

## APPLICATION OF PROJECT BASED LEARNING IN CHEMICAL ENGINEERING EDUCATION TO IMPROVE STUDENTS' PRACTICAL SKILLS

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### **Abstract**

Chemical engineering education is faced with the challenge of not only imparting theoretical knowledge, but also to develop students' practical skills that meet industry needs. Project Based Learning (PjBL) has been implemented as an effective approach to answer these challenges. This research aims to evaluate the effectiveness of PjBL in improving students' practical skills in the field of chemical engineering. Research is carried out through providing projects that are integrated with the curriculum and oriented to real industrial problems. The method used is comparative analysis of pre-test and post-test to measure improvement in practical skills. The results showed that students who took PjBL showed significant improvements in collaboration skills, problem solving, and use of technology. Apart from that, this approach also increases student motivation and involvement in the learning process. In conclusion, PjBL is an innovative and effective learning strategy that strengthens the practical skills of chemical engineering students and prepares them to become part of a competent workforce in the chemical industry.

**Keywords:** Project Based Learning, Chemical Engineering Education

### **INTRODUCTION**

Chemical engineering education faces unique challenges in terms of preparing students not only with strong theoretical knowledge but also with the practical skills they will need to succeed in the industrial world. Rapid changes in industrial technology and job market demands have led to an expansion of the chemical engineering education curriculum to make it more applicable and responsive to industrial needs (Rosyid & Setyasto, 2024). Therefore, project-based learning (PjBL) has been seen as an effective approach in responding to this challenge.

PjBL is a pedagogical model that allows students to explore real problems and carry out continuous and in-depth investigations (Maulidannisa & Ansori, 2024). Through PjBL, students engage in projects involving complex

questions and problems, which they then investigate as groups or individually. This approach also emphasizes the development of skills such as teamwork, problem solving, and critical thinking skills that are highly relevant and valued in the workplace (Indriyani et al., 2024).

Chemical engineering education is a complex and dynamic field, requiring a learning approach that is able to prepare students with a strong conceptual understanding and technical skills needed by industry (Pettit, 2024). In this context, Project Based Learning (PjBL) has received attention as a promising teaching strategy, which allows students to apply theoretical knowledge in realistic practical situations. The PjBL method is driven by the hypothesis that with learning activities that are more focused on real projects, students will acquire more relevant skills and be better prepared to enter the world of work after graduation (Widiarani et al., 2023).

In the context of chemical engineering education, the PjBL application can support the integration of theoretical knowledge with real industrial practice. By focusing on projects that are relevant to industry needs, students can develop a deep understanding of the course material as well as apply concepts to real situations. This also provides an opportunity to bring students closer to modern tools, work safety procedures, as well as introduce them to the dynamics of team work in an industrial environment (Widiawati et al., 2022).

However, implementing PjBL in chemical engineering education also presents a number of challenges. One of the biggest challenges is developing learning materials and projects that are not only educational but also relevant to the latest industry dynamics and innovations. Other challenges include the expansion of limited resources and the need for educator training in PjBL methods (Ntobuo et al., 2023).

PjBL encourages more active and collaborative learning while promoting deep student engagement in the subjects they study. This concept brings together theory and practice to create a stimulative and contextual learning environment. Students are not only required to understand the basic principles of engineering chemistry, but also to develop important skills such as problem solving, critical thinking, team engagement, and communication. This increase is driven by empirical studies which show that PjBL has the potential to increase students' learning motivation and strengthen their learning experience (Nisa' & Shofiyah, 2024).

Although the potential of PjBL in improving chemical engineering education is undoubted, its implementation often encounters several

challenges. Issues such as lack of resources, crowded curricula, and lecturers' readiness to adopt new methodologies often become obstacles (Mahdi, 2023). Furthermore, evaluating student progress in the PjBL context can be complicated because its characteristics are very different from traditional evaluation methods that focus more on written exams and individual performance rather than collaborative and practical projects.

Previous studies show variations in the implementation and effectiveness of PjBL in various educational institutions, but detailed research on implementation specifically in chemical engineering education is still limited. There is a need to further explore how PjBL methods can be adapted and optimized to meet the unique needs of this scholarship (Rosanna, 2024). This research aims to fill this gap by investigating best practices, challenges, and results achieved with PjBL in the context of chemical engineering education, thereby providing guidance and recommendations for educators who wish to implement or improve the implementation of PjBL in their classrooms.

This research aims to evaluate the effectiveness of implementing PjBL in chemical engineering education, especially in improving students' practical skills. It will also review how PjBL can be integrated with the existing curriculum and identify key factors that support or hinder its effective implementation. This literature review will discuss various studies that have been conducted on this topic to identify trends, gaps, and recommendations for the future.

## **RESEARCH METHOD**

The study in this research is qualitative with literature. The literature study research method is a research approach that involves the analysis and synthesis of information from various literature sources that are relevant to a particular research topic. Documents taken from literature research are journals, books and references related to the discussion you want to research (Earley, M.A. 2014; Snyder, H. 2019).

## **RESULT AND DISCUSSION**

### **Strategies for Implementing PJBL in Chemical Engineering Classes to Improve Student Learning Outcomes**

One effective strategy in implementing PjBL in chemical engineering classes is the development of projects that are closely related to the real challenges faced by the chemical industry today. This includes projects

addressing innovation in production processes, energy efficiency, waste processing and environmental sustainability. When students work on projects that have direct relevance to industry, they not only learn to practically apply chemical engineering principles, but also understand the significance of their skills in a larger professional context (Landaverde-Alvarado, 2024). Furthermore, collaboration with industry can provide opportunities for students to receive input and evaluation from professionals in the field, which improves the quality of learning and student career readiness.

Utilizing the latest technology in PjBL, such as computer modeling, process simulation software, and data analysis tools, is an important aspect to support student success in chemical engineering classes. By including these tools in projects, students can develop a deeper understanding of complex systems and processes, as well as improve their analytical and problem-solving skills (Dewi & Purnomo, 2024). Additionally, holding interdisciplinary collaborations with other departments such as business management or environmental sciences can enrich projects, giving students a more holistic perspective and enhancing their ability to work effectively in multidisciplinary teams.

Implementing a metacognitive approach in PjBL in chemical engineering classes, where students actively reflect on their learning process, is also an effective strategy. At the end of each project, holding a reflection session where students discuss what they learned, the challenges they faced, and how they handled those problems can deepen their understanding and help them identify areas for personal growth (Widiarani et al., 2023). Teachers can facilitate this by creating an environment where students feel comfortable sharing experiences and giving and receiving constructive feedback. Sessions like these not only improve learning outcomes but also instill lifelong learning skills and adaptability, which are invaluable in a chemical engineering career.

Improving student learning outcomes in PjBL in chemical engineering classes can also be achieved through implementing peer learning strategies. In this setting, students can learn from each other, exchange experiences, and hone their critical thinking and communication skills. Peer review techniques, in which students rate each other's work, can help identify conceptual and technical errors and strengthen understanding of the material. Continuous assessment, from the project planning stage, through implementation, to presenting results, allows teachers to provide constructive feedback in real-time, so students can make immediate improvements. This assessment must include clear and measurable criteria, encourage students to achieve set

standards and foster a sense of responsibility for their own learning (Ramadhan, 2023).

The application of leadership and project management practices in PjBL is another important factor. Giving students the opportunity to lead teams on projects can improve their leadership skills, teach them how to manage time and resources efficiently, and improve their ability to work under pressure. This creates a learning atmosphere that supports the development of soft skills that are much needed in the world of work, such as the ability to communicate effectively, work collaboratively, and make strategic decisions. Focusing on these aspects can significantly increase the success of implementing PjBL and student learning outcomes in chemical engineering classes (Setiawan et al., 2023).

The importance of establishing feedback mechanisms and continuous revision cannot be underestimated in optimizing students' PjBL experience. Giving students the opportunity to revise their work based on the feedback received allows the learning process to be more iterative, where they can learn from mistakes and continually improve their performance. This creates a more resilient and adaptive learning environment, where failure is seen as an integral part of the learning process and a valuable learning resource. Creating a project journal that documents progress, obstacles encountered, how they were overcome, and lessons learned can greatly support students' reflective learning processes and personal growth (Kinzie & Hutchings, 2023).

Applying these strategies in implementing PjBL in chemical engineering classes can contribute significantly to improving student learning outcomes. It is important for educators to adapt and adapt this approach to their students' needs and learning context to obtain the best results.

### **Challenges and Obstacles for Educators and Students in Implementing PJBL in Chemical Engineering Education**

One of the main challenges in implementing Project-Based Learning (PjBL) in chemical engineering education is limited preparation and resources. Educators often find it difficult to design projects that are not only challenging and relevant to the course material, but also practical for students to undertake (Josua et al., 2022). This challenge is compounded by limited resources such as class time, laboratories and equipment, as well as funds for materials and tools. Extensive preparation is required to ensure that projects can be implemented within these constraints, often requiring educators to seek creative solutions or less-than-ideal alternatives to project components.

Assessment is a particular obstacle in PjBL because project complexity often exceeds traditional assessment schemes. In chemical engineering education, projects are often multidisciplinary, demanding assessments that include not only mastery of technical concepts, but also teamwork, leadership, and communication skills. Determining fair and objective assessment criteria, capable of evaluating multifaceted aspects of student work, is a challenge for educators (Amalia et al., 2024). This can lead to uncertainty or dissatisfaction among students regarding how assessments are conducted, which in turn can affect their motivation and learning experience.

Students' readiness for independent learning and managing their projects is another challenge in PjBL. Many students are accustomed to a passive learning approach and feel uncomfortable with the greater responsibilities required by PjBL. The change in role from educator as information provider to facilitator can be difficult for students and educators alike. Educators may find it difficult to adapt their teaching style, while students may struggle to take initiative in their learning. A lack of time management, problem solving and teamwork skills also adds to the complexity of implementing PjBL, requiring a more structured approach and ongoing guidance from educators (Hyrnsalmi, 2023).

Facing these challenges requires cooperation and commitment from both parties, educators and students, to achieve success in this innovative learning approach in chemical engineering education.

In the current digital era, information technology plays a vital role in implementing PjBL, but the use of technology is often a challenge in itself. For chemical engineering education, where computer simulations and specialized software are often an important part of projects, access to and proficiency in technology is critical. Students and educators may have limitations in terms of the technical skills required to operate specialized software or access online databases (Cardarelli, 2023). This can cause learning to be hampered if adequate information technology training is not provided as part of the curriculum.

Successful implementation of PjBL in chemical engineering often requires collaboration between scientific disciplines or even with industry. Educators may encounter obstacles in establishing relationships or partnerships with relevant industry to provide real context to proposed projects (Sabio & Sabio, 2024). Additionally, projects involving interdisciplinary collaboration can present coordination challenges, where differences in methodology and terminology between areas of expertise need to be

harmonized. This requires additional efforts in communication and project management that may not yet be core skills for students or even educators.

PjBL requires consistency in implementation to ensure its sustainability in the chemical engineering education curriculum. This presupposes support from institutions, both in terms of education policy and budget allocation, to ensure that learning-based projects are not just one-off events. The involvement of education administrators and continuity of collaboration programs with industry is key to maintaining the PjBL initiative. Without long-term commitment and continuous improvement based on feedback, uncertainty can arise in achieving the expected learning outcomes and in maintaining the relevance of PjBL to the latest developments in chemical engineering (Harida et al., 2022).

By paying attention to and overcoming these challenges, chemical engineering education can optimize the benefits of implementing PjBL to produce graduates who are not only academically strong but also have high practical skills and professional skills.

### **PJBL Contributes to the Mastery of Competencies by the Modern Chemical Industry by Chemical Engineering Students**

Project-Based Learning (PjBL) provides chemical engineering students with the opportunity to apply the theory learned in class to real situations, which is very relevant to the needs of the modern chemical industry (Prybutok, 2024). Through PjBL, students are given concrete projects that require the collaborative application of scientific and technical knowledge. This not only improves their understanding of chemical engineering concepts, but also hones their technical skills such as the use of specialized software, data analysis, and complex problem solving. By presenting tasks similar to those found in the chemical industry, students can build competencies that are immediately applicable once they enter the job market (Prastiyan et al., 2023).

In PjBL projects, students often work in teams to plan, execute, and evaluate their projects, which supports the development of collaborative competencies that are essential for the modern chemical industry. This teamwork encourages students to interact and engage in productive discussions, leading to collective solutions that enrich their learning process. This type of collaboration is particularly valuable in the chemical industry, where projects often involve specialists from multiple disciplines (Williams et al., 2022). Through PjBL, chemical engineering students also learn to

communicate effectively across areas of expertise, an essential skill for addressing the multidisciplinary challenges often faced in the modern workplace.

One of the main advantages of PjBL is its ability to prepare students to understand and respond directly to the needs of the chemical industry. Often, projects undertaken within PjBL are based on real case studies or problems faced by industry partners. Conditions like this provide students with direct experience in facing realistic and urgent challenges that are appropriate to the actual industrial context (Delia, 2022). Therefore, students not only learn to develop theoretical solutions, but also implementable and sustainable strategies. This learning directly supports students in translating their academic competencies into results-oriented skills that are highly valued in the contemporary chemical industry.

In PjBL, chemical engineering students also have the opportunity to work with the latest technologies that are widely used in the modern chemical industry. The application of technologies such as computer modeling, process simulation, and automation technologies in their projects, allows students to gain the skills that today's industry needs. This opportunity not only prepares them to work effectively with advanced equipment and software, but also develops their understanding of how technological innovation can drive efficiency and sustainability in chemical operations (Cheong & Hashim, 2023).

Through PjBL, students are invited to not only solve problems, but also to identify problems and develop innovative and creative solutions. In a fast-growing industry like chemistry, the ability to innovate and adapt is key. Students learn to look beyond traditional methods and are encouraged to try new approaches that can provide more effective and sustainable solutions. Project-based learning creates an ideal environment for exploration and experimentation, which is critical in fostering innovative thinking (Ohlemann et al., 2023).

Another important aspect of PjBL is the continuous monitoring and feedback system implemented throughout the project process. Lecturers and industry mentors are often actively involved in providing regular evaluations, which help students adjust their processes and work methods according to the feedback provided. This process makes it easier to detect errors early and correct the direction of the project if necessary, as well as improving the quality of the final result. The success of this approach means not only achieving satisfactory results, but also developing students' ability to respond to criticism and use feedback constructively in their work (Hijriani et al., 2023).

## CONCLUSION

The application of Project Based Learning (PjBL) in chemical engineering education has proven to be an effective method for improving students' practical skills. Through this method, students not only gain theoretical knowledge, but are also directly involved in practicum experiences that are relevant to real-world challenges in the chemical industry. PjBL facilitates student interaction with the latest technology, promotes teamwork, and develops problem-solving abilities. Students are taught to think innovatively, where they not only learn to solve problems but also identify and develop creative solutions. In addition, a continuous monitoring and feedback system ensures the development of project quality and sharpens students' ability to respond to criticism and use feedback constructively. Overall, PjBL prepares chemical engineering students to integrate efficiently into the industrial workforce with high practical skills and a capacity for innovation and adaptation.

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