Research in Engineering Education Symposium (REES)
Regional Conference in Engineering Education (RCEE) &
Research in Higher Education (RHEd)
September 29 – October 3, 2025
Johor, Malaysia

Future Proofing Engineers Through Design Thinking and Real-World Learning

Azlan Ahmad, Nurhayati Mellon, Oh Pei Ching, and Nursyarizal M Nor
Integrated Engineering Department, Universiti Teknologi PETRONAS, Malaysia
Corresponding Author's Email: azlan.ahmad@utp.edu.my

ABSTRACT

BACKGROUND & CONTEXT

Engineering graduates must possess not only technical competence but also the capacity for lifelong learning as professional demands evolve. At Universiti Teknologi PETRONAS (UTP), attainment for Course Learning Outcome 5 (CLO5), which reflects lifelong learning, declined from 88.75 to 82.11 within a semester, with widening variability among students. The previous Engineering Team Project (ETP) taught design thinking through brief lectures and simplified exercises, treated by students as procedural checklists lacking sustained reflection or real-world context. This limited the adaptive mindsets and resilience needed for continuous learning.

PURPOSE OR GOAL

This study redesigned the ETP to explicitly embed lifelong learning through a mindset-driven, design-led pedagogy. It examined whether integrating structured design thinking, agile tools, and industry engagement could improve students' self-directed learning, reflective capacity, and confidence in handling ambiguous problems.

APPROACH OR METHODOLOGY

The redesigned ETP integrated the Double Diamond framework with agile tools such as Kanban boards, aligning each phase with a lifelong learning mindset — empathy, critical thinking, co-creation, and resilience. A mixed-methods design compared a control cohort (traditional delivery) with an intervention cohort (redesigned delivery), using institutional CLO5 scores, a validated post-intervention Likert survey, and student reflections.

OUTCOMES

The intervention cohort showed a 6.42-point rise in median CLO5 scores (82.11 to 88.53) with reduced variability. Self-reported creativity, collaboration, and confidence in applying learning improved from the 4.1–4.3 to 4.6–4.7 range. Students reported greater comfort with ambiguity and independent learning, and several teams attracted industry interest, with one securing external funding.

CONCLUSIONS

Embedding design thinking and agile methodologies within an authentic, industry-linked project structure measurably strengthens engineering students' lifelong learning competencies, consistent with existing literature on design-led education. The model offers a scalable, cost-effective approach for institutions seeking to embed lifelong learning without major infrastructure changes.

KEYWORDS

Lifelong Learning, Design Thinking in Engineering Education, Self-Regulated Learning.

https://doi.org/10.52202/086293-0073

Introduction

The ability to learn continuously and adaptively is a defining skill for 21st-century engineers. As technological, economic, and societal change accelerates, engineering graduates must possess not only technical proficiency but also the capacity for independent knowledge acquisition and adaptability to evolving professional landscapes. However, many engineering curricula still underemphasize lifelong learning. At Universiti Teknologi PETRONAS (UTP), this concern became prominent when recent performance data showed a decline in students' readiness for continuous learning. Specifically, the average attainment for Course Learning Outcome No. 5 (CLO5), which reflects lifelong learning competencies, decreased from 88.75 to 82.11 within a semester, as shown in Figure 1. This drop, accompanied by a widening standard deviation, suggested inconsistent student engagement with self-directed and reflective learning practices. If unaddressed, this trend risks producing engineering graduates unprepared for the demands of a dynamic and uncertain future.

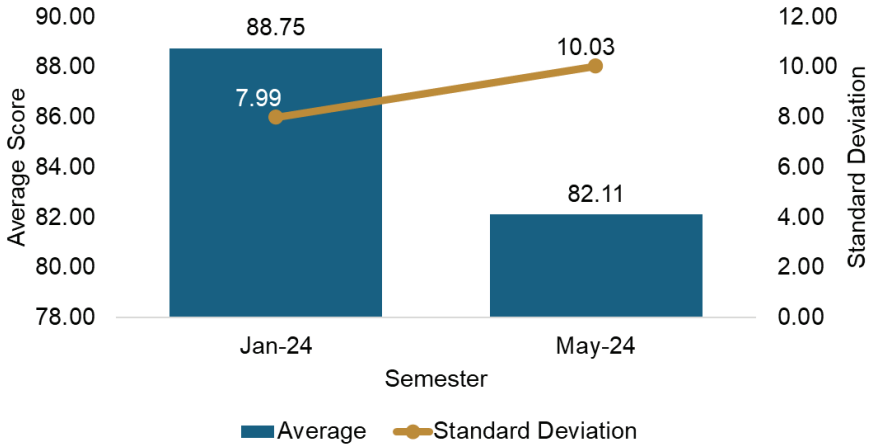


Figure 1: Median Score Attainment for Lifelong Learning

Despite widespread adoption of project-based learning (PBL), many implementations do not effectively foster lifelong learning. The previous version of UTP's Engineering Team Project (ETP) introduced students to design thinking through brief lectures and simplified exercises. These activities were often viewed as procedural checklists, limiting students' ability to apply design principles to real-world or ambiguous scenarios. The learning experiences lacked sustained reflection and contextualisation. This hindered the development of adaptive mindsets necessary for lifelong learning (Bidokht and Assareh, 2011). Students were not provided with the opportunity to iterate meaningfully, reflect deeply, or act on constructive feedback, leaving them without the resilience, curiosity, and adaptability required to thrive in evolving environments (Kucuksuleymanoglu, 2025).

Aim

This paper aims to address the critical gap in engineering education by presenting a structured, mindset-driven pedagogy that explicitly embeds lifelong learning into the engineering curriculum. The restructured ETP at UTP was designed to align learning outcomes with real-world relevance and to cultivate mindsets essential for continuous learning. By integrating design-led thinking, agile tools, and industry collaboration, the course sought to enhance students' self-directed learning, reflective capacity, and confidence in navigating complex problem contexts. The goal was to transition students from passive knowledge recipients to active learners prepared for ongoing personal and professional development.

https://doi.org/10.52202/086293-0073

Methodology

The ETP was restructured to integrate the Double Diamond framework, which includes Discover, Define, Develop, and Deliver phases, alongside agile project management tools such as Kanban boards, as shown in Figure 2. This design guided students through two semester-long engagements with authentic challenges provided by industry partners. Each phase cultivated a mindset aligned with lifelong learning, which are empathy during Discover, critical thinking in Define, co-creation in Develop, and resilience in Deliver.

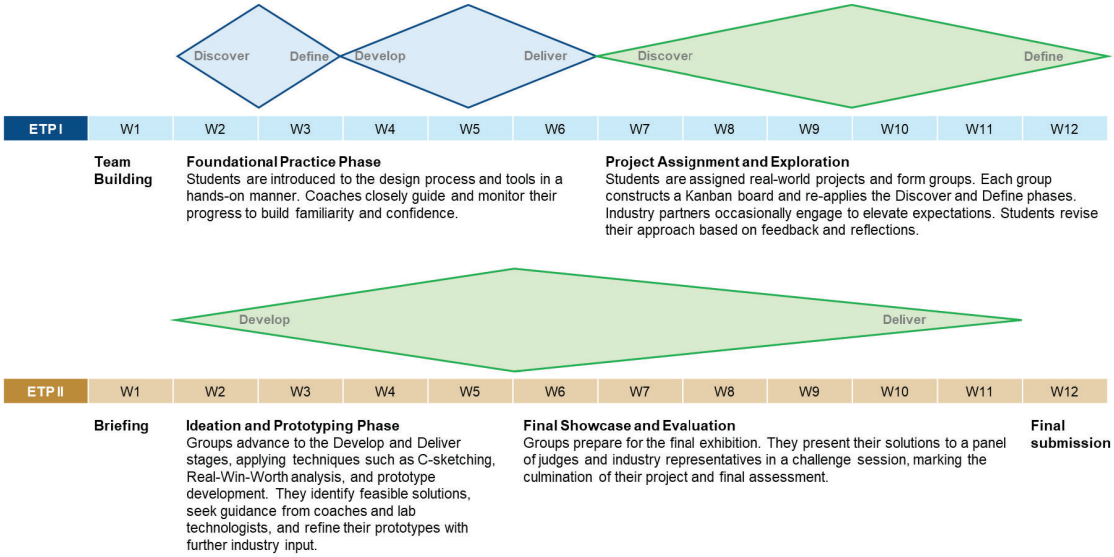


Figure 2: Embedment of Double Diamond Design Thinking Across the Semester

This design approach promotes cognitive flexibility, which is increasingly recognised as a core attribute of continuous learning in the context of ongoing technological change (Fuchs et al., 2023). The approach also emphasized open-ended problem framing, continuous reflection, and iterative feedback from academic coaches and industry mentors. Students documented their learning processes, revisited assumptions, and refined their solutions through feedback loops. These practices supported the development of metacognitive skills and self-regulated learning strategies (Wu, 2024).

The pedagogical model drew inspiration from global best practices. These practices were then adapted to UTP's local context. Frameworks from institutions such as the Singapore University of Technology and Design, Olin College of Engineering, and Massachusetts Institute of Technology's induction models were synthesized into UTP's Design Nexus. Figure 3 summarizes the team learning journey with various stakeholders; (a) Participating in a 10-day Executive Education Programme at SUTD, focusing on Design Innovation, (b) Gaining insights on project scoping from Olin College of Engineering in Massachusetts, USA, and (c) Engaging in knowledge exchange with MIT and University College London on mass induction programme strategies. These principles were localised into a culturally relevant, outcomes-driven pedagogy designed to sustain engagement across disciplines. Its originality lies in its ability to operationalise transformative learning through a structured sequence of tools, mindsets, and collaborative processes (Hero and Lindfors, 2019; Bolmsten and Kitada, 2020).

The model was rooted in experiential learning theory, aligning each phase of the Double Diamond framework with Kolb's learning cycle (Wijnen-Meijer et al., 2022). Agile practices reinforced continuous planning, prioritisation, and reflection. Failure was embraced as part of the learning process. This encouraged both resilience and confidence (Shay and Pohan, 2021). This study adopted a mixed-methods research design to evaluate the impact of a redesigned teaching model on students' lifelong learning competencies. The combination of

https://doi.org/10.52202/086293-0073

quantitative and qualitative data allowed for a comprehensive assessment of both measurable performance outcomes and deeper shifts in learning behavior and mindset.



(a) (b) (c)

Figure 3: Learning Journey with Various Stakeholders

Quantitative data were collected from two main sources. First, the study analyzed CLO5 scores, which reflect student performance in self-directed learning and continuous development. These scores were extracted from institutional assessments conducted at the end of each semester. Second, a structured post-intervention survey was administered to capture student self-assessment across three constructs: creativity, collaboration, and application of learning. These constructs were aligned with indicators of lifelong learning as defined by Seevaratnam et al. (2023) and were measured using a 5-point Likert scale. The survey instrument underwent face validation by three experts in engineering education to ensure clarity and relevance.

The study employed a comparative approach across two cohorts. The control group consisted of students enrolled in the ETP during the January 2024 semester, which followed the traditional lecture-based design thinking delivery. The intervention group comprised students from the May 2024 semester, who experienced the restructured course based on the Double Diamond framework and agile project management practices. Both groups were comparable in terms of academic level (Year 2), programme enrollment, and team-based project format.

Result

The redesigned ETP demonstrated measurable improvements in students' lifelong learning competencies. As shown in Figure 4, the median score for CLO5 increased from 82.11 to 88.53, reflecting a 6.42-point gain in students' demonstrated ability to engage in self-directed and continuous learning. At the same time, the standard deviation dropped from 10.03 to 9.66, suggesting a reduction in variability and more consistent performance across the cohort.

Figure 5 reveals a notable improvement in self-perceived competencies. Specifically, students reported a rise in creativity confidence from a mean score of 4.1 to 4.6 on a 5-point Likert scale, indicating a substantial shift toward enhanced ideation and problem-solving self-efficacy. Similarly, collaboration scores increased from 4.3 to 4.7, reflecting stronger interpersonal and teamwork skills, which are critical for project-based and interdisciplinary engineering tasks.

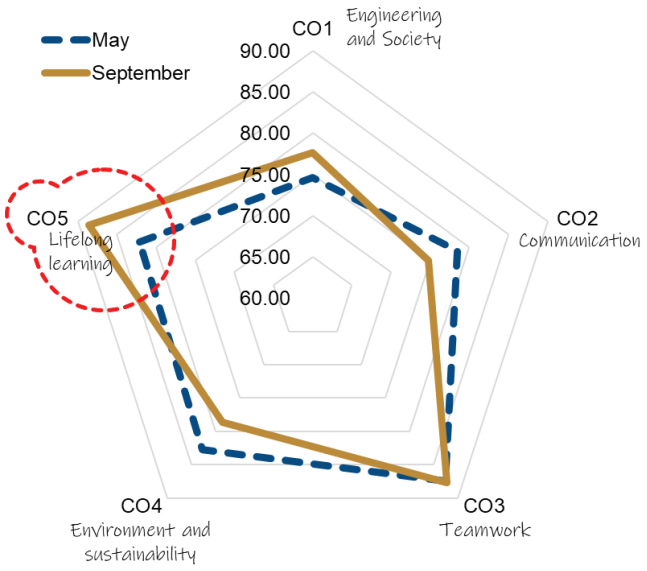


Figure 4: Median Score Attainment for Each Course Outcome (CO) for ETP students

Notably, students' confidence in applying the learned methodologies in future contexts rose from 4.2 to 4.6, demonstrating the perceived transferability and practical value of the skills acquired. These findings align with Seevaratnam et al. (2023), who assert that embedding design thinking within engineering curricula enhances both creative confidence and professional adaptability. Furthermore, they echo the work of Hero and Lindfors (2019), who emphasized that multidisciplinary, design-led education fosters transferable competencies necessary for long-term professional growth.

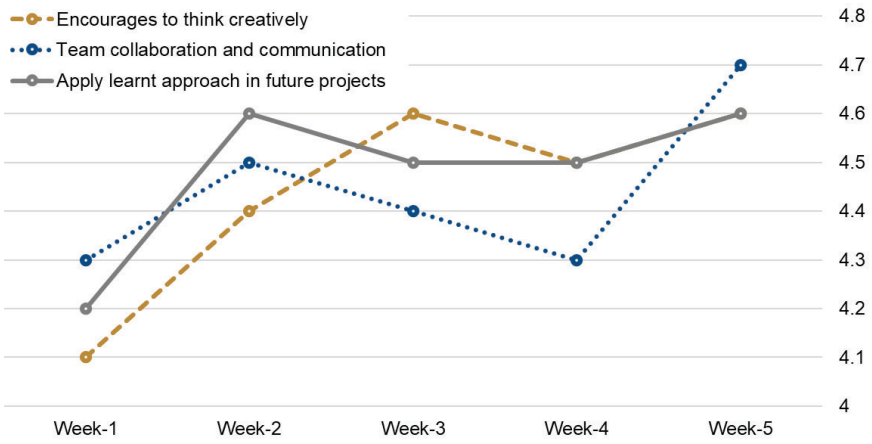


Figure 5: Student's Rating on Redesigning ETP from Week 1 to Week 5

These trends reflected greater engagement, agency, and recognition of the real-world relevance of the course. The results, visualized in Figure 6, suggest that this improvement was underpinned by students' immersive engagement in the Double Diamond Design Thinking process, supported by structured, hands-on activities. This is also agreed by Bandi and Reddy (2024), who noted that PBL and design thinking approaches significantly improve student performance, teamwork, multidisciplinary knowledge, and leadership skills.

https://doi.org/10.52202/086293-0073



Figure 6: Students immersed in the Double Diamond Design Thinking process through hands-on, tool-based activities

Qualitative data from student reflections, revealed shifts in mindset and learning behavior. Students reported increased comfort with ambiguity. They were also more motivated for independent learning and receptive to feedback. They felt more capable of adapting their thinking and more confident in managing complex problem scenarios. Final project outcomes also reflected these shifts, with several teams receiving interest from industry partners. One team secured external funding to further develop their solution. As highlighted in Figure 7, a key feature of this model was the continuous collaboration with industry mentors who participated in check-in sessions, offering timely feedback and practical insights to enrich the learning experience.

These results demonstrated not only academic improvement but also enhanced readiness for lifelong learning beyond university. A similar trend was observed by Tartibu and Steenkamp (2020), who found that design projects motivate students to study independently and integrate engineering concepts into practice.



Figure 7: Industry partners joined the check-in sessions to provide real-world insights and enhance the learning experience

The structured use of Agile tools and regular feedback supported self-paced learning, goal-setting, and metacognitive awareness. Students could monitor and adjust their learning strategies more effectively. Each phase of the Double Diamond framework reinforced specific cognitive and behavioral traits associated with lifelong learners. Empathy, critical thinking, co-creation, and resilience were deliberately fostered through experiential processes. These competencies mirrored those identified in the World Economic Forum's Future of Jobs 2023 report as essential for future-ready professionals.



Figure 8: Final showcase where students exhibited their projects, receiving feedback and evaluation from coaches and industry partners

Furthermore, the course helped address disparities in learning experiences. Struggling students benefited from a supportive, structured environment that offered scaffolding and peer collaboration. The consistent gains across the cohort suggested that the redesigned model not only elevated performance but also contributed to a more equitable learning experience. One can observe in Figure 8 that the final student showcase further amplified this experience by providing a professional setting for peer learning, industry validation, and reflective assessment. It provided a scalable and cost-effective solution for institutions aiming to embed lifelong learning without extensive infrastructure changes. Previous literature supports engaging students in empathetic design to improve learning through better understanding of student challenges and idea generation for improved experiences (Hemmerich et al., 2023).

To strengthen the relevance of this intervention to engineering education accreditation, the outcomes of the redesigned Engineering Team Project (ETP) were explicitly mapped against selected Engineering Programme Outcomes (EAC Standards). Table 1 summarizes how the intervention addresses PO11, PO3, and PO9 through specific course elements and measurable evidence.

Table 1: Mapping of the Redesigned ETP to EAC Standards

Programme Outcome	How the Intervention Addresses This Outcome	Evidence from the Study
PO3 Design Solutions	The course uses the Double Diamond framework combined with agile methodologies, guiding students to design innovative solutions that address authentic, industry-provided challenges.	• Students applied design-led thinking to real-world projects. • Several teams' solutions attracted industry interest and funding. • Industry mentors validated the practicality and societal relevance of the student projects.

https://doi.org/10.52202/086293-0073

PO9 Communication	Regular presentations, industry check-ins, peer-to-peer sharing, and final showcases enhanced students' oral and written communication skills across multiple stakeholder groups.	• Students successfully pitched solutions during final showcases. • Industry mentors provided positive feedback on students' communication and professionalism. • Collaboration scores rose from 4.3 to 4.7, reflecting improved interpersonal and communication skills.
PO11 Lifelong Learning	The redesigned ETP embeds reflective practices, iterative feedback, and self-regulated learning strategies, fostering students' capacity to continuously acquire and apply knowledge.	• CLO5 median score increased from 82.11 to 88.53. • Student reflections indicated higher motivation for independent learning and greater comfort with ambiguity. • Enhanced metacognitive awareness through structured reflection logs and feedback loops.

Conclusions

Lifelong learning is indispensable for engineers navigating the complexities of modern professional environments. This study provides compelling evidence that structured, real-world learning environments embedded with design thinking and agile methodologies significantly enhance students' ability to engage in continuous learning. The Engineering Team Project's revised model offers a practical framework for integrating lifelong learning into engineering curricula. By promoting metacognition, reflection, and adaptability through experiential learning, the course prepares students not only for graduation but also for lifelong professional development. As engineering education evolves, the imperative is not only to teach technical skills but to cultivate learners equipped to thrive amidst uncertainty and change.

Institutions aiming to replicate this model should consider several key strategies. First, integrate design thinking with real-world industry challenges to ensure relevance and engagement. Second, embed structured reflection and feedback mechanisms that encourage self-regulated learning and metacognitive awareness. Third, provide training for academic coaches and industry mentors to maintain consistent guidance and alignment with learning outcomes. Finally, adopt a phased or pilot approach to allow for contextual adaptation before scaling the model institution-wide.

Limitations

This study was conducted in Malaysia, where cultural diversity and assimilation are deeply embedded in educational settings. The course design leverages this diversity by intentionally grouping students across gender, ethnicity, and backgrounds to enrich teamwork and learning outcomes. The fully project-based format also allows flexibility in delivery, enabling adaptation to dynamic classroom contexts. However, successful replication in other institutions may depend on the extent to which similar diversity, institutional support, and top-down commitment to project-based learning are present.

References

Bandi, S. M. N. S., & Reddy, C. L. (2024). Enhancing Engineering Education: Exploring the Impact of Problem-Based Learning on Freshman Students' Skills and Engagement–A Case Study. Journal of Engineering Education Transformations, 38(Special Issue 1).

Bidokht, M. H., & Assareh, A. (2011). Life-long learners through problem-based and self directed learning. Procedia Computer Science, 3, 1446-1453.

Bolmsten, J., & Kitada, M. (2020). Agile social learning–capacity-building for sustainable development in higher education. International Journal of Sustainability in Higher Education, 21(7), 1563-1586.

Fuchs, H., Benkova, E., Fishbein, A., & Fuchs, A. (2023). The importance of psychological and cognitive flexibility in educational processes to prepare and acquire the skills required in the Twenty-First century. In The Global Conference on Entrepreneurship and the Economy in an Era of Uncertainty (pp. 91-114). Singapore: Springer Nature Singapore.

Hemmerich, A., De Paoli, M., & Fleisig, R. V. (2023). Design thinking in collaboration with students to identify and address learning challenges in two science and engineering courses. In 2023 ASEE Annual Conference & Exposition.

Hero, L. M., & Lindfors, E. (2019). Students' learning experience in a multidisciplinary innovation project. Education+ Training, 61(4), 500-522.

Kucuksuleymanoglu, R. (2025). Resilience in Lifelong Learning for Individuals. In Resilience, Adaptability, and Cultural Awareness Within the Educational Landscape (pp. 69-96). IGI Global Scientific Publishing.

Seevaratnam, V., Gannaway, D., & Lodge, J. (2023). Design thinking-learning and lifelong learning for employability in the 21st century. Journal of Teaching and Learning for Graduate Employability, 14(1), 182-201.

Shay, J. E., & Pohan, C. (2021). Resilient instructional strategies: helping students cope and thrive in crisis. Journal of microbiology & biology education, 22(1), 10-1128.

Tartibu, L., & Steenkamp, R. (2020). An assessment of the students' attitudes toward engineering design and build projects. In 2020 IFEES World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC) (pp. 1-5). IEEE.

Wijnen-Meijer, M., Brandhuber, T., Schneider, A., & Berberat, P. O. (2022). Implementing Kolb s experiential learning cycle by linking real experience, case-based discussion and simulation. Journal of medical education and curricular development, 9, 23821205221091511.

Wu, X. Y. (2024). Unveiling the dynamics of self-regulated learning in project-based learning environments. Heliyon, 10(5).

Acknowledgements

The authors would like to express their sincere gratitude to Universiti Teknologi PETRONAS for the institutional support and strategic backing of the Integrated Engineering Department initiative, which enabled the redesign of the Engineering Team Project course. We are also grateful to our students for their openness, resilience, and critical reflections, which provided valuable insights into the effectiveness of this approach. Finally, the authors acknowledge the industry partners, including DynaSegmen, Keysight and Prasarana and other direct and indirect collaborators, for offering real-world challenges and feedback that greatly enriched the learning experience.

Copyright Statement

Copyright © 2025 Azlan Ahmad, Nurhayati Mellon, Oh Pei Ching, and Nursyarizal M Nor: The authors 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 authors 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 authors.

https://doi.org/10.52202/086293-0073