

APPLICATION OF RESEARCH-BASED LEARNING TO UNDERSTANDING THE COLORS OF BIOTECHNOLOGY

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Abstract

The Chemical Engineer is a fundamental actor in the development of Biotechnology, applying their knowledge to design and scale biotechnology processes that allow for the transformation of biological raw materials into high-value-added products, such as pharmaceuticals, chemicals, and advanced fuels. However, the traditional Chemical Engineering curriculum often presents limitations in the transversal knowledge of biological aspects. This fact creates a fragmented perspective for future professionals that restricts the acquisition of deep biotechnological competencies. To overcome this limitation, the innovation project PID2025_80 aims to foster in Industrial Chemical Engineering students a holistic understanding of biotechnological processes and key skills that enable them to face the challenges of a constantly evolving sector through the Research-Based Learning (RBL) methodology. The Project has been structured as follows: 1. Course design and organization. 2. Integration of the RBL in the classroom. 3. Development of cross-curricular teaching materials. 4. Evaluation of the impact of the RBL methodology. 5. Dissemination and transfer of results. The application of RBL enabled students to engage with real-world industrial biotechnology research through a dual approach. First, the professors guided theoretical and practical laboratory sessions focused on biochemical conversion routes for biofuel production, culminating in the creation of infographics. Second, the methodology promoted student autonomy by encouraging them to select and investigate a contemporary biotechnology challenge using a structured research framework and present it. Overall, RBL can help students to strengthen technical and research skills, cognitive and communication abilities, teamworking, and leadership.

Keywords: *Biotechnology, chemical engineering, research-based learning.*

1. Introduction

The intersection of biology and engineering has catalyzed a new era of industrial production, where living organisms and biological systems are harnessed to solve some of the world's most pressing challenges. Within this context, the Chemical Engineer is uniquely positioned to bridge the gap between basic molecular science and the macroscopic scale, providing real-world applications in medicine, energy, and industrial-scale manufacturing (National Academies of Sciences, Engineering, and Medicine, 2022). By applying core principles of thermodynamics, transport phenomena, and reaction kinetics, these professionals can transform feedstocks into life-saving pharmaceuticals, sustainable chemicals, new materials, and next-generation biofuels, which is crucial to satisfy the needs of a growing bioeconomy.

Despite their critical role, traditional engineering training disconnects with the multidisciplinary demands of modern biotechnology, as the standard Chemical Engineering curriculum often prioritizes inert chemical systems. This lack of transversal knowledge regarding biological nuances leaves future engineers with a fragmented perspective. To promote the learning experience of biotechnology content, student-centered, active teaching methodologies such as research-based learning (RBL) can be applied to transform passive observation into hands-on discovery, where the students act as firsthand producers of knowledge. This type of methodology can promote more effective learning, along with gaining transversal skills such as autonomous learning, critical thinking, and others (Pourhejazy et al., 2024). RBL employs

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teacher-guided instruction to connect learning to research in the classroom, utilizing activities such as analyzing, synthesizing, and evaluating to help students assimilate and apply the knowledge (Susiani et al., 2018). In this scenario, this work aimed to apply RBL and evaluate its impact on Industrial Chemical Engineering students studying the subject Industrial Biotechnology.

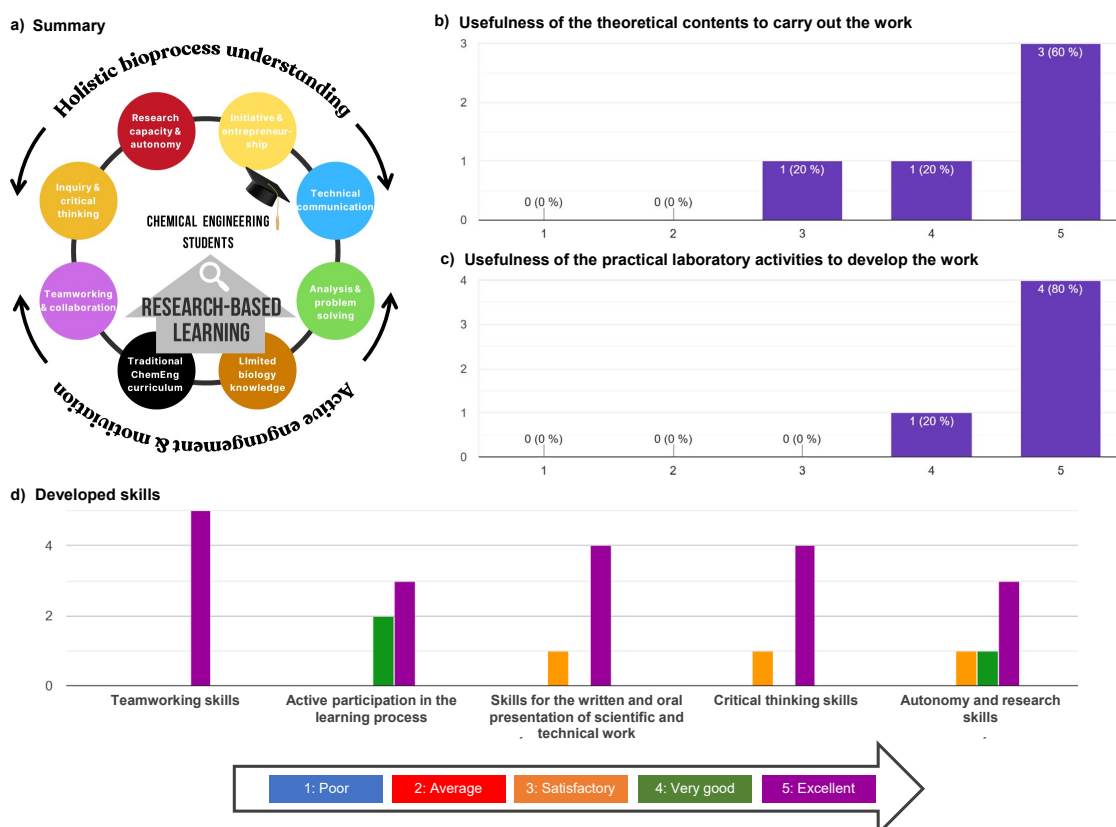
2. Design

RBL was proposed to foster a holistic understanding of biotechnological processes for Industrial Chemical Engineering students at the University of Jaén (UJA) in the present academic year. It was applied within the subject Industrial Biotechnology, which is included in the third year of the academic program. The number of students was eleven, but only nine of them completed the experience by RBL. The Project was structured as follows: 1. Course design and organization. 2. Integration of the RBL in the classroom. 3. Development of cross-curricular teaching materials. 4. Evaluation of the impact of the RBL methodology. 5. Dissemination and transfer of results.

Concerning Points 1 and 2, the course was split into lectures and practical sessions. The theoretical sessions in the classroom provided general knowledge of biology aspects related to industrial microorganisms, enzymology, microbial growth, and bioreactor concepts. The practical sessions translate theoretical concepts into practice through guided teamwork activities (teams of two/three students) using industrial microorganisms and enzymes in a microbiology lab. The students also had a session to introduce scientific databases (Google Scholar and Scopus) to find scientific works on bioethanol production, which enables the students to connect the practical sessions with the collected information at the end of the subject. Moreover, the methodology was designed to promote student autonomy by encouraging them to investigate a contemporary biotechnology challenge using a structured research framework as a final activity. After finishing the practical and theoretical units, students presented and discussed their findings in the classroom.

To achieve Point 3, the project team prepared a custom video about RBL and practice notebooks, which were available on the UJA virtual teaching/collaboration platform Platea. Moreover, to reinforce real-world connections, a technical presentation featuring industrial equipment was developed that students encountered during a technical visit to a pilot plant on functional food development. Finally, to preliminarily evaluate the impact of the RBL framework (Point 4), a 5-point Likert questionnaire was used to collect students' opinions on learning and skills, which are illustrated in Figure 1a.

Figure 1. Results of the research-based learning approach evaluated using 5-point Likert questionnaires.



3. Results and discussion

The methodology was designed to encourage active student participation through preparing works focused on innovative biotechnology processes, presenting (creating visual content), and discussing in class. According to the research topic, their works were classified into the following biotechnology colors: white, yellow, blue, grey, and red (Table 1).

Table 1. Results of the research-based learning approach evaluated using 5-point Likert questionnaires.

Topic	Color	Topic	Color
Lactic acid production	White	Bioremediation of heavy metals	Grey
Hyaluronic acid production	White	Plastic-degrading microorganisms	Grey
Biotechnology milk	Yellow	Bioremediation of waters	Grey
Beer production	Yellow	Actinobacteria drugs	Red
Microalgae protein purification	Yellow/blue		

The data gathered indicated a highly positive reception of this pedagogical approach, concerning the support of lectures and practical lab sessions to help students apply biotechnological principles to their final assignments (Figure 1b and 1c, respectively). The approach fostered “Active participation in the learning process”, falling into the “Very good” and “Excellent” categories (Figure 1d). Overall, positive students’ perception of skill development was also found for the rest of the skills, with most ratings falling into the “Very good” and “Excellent” categories. However, while still positive, “Autonomy and research skills” shows the most variation, including some “Satisfactory” ratings, suggesting students may feel they need more support in independent work to be more confident. Students demonstrated teamwork during their lab assignments, and the resulting data showed a predominant perception of “Excellent” (Figure 1d). These preliminary results align with the perspective of authors who advocate for an engineering curriculum that balances transversal competencies and technical skills to fit with professional environments (Ferreira et al., 2024). In this sense, student-centered, active teaching methodologies, as RBL, are applied to foster deep engagement and professional readiness, ultimately driving higher rates of academic success (Fortelius et al., 2015).

4. Conclusions

These results underscore the potential of RBL to strengthen both learning outcomes and transversal/professional skills, especially in teamworking, critical thinking, active participation, and technical communication. A limitation of this study is the small sample size, as the number of students was small and the participation in the voluntary questionnaire was partial. To strengthen the statistical power of these preliminary findings, it is expected to reproduce this methodology across several academic years to ensure a larger dataset.

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