

IMPLEMENTING RESEARCH-BASED LEARNING TO ENHANCE COMPETENCIES IN INDUSTRIAL BIOTECHNOLOGY EDUCATION FOR CHEMICAL ENGINEERING STUDENTS

Irene Gómez-Cruz¹, María del Mar Contreras¹, Minerva C. García-Vargas²,
Cristóbal Cara¹, & Juan Miguel Romero-García^{1,3*}

¹Department of Chemical, Environmental and Materials Engineering,
and Institute of Biorefineries Research (I3B), Universidad de Jaén, Campus Las Lagunillas (Spain)

²Department of Industrial Engineering, Technological Institute of Zitácuaro/
National Technological Institute of Mexico, Zitácuaro (Mexico)

³Department of Chemical Engineering, Universidad de Murcia, C. Campus Universitario (Spain)

Abstract

This project introduces a Research-Based Learning (RBL) approach in the Industrial Biotechnology course at the University of Jaén to enhance practical and research skills in Chemical Engineering students. Through hands-on, team-based projects using advanced lab equipment, students engage in authentic biotechnological challenges, fostering critical thinking, collaboration, and autonomy. Preliminary results show increased motivation, improved academic outcomes, and strengthened professional competencies. The model is designed to be scalable and transferable to other technical courses, with dissemination planned via publications and open educational resources.

Keywords: *Research-based learning, industrial biotechnology, engineering education, research competencies, active learning.*

1. Introduction

Nowadays, industrial biotechnology is a strategic pillar for sustainable development, with applications in the fields of agriculture, food, medicine, pharmacy, and bioremediation (Ozyigit et al., 2023). In this context, training chemical engineers with experimental, analytical, and research skills is essential.

Research-Based Learning (RBL) has established itself as an effective active methodology for promoting deep learning, critical thinking, and the development of scientific and professional skills in higher education (Bui & Khuu, 2020; Jungmann, 2019). In the field of biotechnology, previous experiences have shown that RBL improves conceptual understanding, attitudes toward science, and academic performance, especially in laboratory settings (Ramli & Bohori, 2025).

In this context, this study aims to integrate teaching and research in engineering education, promoting more applied, authentic teaching oriented toward solving real problems.

2. Design

The study was conducted using a method that combines observation and experimentation, using both quantitative and qualitative data. It was carried out in the Industrial Biotechnology course, within the Chemical Engineering degree program at the Higher Polytechnic School of Linares (University of Jaén). The activity was organized through research projects applied to real problems in the field of industrial biotechnology, following models previously used in engineering and biotechnology.

The teaching method combines theoretical classes with practical activities where students conduct research with the help of the teacher, in order to provide them with guidance on how to learn efficiently and avoid the difficulties that can arise from unguided learning (Jungmann, 2019; Wu et al., 2021).

*jrgarcia@ujaen.es

3. Objectives

The overall objective of the study is to evaluate the impact of RBL on the development of technical, research, and cross-disciplinary skills in chemical engineering students.

The specific objectives are:

- To improve the acquisition of experimental and analytical skills in industrial bioprocesses.
- Encourage the formulation of scientific questions, hypotheses, and experimental design.
- Increase student motivation, commitment, and autonomy.
- Develop cross-cutting skills such as teamwork, project management, and scientific communication.
- Evaluate student perception and the effectiveness of the model using structured assessment tools.

4. Methods

The implementation of the RBL takes place in laboratories equipped with fermenters, spectrophotometers, chromatographic systems, and other technologies commonly used in industrial biotechnology. Students work in teams to define problems, formulate hypotheses, design and execute experiments, analyze data, and communicate results through technical reports and oral presentations.

The methodological approach is based on guided research models validated in science and engineering education, which combine student autonomy with teacher supervision to ensure the quality of the training process (Wu et al., 2021).

The evaluation of the experience includes:

- Satisfaction and learning perception surveys.
- Analysis of academic performance.
- SWOT analysis of the implementation.
- Qualitative evaluation of reports and presentations to assess the development of research and communication skills.

5. Discussion

Preliminary results show that RBL improves motivation, active participation, and understanding of industrial bioprocesses. However, the analysis identified certain challenges that require strategic consideration (Figure 1).

Figure 1. SWOT Analysis of the Implementation of RBL in Industrial Biotechnology.

S <u>Strengths</u> - Integration of teaching and research - Improved student motivation - Development of technical, research, and transversal skills	W <u>Weaknesses</u> - High teaching workload - Dependence on resources - Specialized infrastructures
O <u>Opportunities</u> - Transferability to other courses - Connection with the industrial sector - International trends in active learning	T <u>Threats</u> - Budget limitations - Resistance to methodological change - Academic workload overload

This SWOT analysis offers a strategic vision to maximize the strengths and opportunities of the ABI in Industrial Biotechnology, while addressing identified weaknesses and mitigating potential threats that could affect the continuity of the initiative.

6. Conclusions

The implementation of RBL in the Industrial Biotechnology course has proven to be an effective pedagogical strategy for strengthening technical, research, and cross-disciplinary skills in chemical engineering students. The model promotes a more applied education, aligned with the demands of the biotechnology sector and international standards in engineering education.

In addition, the proposed approach is presented as a scalable model that can be transferred to other experimental subjects and technical degrees. The dissemination of the results through scientific publications, conferences, and open educational resources will contribute to promoting the adoption of RBL in engineering education and strengthening the integration between teaching and research.

Acknowledgments

Irene Gómez-Cruz expresses her gratitude to the grant DGP_POST_2024_00733 from the Andalusian Government. Juan Miguel Romero-García would like to acknowledge Universidad de Jaén (action 7. Postdoctoral grant). The authors wish to express their sincere gratitude for the support received within the framework of the Teaching Innovation Project funded by the 2025 call of the Teaching Innovation and Improvement Plan of the University of Jaén (PID-UJA 2025–2029), which enabled the development of the academic activities carried out, including the preparation of this article. The authors also acknowledge the valuable institutional support of the Tecnológico Nacional de México / Instituto Tecnológico de Zitácuaro, whose academic and administrative collaboration significantly contributed to the strengthening of this work.

~

References

- Bui, L. T. N., & Khuu, V. T. (2020). Inquiry-based learning: an effective approach to teaching science aiming to develop students' competencies. *Journal of Contemporary Educational Policies and Practices*, 4(1), 61–68. <https://doi.org/10.52296/vje.2020.9>
- Jungmann, T. (2019). Inquiry-Based Learning in the Engineering Sciences. In H. A. Mieg (Ed.), *Inquiry-Based Learning – Undergraduate Research* (pp. 205-215). Springer: Cham. https://doi.org/10.1007/978-3-030-14223-0_19
- Ozyigit, I. I., Dogan I., Hocaoglu-Ozyigit, A., Yalcin, B., Erdogan, A., Yalcin, I. E., Cabi, E., & Kaya Y. (2023). Production of secondary metabolites using tissue culture-based biotechnological applications. *Frontiers in Plant Science*, 14. <https://doi.org/10.3389/fpls.2023.1132555>
- Ramli, M., & Bohori, R. (2025). Guided Inquiry-Based Learning in Biotechnology: Effects on Students' Scientific Attitudes and Academic Achievement. *Journal of Science and Mathematics Education*, 1(3), 75–81. <https://doi.org/10.70716/josme.v1i3.241>
- Wu, X. B., Sandoval, C., Knight, S., Jaime X., Mcik M., & Schielack, J. F. (2021). Web-based authentic inquiry experiences in large introductory classes consistently associated with significant learning gains for all students. *International Journal of STEM Education*, 8(31). <https://doi.org/10.1186/s40594-021-00290-3>