11th International Conference on Higher Education Advances (HEAd'25)
Universitat Politècnica de València, València, 2025
DOI: https://doi.org/10.4995/HEAd25.2025.20071

Integration of Various Active Methodologies in the Training of Industrial Engineers in Master's Degree: Results and Reflections

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How to cite: Acha Peña, E.; Viar, N. (2025). Integration of Various Active Methodologies in the Training of Industrial Engineers in Master's Degree: Results and Reflections. In: 11th International Conference on Higher Education Advances (HEAd'25). Valencia, 17-20 June 2025. https://doi.org/10.4995/HEAd25.2025.20071

Abstract
In the industrial engineering education field, the implementation of active methodologies is a key strategy to improve student learning and participation. This manuscript presents an educational experience developed in a second-year specialisation course in a master's degree in industrial engineering, where different active methodologies have been used to promote deeper and more meaningful learning. During the development of the subject, methods such as the case method, debate, presentations by students, visits to companies, attendance of experts in the classroom and the simulation of participation in a congress have been used. These methodologies have not only allowed students to apply theoretical knowledge in practical contexts, but have also promoted essential skills such as critical thinking, effective communication and teamwork.

Keywords: *Industrial Engineering; Flipped Learning; Case method; Debate; Experts; visits to industries*

1. Introduction

Industrial engineering education has undergone a significant transformation with the incorporation of active learning methodologies. These methodologies seek to involve students more directly and participatively in their learning process. Unlike traditional approaches, where the educator is the main transmitter of knowledge, active methodologies promote student-centred learning, where the student becomes the protagonist of his or her own training.

The use of active methodologies in higher education has been associated with multiple benefits, including the development of critical skills such as analytical thinking, problem solving, effective communication and teamwork (Freeman et al., 2014; Prince, 2004). These methodologies also foster greater knowledge retention and better application of theoretical concepts in practical contexts (Michael, 2006).

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Editorial Universitat Politècnica de València

Among the most commonly used active methodologies are the case method, which allows students to analyse and resolve real or simulated situations; debate, which stimulates critical thinking and argumentation; and student presentations, which develop communication skills and information synthesis (Hernández-de-Menéndez et al., 2019). In addition, visits to companies and the attendance of experts in the classroom provide a direct connection with the professional world, enriching the educational experience with up-to-date perspectives and knowledge. The use of active methodologies also allows students to develop and work on transversal competences and on Sustainable Development Goals (SDG).

This manuscript aims to explore the implementation of various active methodologies in a second-year specialisation course in a master's degree in industrial engineering. The aim is for students to apply to real industrial processes what they have learned in previous undergraduate and master's degree subjects, integrating active methodologies, cooperative work, flipped learning, the case method, role-playing, oral presentations and the inclusion of the Sustainable Development Goals in an in-depth manner, encouraging a critical spirit.

2. Methodology

This work was carried out in a subject of the second year of the master's degree in Industrial Engineering, Process Integration and Industrial Chemical Plants, in the speciality of Chemical and Process Engineering. It is a 4.5 ECTS course taught over 15 weeks, in which 10 people were enrolled in the 2024-2025 academic year. Eight of the students were students from the School of Engineering, who had linked the Bachelor's Degree in Industrial Engineering with the Master's Degree. These students had already worked with flipped learning methodology in another subject from the same area (Design of Chemical Processes, (Requies et al., 2024)). The other two people were two Erasmus students from fields other than industrial engineering. The methodologies described in this paper were implemented in the first half of the course, up to week 8. During these 8 weeks we worked with 4 topics: 1-Introduction, 2-Sulphur industries, 3-Sodium and chlorine industries, and 4-Glass industries. The evaluation of this half of the course was divided into two parts: 60 % of the mark was assigned to group or collaborative work and 40 % to an individual minimum test of concepts carried out in class for each topic.

No official course notes were available, in some topics a presentation was used with the minimum knowledge or context of the sector, but most of the content was generated through activities by the students. For each sector studied the students had to produce a summary document of about 8 pages. The class was divided into 3 groups. Each group was in charge of producing one of the topic documents and supervising another one. The deadline for the document was one week after the completion of that unit. One week later, the minimum test of concepts was carried out in class, lasting approximately 30 minutes and consisting of 5 multiple-choice questions and 4 short questions to be developed.

In each subject students worked with basic concepts that they had already acquired in previous subjects of the degree or master's degree and were complemented with information available in official European sectoral documents, BREFs, best available techniques documents, environmental impact assessment, occupational health and safety, etc. In some cases this content was also complemented with a talk in the classroom by an expert, and visits to companies related to the sectors studied in class. Specifically, visits were made to a sulphuric acid production company, a flat glass production company, a steelworks, and a refinery. During the visits to the companies, the students had to ask at least one question to the person in charge who showed us around the facilities. This question was prepared before going on the visit and could be related to the theory seen in class or to doubts that had arisen, and the educator reviewed them before the day of the visit.

Through the different methodologies used, general transversal competences described in the Catalogue of Transversal Competences of the UPV/EHU (UPV/EHU, n.d.) were worked on: Social commitment, critical thinking, and communication and multilingualism. In addition, the Sustainable Development Goals were integrated into the discussions (UPV/EHU, 2019). Discussions were focused on SDG 7 (Affordable and clean energy), SDG 9 (Industry, innovation and infrastructure), SDG 12 (Responsible production and consumption), and SDG 13 (Climate action).

Some of the expected improvements in the teaching-learning process of students in this part of the subject were: I) Improve autonomous development through the use of inverted classroom methodology. II) Develop group work: peer learning, strengthening critical thinking. III) Critical analysis of the integration of the SDGs in processes that may affect the environment in terms of the design and implementation of chemical processes.

3. Results and Discussions

3.1. Opening Session

The course started with an introductory lecture, through an activity focused on the presentation of the subject. The objective was to introduce students to the key issues of the subject and encourage reflection on the importance of various aspects in the chemical industry, such as the environment, safety, economics, occupational hazards and SEVESO accidents. The duration of the activity was approximately 1 hour.

The structure of the activity was as follows:

- Introduction (10 minutes): Introduce yourself and give a brief introduction about the subject. Explain that today's activity will help them to identify the key issues that will be addressed during the course.

- Group formation (5 minutes): Divide students into groups of 2 or 3. Assign each group one topic: environment, safety, economics, occupational hazards, SEVESO accidents.

- Research and Discussion (20 minutes): Each group should discuss and write down the key points related to their assigned topic.

- Group presentation (15 minutes): Each group presents its findings to the rest of the class. Encourage discussion and exchange ideas between the groups.

- Conclusion (10 minutes): Summarise the key points discussed during the activity. Explain how these aspects will be integrated of having a holistic view of the chemical industry.

3.2. Sulphur Industry (flipped learning, expert panel)

This topic was already well known to almost all the students in the class. For 10 minutes the students compile in groups of 2 or 3 what they remembered about this industry. Each group wrote on the blackboard their compilation and then we made a comparison between what was written by each group, correct or clarify what was necessary. The educator checked that all the important content to remember about this industry was there, together with the basic concepts. Then, in the same groups, they had to analyse how the conversion of that process could be improved (15 min), we put it together and ensure minimum concepts (heat exchangers, catalysts, energy production, etc.).

The second session started with a short summary of the sulphuric acid production process, and in groups they had to identify the main environmental problems in this process, where and how to solve them. After 20 minutes of internal discussion, the groups had to share their ideas in about 10 minutes. Then for 20 minutes they had to analyse in groups more general aspects of the process (which Sustainable Development Goals interact, control problems in the process, which points are most critical, handling of substances involved, hazardousness, risk to health and the environment, occupational safety, et.). Concluding this part with another general discussion of about 10 minutes. The session ended with a review by the educator with a closing presentation. This presentation was given to the students as support material.

In the third session, the flipped learning dynamic was used, the students had searched before this session for European BREFFS documents related to sulphur industries, and Environmental Impact Assessments of companies related to the use, extraction or production of sulphur derivatives. The first 10 minutes were used to review what the students had found. Students were assigned what aspect to focus on. They worked individually for this during 15 minutes, and they will present it in the next session for 5 minutes. They had to hand in a 1-sided document on what they are going to present, which the educator reviewed and confirmed that the point of view seemed appropriate. They were told that the presentation will be evaluated on: technical content, synthesis capacity, adjustment to the maximum time limit, visual support of the presentation, bibliographic sources used and communication skills. In this same session, an Expert Panel session was held, where a person who has been working for 15 years on industrial safety issues and SEVESO legislation on accidents with chemical industries in the Basque Country gave a talk. In this presentation, the expert related the cycle of products generated from raw materials produced in the chemical industry of the Basque Country.

In the fourth session of the Sulphur Industry subject each student made the presentation of the subject that corresponded to him/her. This presentation was assessed and marked. The rest of the students had to take notes on the lectures, correct or add to them as they see fit. Each student must also ask at least one question in one of the presentations. The appropriateness and interest of the question asked was also assessed.

3.3. Sodium and chlorine industries (role playing methodology, puzzle)

This topic was new for all students, the main methodology used was role-playing. In the first session of this topic, it was explained to them how we were going to work on this topic, and the general outline of the sessions and tasks. The educator then gave an introduction to sodium and chlorine industry. In the learning methodology, the students were going to be part of two companies from the sector. In each company there will be different types of engineers. Each student was assigned a company and a role. At the end of this first session, the people from the same company got together and had to construct a basic process diagram in about 30 minutes. Finally, they draw the two flow diagrams on the blackboard and explain them briefly.

In the second session all the roles of the same company met again and had to analyse the types of roles they have. After this analysis they generated a list with the main ideas of their role. Then the people who had the same role got together and reviewed their notes and complemented each other. Each role wrote a list on the board with the main ideas and explained it to the rest of the class. I presented the case they were going to deal with in each company at the congress, where each student will focus on applying their role.

During the third session, the final activity of this topic was explained to the students in detail. Each company was going to attend an industrial congress. In order to attend this congress, they had to hand in an abstract beforehand, as it is done in real congresses. During the third session the students worked on preparing the documentation and the presentation. They could go checking with the educator any doubt they had.

For the fourth session, a poster of the congress was prepared, which was placed at the entrance of the classroom door before the arrival of the students. An identifying sign with their name was prepared for them, just as it is done in real congresses. The students were also integrated into the activity and came dressed for the occasion. Each company had 15 minutes of presentation plus 10 minutes for questions from the audience (the rest of the students). Each student had to ask a question during the presentation of the other group. The presentation was assessed and marked similarly to the presentation of the previous unit.

3.4. Glass industries (judgement methodology)

In this last topic, the final discussion of what was learnt about glass companies took place through a judgement activity. Each student had to prepare a different topic in the context of the glass industries. During the rest of the first session dedicated to the glass industry, and during the second session, the students were able to work on their specific topic, asking the educator for any doubts about approach or content they might have.

In the third and final session, the judgement activity took place. The students were divided into two groups, being the educator the judge. The trial was set up as a lawsuit between a traditional glass company opposing the construction of a new company that manufactures biodegradable glass, due to economic, labour, safety, environmental and process arguments. One group was the traditional company and the other group represented the biodegradable glass company. The students were told what the timing of the trial would be, so that they could structure their discussion and defence of their arguments. For 15 minutes each group prepared their speech, focusing on the most important points, researching references, and preparing possible witnesses or technical experts (who were represented by students from that group). After this initial preparation time, the tables and chairs were arranged in a trial format, with the educator as the judge. During the first 5 minutes, the defence presented its main arguments, followed by 5 minutes of explanation by the prosecution. They then had 5 minutes to reorganise their arguments, and look for weaknesses on the other side, think about whether they were going to question witnesses or technical experts. The defence then had 5 minutes and the prosecution another 5 minutes. Finally, the educator gave a general verdict of 5 minutes, emphasizing the importance to take into account different aspects before evaluating a new technological approach.

The evaluation of this group activity took into account the following aspects: 1- Presentation of the case. 2- Use of evidence. 3- Interrogations carried out. 4- Role-playing. 5- Final argumentation. The discussions done during the judgment had to be based on technical and scientific evidence, well argued and referenced.

3.5. Discussions

The implementation of all the activities described in the Methodology section required a great deal of effort on the part of the educator, although the final result was very satisfactory. The key to success was that the workload was not excessive for the students, and that this work was rewarded with a high percentage in the assessment. Almost half of the mark was also kept as individual assessment as a way of being able to differentiate what each student had learnt, which was important to maintain the motivation of all the students to learn and understand, and to avoid students being dragged towards a pass mark because of the work of others.

The size of the group made the work manageable for the educator and the activities very interactive and didactic. This was helped by the fact that the students involved were enthusiastic and participative at all times. Moreover, as this was a second year master's group, the students had a high level of basic knowledge that allowed them to understand and discuss the industrial processes worked on with a certain ease, reaching high levels of understanding and enabling them to reach the process discussion phase, implement innovations, improvements, challenges, interconnect ideas, implement the vision of different roles within the industry, etc.

The visits to the companies were also very motivating for students and educators. The students saw the processes we had been working with in class on a real scale, they were able to talk to the engineers in charge of the processes, ask them questions, operation parameters, curiosities, etc. In addition, it served as a first letter of introduction and behavioural test for a possible interview that they will have to face in the near future, and they could also ask the companies what profiles they need, how to get to work there, what types of work they do, etc. For the educator, these visits were also very interesting from an industrial point of view, but above all it was a very satisfying experience to observe how the students performed in a real environment, how well their questions were received, the good feeling they caused during the visits. All this was a pleasant reward for the great effort made in the preparation of the subject,

The knowledge acquired by the students coming from the industrial engineering degree was high, and this was demonstrated both in the individual tests (with grades of B or A) and in the group or oral tests (with grades of A in most cases). In the case of students from different areas, the two Erasmus students, the level of understanding of the processes achieved was much lower, but sufficient, with a high level of involvement in the subject, in the content and in their classmates, so they also passed the subject.

At the end of the course, students were asked questions to find out their degree of satisfaction with the course and the methodologies used. Several questions were asked regarding the employed methodology. The students indicated that the employed methodology was adequate and helped them understanding the industrial processes, with a negative point of being the time limited. In the questionnaire, 75 % of the students indicate that their ability to interrelate technical concepts with social, environmental and economic aspects after the section of the course tough with active methodologies was high. Those students also think that these methodologies improved their ability to work in a team and collaborate with their colleagues.

4. Conclusions

The educational experience presented in this work was very satisfactory for both the students and the educator involved. As there were only 10 students and it was a specialised subject in the second year of the Master's degree, it was an ideal context to carry out the subject in a more active way with the students. This helped them to visualise the chemical industry from points of view not previously covered in other undergraduate and Master's degree subjects (safety, job roles, etc.) as well as implementing all the knowledge they had already acquired in the previous 5 years of study.

Using different learning dynamics allowed students to acquire the desired knowledge of the various industries in terms of content. In addition, students achieved a deeper understanding of technical aspects by working on various aspects associated with the process industries, such as the different roles that exist in companies, sustainability through the Sustainable Development Goals, occupational safety, chemical risks, environmental impacts, etc. The involvement achieved by the students also allowed them to work on critical analysis, an in-depth analysis of the material, oral expression and written expression.

This paper has highlighted the benefits and challenges of implementing active methodologies in the training of industrial engineers. Through this application example, it is hoped to contribute to the debate on best practices in engineering education and to offer recommendations for future educational programs.

References

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Hernández-de-Menéndez, M., Vallejo Guevara, A., Tudón Martínez, J. C., Hernández Alcántara, D., & Morales-Menendez, R. (2019). Active learning in engineering education. A review of fundamentals, best practices and experiences. *International Journal on Interactive Design and Manufacturing*, *13*(3), 909–922. https://doi.org/10.1007/s12008-019-00557-8

Michael, J. (2006). Where's the evidence that active learning works? *American Journal of Physiology - Advances in Physiology Education*, *30*(4), 159–167. https://doi.org/10.1152/advan.00053.2006

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Requies, J., Laura Barrio, V., Acha, E., Agirre, I., Viar, N., & Gandarias, I. (2024). Integration of sustainable development goals in the field of process engineering through active learning methodologies. *Education for Chemical Engineers*, *49*, 26–34. https://doi.org/https://doi.org/10.1016/j.ece.2024.08.001

UPV/EHU, U. of the B. C. (n.d.). *Catalogue of Transversal Competences of the UPV/EHU*. http://www.upv.es/visor/media/5db62400-7400-11e8-893e-4310959e86f3/c

UPV/EHU, U. of the B. C. (2019). *EHUagenda 2030 for Sustainable Development*.