



Innovative Pedagogy for Industry Alignment: A Case Study of Project-Based Learning and Simulation in Higher Education

Sharizal Ahmad Sobri^{a,b}

Digital Innovation Research Group, Department of Engineering, Nottingham Trent University, Nottingham NG11 8NS, United Kingdom^a, School of Technology and Engineering Science, Wawasan Open University, 54 Jalan Sultan Ahmad Shah, 10050 George Town, Pulau Pinang, Malaysia^b
Corresponding Author's Email: sharizal.ahmadsobri@ntu.ac.uk

ABSTRACT

BACKGROUND & CONTEXT

Graduates often struggle to transition from academic learning to professional practice due to a persistent theory-practice gap. Traditional lecture-based approaches are frequently misaligned with industry expectations, particularly in areas requiring practical skills such as sustainability assessment and systems optimisation. Addressing this gap is essential to improve student engagement, performance, and employability.

PURPOSE OR GOAL

This study investigates whether the integration of Project-Based Learning (PBL) and simulation tools can enhance students' engagement, skill development, and industry readiness. The aim is to determine how structured instructional design strategies can effectively align academic content with real-world professional practices. The central research question guiding this work is: *How can PBL and simulation bridge the academia-industry gap in engineering education?*

APPROACH OR METHODOLOGY

Two case studies were conducted in redesigned modules: Life Cycle Assessment (N=17 students) and Business Operations & Reliability Management (N=41 students). Using the ADDIE model, interventions included hands-on projects supported by professional tools, i.e. *openLCA* and *FlexSim*. Data collection involved quantitative measures (project scores, exam results, student surveys) and qualitative sources (reflection essays, industry feedback). Descriptive statistics and t-tests were used for analysis.

OUTCOMES

Both interventions resulted in notable improvements in student academic performance, with project scores increasing by up to 13% and exam scores showing statistically significant gains. Students reported higher satisfaction and greater confidence in applying theoretical concepts to real-world problems. Industry partners endorsed the practical relevance of the student work, with some projects achieving publishable quality.

CONCLUSIONS

The findings demonstrate that integrating experiential learning methods such as PBL and simulation within a structured instructional design can effectively bridge the gap between academic theory and industry practice. These approaches not only enhance learning outcomes but also foster the development of practical, industry-relevant competencies in engineering graduates.

KEYWORDS

Project-Based Learning, Simulation, Industry Alignment.

Introduction

In recent years, there has been growing global concern regarding the disconnect between higher education curricula and the demands of the engineering industry. Employers consistently report that new graduates, while often well-versed in theoretical knowledge, lack the practical skills and real-world problem-solving abilities required in the workplace. A UK survey conducted by YouGov & MathWorks (2013) revealed that 59% of businesses and 79% of academics believe there is a noticeable skills gap between employer expectations and the capabilities of STEM graduates. This gap is particularly evident in domains requiring applied competencies such as sustainability assessment, operations optimization, and systems thinking.

Traditional lecture-based teaching methods, which dominate many engineering programs, often fail to equip students with these critical competencies. Such methods typically emphasize content delivery and rote memorization, which, while necessary for foundational knowledge, are insufficient for cultivating the kind of active, integrative skills required in professional engineering environments (Felder & Brent, 2016). As industries evolve rapidly in response to technological and environmental challenges, higher education institutions must adopt pedagogical strategies that prepare students not just to understand theory, but to apply it in dynamic, real-world contexts.

Educational research provides compelling evidence for constructivist and experiential learning models as effective alternatives. Constructivist learning theory, pioneered by Piaget (1976), posits that learners build new knowledge through active engagement and experience, rather than passive absorption. Kolb's (1984) experiential learning theory further supports this by outlining a learning cycle, i.e. comprising concrete experience, reflective observation, abstract conceptualization, and active experimentation, which has been widely adopted in engineering education to bridge theory and practice.

One of the most well-established approaches aligned with these theories is Project-Based Learning (PBL). In PBL, students engage in complex, real-world projects that require application of interdisciplinary knowledge, teamwork, and critical thinking. Prior studies (Hmelo-Silver, 2004; Hartman et al., 2013) have demonstrated that PBL improves student motivation, deepens conceptual understanding, and fosters the development of transferable skills. Hartman et al. (2013), for instance, found that PBL improved both engagement and skill development in introductory business courses, while Freeman et al. (2014), in a meta-analysis of 225 STEM studies, concluded that active learning approaches significantly increase student performance and decrease failure rates.

In parallel, simulation-based learning has emerged as a powerful pedagogical tool for visualising system behaviour and enabling experiential practice in complex domains. Simulations allow learners to interact with dynamic models of real-world systems, enabling them to explore decision-making scenarios and observe the outcomes without real-world risks (Feinstein, Mann, & Corsun, 2002). This is particularly valuable in engineering education, where the complexity of systems often precludes direct observation or experimentation. Tools such as *openLCA* for sustainability analysis and *FlexSim* for operations modelling exemplify how digital simulation can enhance understanding of systems-level thinking and reinforce learning through virtual experimentation (Garrison & Vaughan, 2008).

Moreover, involving industry partners in the development and assessment of course projects can further ensure that the curriculum remains relevant and aligned with professional standards. Real-world case scenarios and tools used in industry not only motivate students, but also improve their employability by exposing them to authentic challenges and workflows. Kong (2021) found that experiential learning methods increase student motivation and engagement, which in turn contribute to better academic and career outcomes.

Against this backdrop, the current study aims to explore how integrating Project-Based Learning and simulation tools, i.e. guided by a structured instructional design model, can bridge the theory-practice divide in engineering education. Specifically, this study addresses the following research question:

How can structured instructional design using PBL and simulation bridge the academia-industry gap in engineering education?

To investigate this, two case studies were conducted in modules at the undergraduate and postgraduate levels. Each module was redesigned using the ADDIE instructional design framework (Piskurich, 2015), incorporating either project-based or simulation-based learning activities that reflect real-world engineering tasks. The outcomes of these interventions are assessed in terms of student engagement, academic performance, skill development, and industry validation.

Methodology

This study adopted a design-based research methodology grounded in scholarly teaching practice, aimed at iteratively improving educational strategies in authentic classroom environments. The central methodological framework applied was the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), a well-established instructional design model used in both education and corporate training contexts (Piskurich, 2015). This model provided a structured and reflective pathway for redesigning two engineering modules at different academic levels, each addressing a specific skills gap identified through stakeholder feedback and performance data.

Research Design and Educational Setting

The research involved two distinct but thematically connected case studies:

Case Study 1: An undergraduate Life Cycle Assessment (LCA) module offered at Universiti Malaysia Kelantan (UMK), with 17 students enrolled. This module was part of the Bachelor of Applied Science in Forest Resources Technology programme under the Faculty of Bioengineering & Technology.

Case Study 2: A postgraduate Business Operations & Reliability Management module taught at Nottingham Trent University (NTU), involving 41 MSc Engineering Management students from the Department of Engineering.

In both contexts, students had previously experienced traditional lecture-based instruction. Analysis of historical performance data, student feedback, and consultation with industry partners revealed a need for more experiential and skills-oriented learning opportunities. The research objective was to design, implement, and evaluate curriculum interventions that would enhance student engagement, practical skill development, and alignment with industry needs.

Application of the ADDIE Model

The interventions in both modules followed the five phases of the ADDIE model as follows:

Analysis Phase: Needs assessments were conducted through interviews with academic staff, alumni, and industry stakeholders. Common themes emerged: students struggled to apply theoretical concepts in practice, lacked proficiency with industry-standard tools, and exhibited low confidence in tackling open-ended engineering problems. These findings echoed broader concerns about the misalignment between engineering education and professional expectations (YouGov & MathWorks, 2013; Freeman et al., 2014).

Design Phase: The curriculum was redesigned to incorporate Project-Based Learning (PBL) and simulation-based learning, informed by constructivist and experiential learning theories (Kolb, 1984; Piaget, 1976). In Case Study 1, a semester-long sustainability project using the *openLCA* software was introduced. In Case Study 2, *FlexSim* software was integrated to

enable students to simulate and optimise operational systems. Clear learning outcomes were established, focusing on applied skills such as lifecycle modelling, system simulation, and decision-making under realistic constraints. Rubrics and milestone-based assessment schedules were co-developed to scaffold student learning and ensure alignment between teaching, learning activities, and assessment strategies (Nicol & Macfarlane-Dick, 2006).

Development Phase: Supporting materials (including tutorials on *openLCA* and *FlexSim*, exemplar datasets, instructional videos, and project briefs) were developed to facilitate implementation. These resources were designed to support students from diverse backgrounds and varying levels of prior experience with simulation tools. Digital infrastructure was also arranged: *openLCA* (a free, open-source tool) was installed on institutional systems, while *FlexSim* licenses were made available through university provisions.

Implementation Phase: The redesigned modules were delivered over a semester. In both modules, traditional lectures were replaced or complemented by interactive workshops, team-based project sessions, and industry consultation periods. The instructor adopted the role of a facilitator, offering “just-in-time” support and formative feedback. Project milestones included problem scoping, tool familiarisation, model building, analysis, and presentation of findings. In the simulation module, students engaged in lab-based exercises to incrementally build confidence with *FlexSim* before undertaking the capstone project.

Evaluation Phase: A mixed-methods approach was employed to evaluate outcomes, consistent with best practices in educational research (Creswell, 2014). Quantitative data were collected through project scores, examination results, and end-of-course surveys using Likert-scale items. Where applicable (e.g., Case Study 2), inferential statistics such as independent-sample t-tests were applied to compare outcomes with previous cohorts. Qualitative data were gathered through student reflection essays, open-ended survey responses, classroom observations, and industry mentor feedback. Thematic analysis was used to identify recurring patterns related to student engagement, perceived relevance, and self-efficacy (Kolb, 1984; Kong, 2021).

Ethical Considerations

All research activities adhered to institutional ethics protocols. Students were informed that their data would be anonymised and used solely for research purposes, with voluntary consent obtained. To ensure equitable access, additional support was offered to students who lacked access to required hardware or prior exposure to simulation tools. In both modules, transparency in assessment was promoted through detailed rubrics and peer assessments to promote accountability and fairness (Nicol & Macfarlane-Dick, 2006). Industry collaboration was managed under confidentiality agreements to protect proprietary information, and student projects were anonymised when shared externally.

Limitations

The study acknowledges several limitations that may affect the generalisability and scope of its findings. The sample sizes were relatively small and drawn from two distinct institutional contexts, which limits broad applicability. Additionally, comparisons relied on historical cohorts rather than a concurrent control group, reducing experimental rigour. Students initially struggled with the open-ended nature of the tasks and the technical learning curve associated with *openLCA* and *FlexSim* software. Team-based projects also introduced challenges related to workload distribution and collaboration. Lastly, the interventions required significant instructional time and resources, which may pose scalability concerns without institutional support.

Case Study 1: PBL Intervention in a Life Cycle Assessment Module

Context and Rationale

The first case study was conducted within the *Life Cycle Assessment (LCA)* module at Universiti Malaysia Kelantan (UMK), as part of the Bachelor of Applied Science in Forest Resources Technology programme. The class comprised 17 students. Traditionally, this module relied on lectures and paper-based assignments focusing on theoretical concepts and hand calculations. However, both alumni feedback and employer consultations revealed that graduates often lacked the ability to perform practical sustainability assessments or operate industry-relevant software tools. In response, the module was redesigned using a Project-Based Learning (PBL) approach grounded in experiential learning theory (Kolb, 1984), incorporating *openLCA*, i.e. a professional tool widely used in environmental impact modelling.

Intervention Design and Implementation

Students were divided into small groups (3–4 members) and assigned an open-ended project: to develop a sustainable manufacturing plan for a real product (e.g., a chair, packaging, or consumer item). The scope required teams to assess material sourcing, production, energy use, and end-of-life impacts, using *openLCA* for their modelling. Key components of the intervention included:

- **Authentic Project Briefs:** Mirrored industry consultancy challenges with open-ended problems and trade-offs.
- **Tool Integration:** Training was provided on *openLCA*, including workshops and tutorial videos.
- **Weekly Consultations:** Class time was converted into studio-style workshops, where the instructor acted as a facilitator.
- **Milestone Assessments:** Deliverables included a lifecycle inventory, hotspot analysis, sustainability recommendations, and a final report and presentation.

Assessment components included the *openLCA* model files, a written group report, a final group presentation, and individual reflection essays. The rubric evaluated technical accuracy, creativity, feasibility, communication, and application of theory.

Quantitative Results

To evaluate the impact of the PBL intervention, Table 1 shows project performance and engagement metrics are compared with the previous cohort that undertook the same module via traditional methods.

Table 1: Key performance indicators (before vs. after intervention)

Metric	Traditional (N=18)	PBL Intervention (N=17)
Average Final Project Score (%)	70.1	80.3
% Students with A or B Grade	40%	71%
Average Attendance Rate (%)	75%	90%
Student Satisfaction (Likert, 1–5)	3.5	4.4
Confidence in Applying LCA (Likert, 1–5)	3.0	4.2

Given the small sample size, a Welch's t-test (appropriate for unequal variances) was performed to compare average project scores. The results were as follows:

- Mean (traditional) = 70.1, SD = 5.9
- Mean (PBL) = 80.3, SD = 6.4
- $t(30.5) = 5.13$, $p < 0.001$

The result indicates a statistically significant improvement in student project performance after the PBL intervention, with a large effect size (Cohen's $d \approx 1.65$), suggesting that the intervention had a substantial impact.

Qualitative Insights

Reflection essays revealed that students appreciated the real-world relevance and practical application of theoretical concepts. One student commented:

"Using openLCA made me feel like a real sustainability consultant. I understood better how choices like energy source or packaging material affect the environment."

Students also noted that teamwork, data uncertainty, and interpretation of simulation results were challenging but valuable for their professional development.

An industry partner from the Environmental Technology Research Centre (ETRC) from SIRIM Malaysia reviewed selected student projects. Their feedback highlighted that:

- Student reports demonstrated strong analytical thinking.
- The software models aligned with current industry sustainability practices.
- One group's project was comparable to "junior consultant" standards and later resulted in a peer-reviewed publication (Mohd Azman et al., 2021).

Discussion and Interpretation

The intervention's success is attributable to several interrelated factors:

- The constructivist structure of PBL allowed students to take ownership of learning, consistent with Piaget's (1976) and Kolb's (1984) theories.
- Integration of *openLCA* software allowed direct skill transfer from classroom to workplace, aligning with studies on experiential learning in engineering (Hmelo-Silver, 2004; Hartman et al., 2013).
- The assessment rubric and feedback cycles promoted deep learning and self-regulated progress (Nicol & Macfarlane-Dick, 2006).

Most notably, students reported increased confidence in using industry tools and a deeper understanding of sustainability issues. The statistically significant improvement in scores affirms that PBL enhanced both engagement and content mastery without compromising theoretical learning. Qualitative student feedback highlighted improved confidence and engagement, consistent with literature reporting higher motivation and deeper learning in PBL

environments (Hmelo-Silver, 2004). Additionally, one group's project was accepted for journal publication, reinforcing the academic and professional relevance of the experience. These outcomes align with recent findings by Felder & Brent (2016) and Hmelo-Silver (2004), who emphasise the value of industry-focused PBL in preparing graduates for sustainability challenges.

Case Study 2: Simulation Intervention in a Business Operations Module

Context and Participants

The second case study was conducted in the *Business Operations & Reliability Management* module within the MSc Engineering Management programme at Nottingham Trent University (NTU), with a cohort of 41 students. Previous iterations of this module relied heavily on theoretical instruction in operations management, queueing theory, and reliability calculations. Student feedback and exam performance, however, indicated difficulty in transferring theoretical knowledge to real-world system design and optimisation. Employers also reported that graduates lacked exposure to advanced digital tools used in industry for modelling complex systems. In response, the course was restructured to include simulation-based learning, enabling students to visualise, manipulate, and optimise system-level operations using *FlexSim*, a discrete-event simulation software commonly used in industrial engineering.

Intervention Design and Implementation

The intervention followed experiential learning principles (Kolb, 1984) and was designed according to the ADDIE instructional model (Piskurich, 2015). The revised course structure included:

- **Introductory Labs:** Students participated in guided exercises to model simple systems, such as production lines and warehouse layouts.
- **Capstone Project:** Student teams (4–5 members) tackled real-world inspired scenarios (e.g., hospital emergency flow, warehouse optimisation), using *FlexSim* to model and improve system performance.
- **Project Milestones:** Teams iteratively developed simulation models, conducted “what-if” analysis, and presented findings. Key metrics analysed included throughput, wait times, resource utilisation, and system reliability.
- **Industry Engagement:** A local operations manager served as an industry mentor, providing feedback on model realism and offering practical insights.

Assessment components included a technical report (including model screenshots, sensitivity analysis, and results interpretation), a live simulation demonstration, and peer-reviewed team evaluations.

Quantitative Results

Table 2 shows performance data are collected from this redesigned cohort and compared to the previous year's cohort taught via traditional lecture-based methods.

Table 2: Key performance indicators: Simulation intervention

Metric	Traditional (N=38)	Simulation-Based (N=41)
Average Final Exam Score (%)	68.2	75.1
Average Simulation Project Score (%)	65.0	78.3
% Students with A or B Grade	50%	63%
Student Satisfaction (Likert, 1–5)	3.2	4.1
Confidence in Applying Concepts (1–5)	3.3	4.0

To assess the significance of these improvements, two independent-sample **t-tests** were conducted:

- **Final Exam Scores**

- $t(77) = 2.12$, $p = 0.037$, indicating a statistically significant improvement in theoretical understanding.

- **Project Scores**

- $t(76) = 5.04$, $p < 0.001$, showing a highly significant improvement in applied problem-solving performance.

Cohen's d for project scores was calculated at approximately 1.15, reflecting a large effect size and suggesting substantial educational impact from the simulation intervention.

Qualitative Insights

Survey feedback and reflective team reports provided additional insights:

- **Engagement:** 88% of students agreed that “using the simulation software made the course more interesting and enjoyable.” Many students voluntarily extended lab sessions and took ownership of improving their models.
- **Confidence:** 90% agreed that they could “visualise and apply theoretical concepts better” after the course, echoing Kolb's (1984) experiential learning loop.
- **Transferable Skills:** Students highlighted learning beyond the technical—project planning, teamwork, iterative problem-solving, and communication of data-driven decisions.

Typical feedback included:

“FlexSim helped us see operations in motion, not just as equations. It was one of the few times I felt like I was doing real engineering work.”

“It took time to learn the tool, but I now feel much more confident in analysing systems and justifying my decisions using simulation data.”

Industry Feedback

The external industry mentor described the student projects as “remarkably realistic” and “relevant to the kind of optimisation challenges faced in actual industrial settings.” Specific praise was given for:

- Use of simulation to test process changes under constraints.
- Clear communication of technical findings to non-specialist audiences.
- Data-driven justification of proposed system improvements.

The mentor recommended deeper integration of business cost implications in future versions and expressed willingness to engage further for student placements, signalling the intervention's success in enhancing employability.

Discussion and Interpretation

The integration of *FlexSim* contributed significantly to bridging the theory-practice gap. This intervention validated the value of simulation-based learning in higher education, particularly for system-oriented modules in engineering management. These findings are supported by related studies (Constantino et al., 2012) that advocate for the use of simulation in enhancing systems thinking and operational analysis in engineering education. The improvements observed in both exam and project performance align with prior literature advocating the use of simulation in STEM education (Feinstein et al., 2002; Garrison & Vaughan, 2008). Students benefited from both visualisation of abstract processes and the opportunity to experiment and iterate, i.e. a hallmark of authentic engineering practice.

Furthermore, increased student confidence and satisfaction align with Kong's (2021) findings that experiential learning boosts intrinsic motivation and perceived capability. Importantly, the use of peer evaluations, structured milestones, and industry validation ensured rigour and fairness in assessing collaborative work. Student reflections also indicated that the simulation experience helped consolidate theoretical knowledge and improved their problem-solving skills, an outcome aligned with Kolb's active experimentation phase. This further supports the growing body of evidence (Prince & Felder, 2006) suggesting that experiential and technology-enhanced learning approaches result in deeper understanding and skill transferability.

Comparative Results

To assess the overall impact of the pedagogical interventions, a cross-case analysis was conducted comparing key learning outcomes in both modules, *Life Cycle Assessment* (Case Study 1) and *Business Operations & Reliability Management* (Case Study 2), before and after the redesign. Four primary indicators were analysed: average project score, proportion of students achieving A/B grades, student satisfaction, and self-reported confidence in applying concepts. Table 3 shows the quantitative summary.

Table 3: Cross-case analysis

Metric	Case 1: Before	Case 1: After	Case 2: Before	Case 2: After
Average Final Project Score (%)	70.1	80.3	65.0	78.3
Proportion of A/B Grade Students (%)	40%	71%	50%	63%
Student Satisfaction (1–5 scale)	3.5	4.4	3.2	4.1
Confidence in Applying Concepts (1–5)	3.0	4.2	3.3	4.0

Statistical analysis using independent-sample t-tests confirmed significant improvements in both final project scores and examination scores in the intervention groups. In particular:

- **Case 1 (PBL):**
 - $t(30.5) = 5.13$, $p < 0.001$, Cohen's $d \approx 1.65 \rightarrow$ large effect size
- **Case 2 (Simulation):**
 - $t(76) = 5.04$ for project scores, $p < 0.001$, Cohen's $d \approx 1.15 \rightarrow$ large effect size
 - $t(77) = 2.12$ for exam scores, $p = 0.037 \rightarrow$ moderate effect

Visual Comparison

The chart below (Figure 1) illustrates the changes across the four metrics. Notably, both case studies demonstrate substantial gains in student performance and satisfaction following the instructional redesigns.

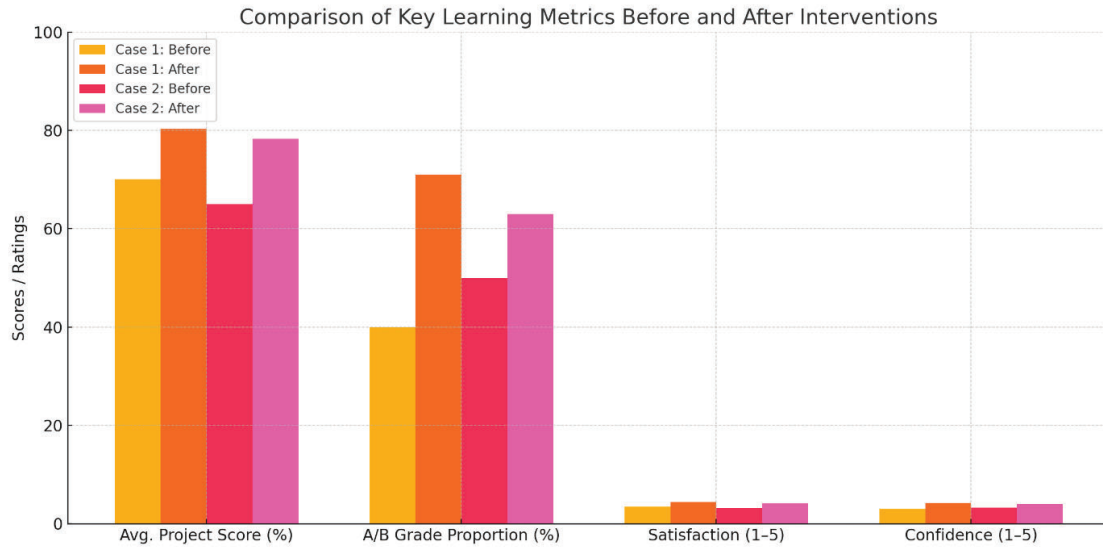


Figure 1: Comparison of Key Learning Metrics Before and After Interventions in Case Study 1 (LCA Module) and Case Study 2 (Business Operations & Reliability Management Module)

As seen in the figure:

- Project scores increased by approximately 10–13 percentage points in both cases.
- A/B grade distribution rose sharply, with Case 1 showing a 31% gain and Case 2 a 13% gain.
- Student satisfaction and confidence levels improved by at least one full point on a 5-point Likert scale across both cohorts.

These trends suggest that both pedagogical strategies, i.e. PBL and simulation, effectively contributed to deeper learning, higher engagement, and improved perceived readiness for real-world challenges.

Interpretation

While both interventions were effective, the magnitude of improvement was slightly greater in the undergraduate PBL setting, possibly due to the novelty of using *openLCA* and the alignment with sustainability goals, which students found meaningful. In contrast, the postgraduate simulation intervention also showed strong gains, particularly in visualising complex systems and experimenting with performance improvements. The consistent positive direction across all metrics supports the conclusion that active, experiential learning methods, when embedded through structured instructional design, can significantly enhance learning outcomes and industry alignment in engineering education.

Conclusion

This study evaluated the integration of Project-Based Learning (PBL) and simulation-based learning in two engineering modules, i.e. Life Cycle Assessment and Business Operations & Reliability Management, using the ADDIE instructional design framework. Implemented at undergraduate and postgraduate levels, the interventions were assessed through mixed methods. The results indicate that active learning strategies significantly improved academic performance, supporting prior evidence of enhanced conceptual understanding in STEM education (Freeman et al., 2014; Prince, 2004). The use of *openLCA* and *FlexSim* familiarised students with industry-standard tools, fostering practical competencies and workplace readiness. Systematic instructional design ensured alignment between learning outcomes and assessments, contributing to the effectiveness of the curriculum redesign. Student reflections and feedback showed heightened motivation, confidence, and interest, while industry input validated the real-world relevance of the projects. Notably, one student-led project resulted in a journal publication, showcasing the academic potential of experiential learning. Future work should examine long-term impacts on graduate outcomes and explore the scalability of combining PBL and simulation across disciplines. Overall, this study reinforces that well-structured, industry-aligned pedagogical innovations can bridge the gap between theory and practice, producing more capable and career-ready engineers.

References

- Costantino, F., Di Gravio, G., Shaban, A., & Tronci, M. (2012). A simulation based game approach for teaching operations management topics. Proceedings Title: Proceedings of the 2012 Winter Simulation Conference (WSC), 1–12. <https://doi.org/10.1109/wsc.2012.6465028>
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: Sage.
- Felder, R. M., & Brent, R. (2016). *Teaching and Learning STEM: A Practical Guide*. San Francisco, CA: Jossey-Bass.
- Feinstein, A. H., Mann, S. and Corsun, D.L. (2002), Charting the experiential territory: Clarifying definitions and uses of computer simulation, games, and role play, *Journal of Management Development*, Vol. 21 No. 10, pp. 732-744. <https://doi.org/10.1108/02621710210448011>
- 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>
- Garrison, D. R., & Vaughan, N. D. (2008). *Blended Learning in Higher Education: Framework, Principles, and Guidelines*. San Francisco, CA: Jossey-Bass.
- Hartman, K. B., Moberg, C. R., & Lambert, J. M. (2013). Effectiveness of problem-based learning in introductory business courses. *Journal of Instructional Pedagogies*, 12, 1–13. <https://eric.ed.gov/?id=EJ1097131>
- Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235–266. <https://doi.org/10.1023/B:EDPR.0000034022.16470.f3>
- Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall.
- Kong, Y. (2021). The role of experiential learning on students' motivation and classroom engagement. *Frontiers in Psychology*, 12, 771272. <https://doi.org/10.3389/fpsyg.2021.771272>
- Mohd Azman, M. A. H., Ahmad Sobri, S., Norizan, M. N., Ahmad, M. N., Wan Ismail, W. O. A. S., Hambali, K. A., Hairi, M. H., Hermawan, A., Mohamed, M., Teo, P. T., Taharin, M. R., & Mat Noor, N. A. (2021). Life Cycle Assessment (LCA) of Particleboard: Investigation of the Environmental Parameters. *Polymers*, 13(13), 2043. <https://doi.org/10.3390/polym13132043>
- Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2), 199–218. <https://doi.org/10.1080/03075070600572090>
- Piaget, J. (1976). Piaget's Theory. In: Inhelder, B., Chipman, H.H., Zwingmann, C. (eds) *Piaget and His School*. Springer Study Edition. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-46323-5_2
- Piskurich, G. M. (2015). *Rapid Instructional Design: Learning ID Fast and Right* (3rd ed.). Hoboken, NJ: Wiley.

Prince, M. J. (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>

Prince, M.J., & Felder, R.M. (2006), Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education*, 95: 123-138. <http://dx.doi.org/10.1002/j.2168-9830.2006.tb00884.x>

YouGov & MathWorks. (2013). *Bridging the Skills Gap in STEM Industries*. Retrieved from <https://yougov.co.uk/society/articles/7536-uk-skills-gap-stem-subject>

Acknowledgements

The author would like to express sincere gratitude to Nottingham Trent University (NTU) and Universiti Malaysia Kelantan (UMK) for providing valuable academic and professional experiences that have significantly contributed to the development of this work. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Copyright Statement

Copyright © 2025 Author's name (Sharizal Ahmad Sobri) : The author assign to the Research in Engineering Education Network (REEN) and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full, and this copyright statement is reproduced. The author also grant a non-exclusive licence to REEN to publish this document in full on the World Wide Web (prime sites and mirrors), on portable media and in printed form within the REES and RCEE & RHEd 2025 proceedings. Any other usage is prohibited without the express permission of the author.