mean values are always greater than 3. Additionally, the most repeated value for the mode is 4. On the other hand, the best assessed activity was the visiting to industrial facilities. Regarding the two questions with lower values, mentioning that question 5 is related to the preparation of a specific CV and that the reason of the low marks could be maybe attributed to the fact that most of the students had not previously faced this task and found it difficult. From this analysis it can be concluded that, among the scheduled sessions, could be interesting to include one talk concerning this issue, which can be given by experts from the "Oficina de Prácticas y Empleo". On the other hand, question 16 is related to the overall perception of the subject. In this case, the low values could be attributed to the fact that the students were assessing the theoretical part of the subject as a whole, and this includes activities, such as the first session, which are not directly related to the project but were a heritage from the previous methodology used in the theoretical block of the course. It is also important to remark that the activity best assessed by the students were the visits to industrial facilities. This is a confirmation that most of them had not previously visited any industrial plant. This is indicative that more efforts should be carried out in this area, not only in the master, but also in the previous academic level, in the Chemical Engineering BSc. Finally, it is also important to point out that, although the students perceive the activity is interesting, they also perceive that the effort they need to complete this theoretical part is also important (the mode of question 10 is 4 while the mode of question 9 is 3).

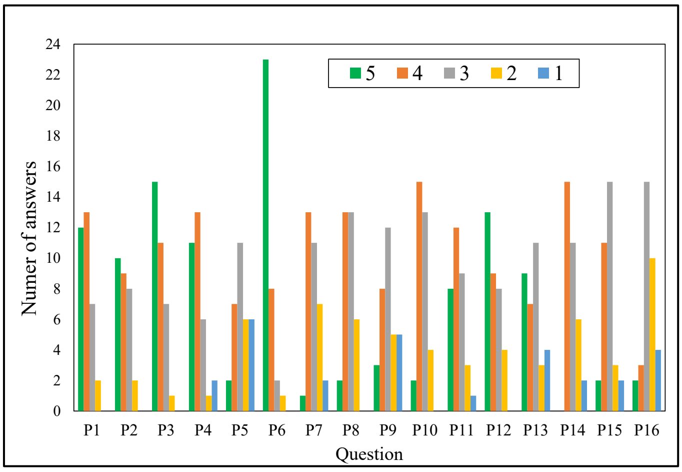

Figure 2. Results of the students' questionnaires.

Table 1. Statistical analysis of the students' questionnaires.

Question	Mean	Mode	Median
P1	4.0	4	4
P2	3.9	5	4
P3	4.2	5	4
P4	3.9	4	4
P5	2.8	3	3
P6	4.6	5	5
P7	3.1	4	3
P8	3.3	4	3
P9	3.0	3	3
P10	3.4	4	4
P11	3.7	4	4
P12	3.9	5	4
P13	3.4	3	3
P14	3.1	4	3
P15	3.2	3	3
P16	2.7	3	3

4. Conclusions

This paper describes the employed methodology based on a CBL approach that have been proposed as innovation and improvement of teaching quality project and that has been implemented in the theoretical part of "Internships in companies or research centers" course. After having finished the theoretical part of the subject employing the proposed methodology, the following conclusions can be derived:

- The activity has been perceived as interesting by the students.
- They also point out that it is necessary a much effort to fulfill the challenges.
- The activity of elaborating a CV must be improved so that the students perceive it more useful.
- The activity the students liked the most was the visiting to industrial facilities, maybe due to it was the first time they visited industrial plants.

However, the main derived conclusion is that, although the methodology proposed has been implemented in a specific subject, the way it has been designed allows its extrapolation to any other subject in which it is possible to define a challenge.

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