Journal of Engineering Education Transformations, Volume 39, January 2026, Special Issue 2, eISSN 2394-1707

Bridging Theory and Practice: Assessing Project and Problem-Based Learning (P2BL) in Undergraduate IoT Course

[1]Josephine Selle Jeyanathan, [2]Nagaraj P, [3]P. Anitha
[1]Department of Electronics and Communication Engineering, Kalasalingam Academy of Research and Education, Krishnankoil, Virudhunagar, India
[2]Department of Computer Science and Engineering, School of Computing, SRM Institute of Science and Technology, Tiruchirappalli, SRM Nagar, Trichy, India.
[3]Department of Computer Application, Kalasalingam Academy of Research and Education, Krishnankoil, Virudhunagar, India
[1]drjjosephine@gmail.com, [2]nagu.is.raj@gmail.com, [3]anithapmcamba@gmail.com

Abstract— **Engineering education increasingly emphasizes the need for pedagogies that move beyond rote learning to foster problem-solving, teamwork, and innovation. Project and Problem-Based Learning (P2BL) provides such a framework by integrating authentic tasks within the curriculum. This study reports on the design, implementation, and evaluation of P2BL in the *IoT Sensors and Devices* course for second-year Electronics and Communication Engineering students. A total of 123 students participated, with 60 enrolled in the P2BL section and 63 in a lecture-based control group. The P2BL design included quizzes, laboratory tasks, idea pitching, hackathon participation, and prototype expo evaluation. Comparative quantitative analyses showed that the P2BL group outperformed the control group in quizzes ($t(118) = 3.50, p = .001$) and laboratory performance ($t(118) = 5.80, p < .001$), though composite performance indices were comparable. One-sample t-tests against a benchmark of 70/100 indicated that P2BL students significantly exceeded expectations in Pitch (M = 74.2, $p = .009$), Hackathon (M = 77.0, $p < .001$), and Prototype Expo (M = 74.9, $p < .001$). Correlation analysis revealed that Pitch scores were the strongest predictor of Prototype quality (r = 0.80), followed by Lab (r = 0.40), while Quiz showed only a weak association (r = 0.30). Qualitative reflections reinforced these findings, with themes of teamwork, creativity, and applied problem-solving frequently reported. Overall, the study demonstrates that P2BL strengthens conceptual learning while fostering innovation and teamwork and can be embedded within existing curricula without altering syllabus structures.**

Keywords—**Project-based learning, Statistical analysis, regression, correlation.**

ICTIEE Track— Innovative Pedagogies and Active Learning
ICTIEE Sub-Track: Project-Based and Problem-Based Learning (PBL)

I. INTRODUCTION

Engineering education is undergoing a major transformation to align with the needs of the 21st-century workforce. While engineering graduates are expected to demonstrate critical thinking, problem-solving, teamwork, and innovation skills, traditional lecture-based instruction often limits students to memorize learning and theoretical understanding (Lavado-Anguera et al., 2024). As a result, many graduates face challenges in applying classroom knowledge to real-world engineering problems, which in turn affects their placements in industries. To address these concerns, active learning pedagogies such as Project-Based Learning (PjBL) and Problem-Based Learning (PBL) have been increasingly adopted in engineering curricula worldwide (Noguez & Neri, 2019). Both approaches encourage students to take ownership of their learning through exploration, collaboration, and the practical application of concepts. In recent years, educators have combined these approaches into a Project and Problem-Based Learning (P2BL) framework, which integrates problem-solving tasks with structured project design leading to product development (Khan et al., 2020). This integration allows students not only to acquire domain knowledge but also to develop professional competencies such as design thinking, project management, and interdisciplinary collaboration. Despite the recognized benefits of P2BL, there remains a need for systematic evidence on its effectiveness in engineering education, particularly in the Indian context where class sizes are large, curricula are rigid (Fernandes, 2017; Ricaurte & Viloria, 2020),

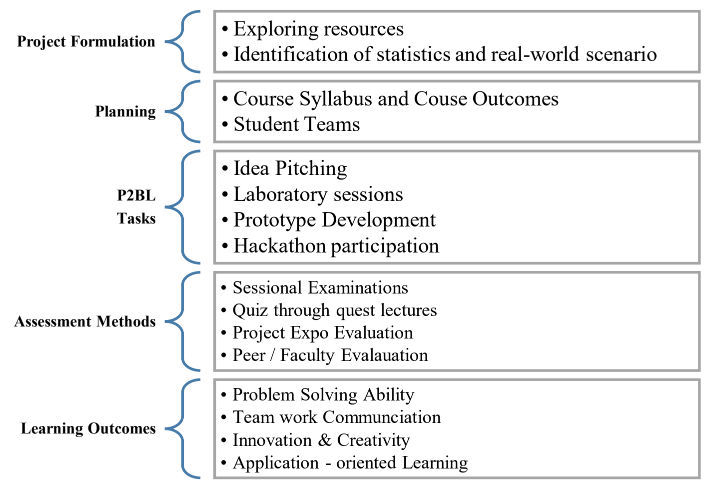

Fig. 1. P2BL Framework for the course: IoT Sensors and Devices

Josephine Selle Jeyanathan
Kalasalingam Academy of Research and Education Virudhunagar Dist 626126
drjjosephine@gmail.com

and assessment practices are mostly exam oriented (Mohammed et al., 2024). Questions remain about how P2BL impacts higher-order learning outcomes, and how it can be practically embedded within existing courses without making it burdensome to the students or faculty.

This study aims to investigate the effectiveness of a structured P2BL approach in the undergraduate course *IoT Sensors and Devices* offered to second-year Electronics and Communication Engineering students. The intervention is designed to enhance problem-solving ability, teamwork, and application-oriented learning by engaging students in a variety of activities such as laboratory sessions, idea pitching, hackathon participation, quizzes, and prototype development evaluated through a project expo. The paper presents the design, implementation, and assessment of this P2BL framework as shown in fig.1 and evaluates its impact through both quantitative outcomes and qualitative student feedback.

II. RELATED WORKS

Project and problem-based pedagogies have been extensively studied as learner-centered approaches that bridge theory and practice in engineering education. Early works emphasized the integration of engineering design principles into project-based learning, showing that structured design tasks significantly enhance creativity, motivation, and students' ability to apply theoretical knowledge to real-world challenges (Lin et al., 2021). Building on this, systematic studies identified key characteristics of PBL such as authenticity of tasks, collaborative teamwork, iterative inquiry, and reflective assessment as critical factors for effective implementation (Markula & Aksela, 2022). These foundational studies laid the groundwork for hybrid frameworks such as Project and Problem-Based Learning (P2BL), which integrate the strengths of both pedagogies.

Subsequent research has demonstrated the positive impact of PBL on student outcomes in higher education. A large-scale study in 2023 highlighted significant improvements in problem-solving, critical thinking, and creativity when students engaged in real-world projects rather than isolated classroom exercises (Markula & Aksela, 2022). In the same year, evidence from a controlled study confirmed that project-based learning enhances both technical competencies and transversal skills such as teamwork, self-directed learning, and communication (Maros et al., 2023). These findings align with broader reviews that emphasize PBL's ability to promote deep learning and encourage industry-relevant graduate attributes (Boakye-Yiadom et al., 2025).

The role of authenticity and student engagement is a recurring theme across recent studies. Various authors in recent years have shown that student engagement—behavioural, emotional, and cognitive—was significantly higher when projects were situated in real-world contexts, such as hackathons and design expos, compared to classroom-only implementations (Kong et al., 2024). This confirms that course-specific design tasks not only increase interest in problem-solving but also reduce issues such as social loafing in group work. Similarly, combining flipped classroom models with project-based learning resulted in statistically significant gains in motivation and learning outcomes, particularly at undergraduate levels, demonstrating the potential of hybrid pedagogies.

Beyond general STEM education, recent works extend PBL into domain-specific applications and technology-enhanced learning. For example, integrating AI literacy frameworks into project-based courses improved students' ability to engage critically with emerging technologies (Köpeczi-Bócz, 2024). In supply chain management, project-based learning approaches contextualized abstract theories into actionable problem-solving activities that improved both conceptual understanding and decision-making (Chang et al., 2024). Similarly, studies in engineering courses combining PBL with hackathon participation and prototype development demonstrated higher levels of innovation-driven learning and entrepreneurial orientation among students (Gunawan et al., 2025).

A significant body of 2025 research has focused on cognitive and skill development outcomes. Empirical studies confirmed that PBL enhances students' problem-solving abilities and critical thinking compared to traditional lecture-based methods (Ashraf et al., 2025). Teacher perception studies revealed that effective implementation requires not only innovative pedagogies but also institutional support, training, and curriculum alignment. Meanwhile, cross-level studies have shown that PBL's success depends heavily on context, resources, and stakeholder involvement, highlighting its adaptability but also its dependency on supportive ecosystems (Aisyah & Novita, 2025).

Finally, emerging innovations highlight PBL's evolution into next-generation pedagogies. The integration of generative AI (GenAI) tools into project-based learning has been shown to foster collaborative idea generation, rapid prototyping, and reflective feedback loops, thus reshaping how students engage with open-ended problems (Perifanou & Economides, 2025). At the same time, critical thinking frameworks and hybrid assessment models underscore the transition of PBL from an "alternative pedagogy" to a mainstream method for preparing engineering graduates with 21st-century skills.

Recent studies in engineering education highlight the growing need for hybrid pedagogies tailored to technology-intensive courses such as IoT. However, most P2BL frameworks have been validated on small cohorts or general STEM subjects, leaving gaps in evidence for large second-year engineering classes and hardware-oriented courses. Studies on IoT-focused experiential learning (e.g., 2023–2025 research on embedded systems, maker-spaces, and rapid prototyping courses) emphasize the importance of multimodal assessment and teamwork-driven innovation. Yet, these works rarely integrate pitching, hackathon events, and prototype expos into a single assessment framework. This gap positions the present study as a contribution to P2BL design specifically aligned with IoT hardware–software coursework.

III. RESEARCH DESIGN

Hypothesis

Although Project- and Problem-Based Learning (P2BL) has been widely adopted across engineering education, several limitations remain in existing studies. Most prior research has been situated in general STEM or teacher-training contexts, with relatively few applications in Electronics and Communication Engineering courses (Gutierrez-Berraondo et al., 2025). There is limited evidence on how structured P2BL frameworks operate in technology-oriented subjects such as *IoT Sensors and Devices*, where both theoretical understanding and practical prototyping are essential.

Another gap concerns assessment. Existing studies tend to evaluate PBL or PjBL primarily through examinations or project reports but seldom employ a multi-modal assessment framework that integrates written exams, laboratory performance, idea pitching, hackathon participation, and prototype expos (Hidayah, 2025). This leaves a gap in understanding how P2BL can be holistically evaluated to reflect both academic and professional competencies.

A further gap lies in understanding how P2BL can be implemented in large, exam-driven classrooms such as those common in Indian engineering institutions. While international studies often report outcomes from smaller groups in resourceful environments, there is limited evidence on whether structured P2BL frameworks can be scaled and sustained in such contexts. Moreover, little is known about how students with diverse academic preparation levels respond to multi-modal assessments that integrate both traditional exams and authentic activities like hackathons and prototype expos. Importantly, very few studies discuss how assessment tools can be embedded into P2BL without altering the prescribed curriculum or syllabus structure, an issue that is particularly relevant in regulated programs (Naseer et al., 2025). Addressing this gap is essential to ensure that P2BL can be adopted in a practical, scalable, and policy-compliant manner in Indian engineering education.

Based on the gaps identified in the literature and the objectives of this study, the following hypotheses are proposed to examine the effectiveness of implementing a structured P2BL framework in the *IoT Sensors and Devices* course.

H1: Students exposed to P2BL in the *IoT Sensors and Devices* course will achieve significantly higher performance on a composite assessment (exams, labs, hackathon, and prototype expo) compared to students taught through traditional methods.

H2: P2BL will enhance students' problem-solving ability and application-oriented learning in IoT tasks.

H3: P2BL will improve teamwork, communication, and innovation skills as evidenced through pitch, hackathon, and prototype expo evaluations.

H4: Student engagement will act as a key mechanism linking P2BL participation to improved academic and professional outcomes.

Participants and Grouping Criteria

The study was conducted with second-year undergraduate students enrolled in the *IoT Sensors and Devices* course in the Department of Electronics and Communication Engineering. A total of 123 students (N = 123) participated in the study. They were divided into two sections: a targeted group (n = 60) that experienced the Project and Problem-Based Learning (P2BL) framework, and a control group (n = 63) that followed the conventional lecture-based and laboratory-oriented approach. Within each section, students were further organized into teams of 4–5 members for project-related activities. All students participated as part of the regular course requirement, ensuring that P2BL was included within the prescribed curriculum and syllabus structure.

P2BL Course Design

The P2BL framework was prepared to integrate both problem-solving and project-based activities within the course. Traditional lecture sessions introduced fundamental concepts of IoT sensors, interfacing techniques, communication protocols, and device applications. These were followed by laboratory sessions where students performed hands-on experiments aligned with lecture content. Building on these foundations, students engaged in idea pitching sessions, where teams proposed IoT-based solutions to real-world problems. Hackathon participation, designed to encourage competition-oriented growth with rapid prototyping and problem-solving under time constraints. Quizzes and sessional examinations, which assessed theoretical understanding and application. Prototype development and demonstration, encouraging in participation of project expo, where student teams showcased their working IoT solutions to faculty and external evaluators. A multi-modal assessment framework as shown in Table 1 was employed to evaluate the academic performance in P2BL process.

To provide clarity on project implementation, sample need statements were defined for students, such as: *environmental monitoring using low-cost IoT sensors, home automation for differently abled users, smart energy metering, and real-time safety alert systems*. These need statements ensured that projects aligned with the syllabus topics on sensors, interfacing, and communication protocols. For hackathon participation, students worked on problem themes released 24 hours beforehand—typically involving rapid prototyping using ESP32/NodeMCU, cloud dashboards (ThingSpeak/MQTT), and sensor data fusion. During prototype development, teams followed a structured workflow: identifying the problem, selecting sensor modules, designing circuits, programming microcontrollers, and validating the prototype through field or lab testing. Faculty mentors provided checkpoints to ensure that each stage connected back to the course learning outcomes.

The IoT Sensors and Devices course is a 3-credit core subject in the second-year ECE curriculum, comprising two lecture hours and two laboratory hours per week. The syllabus covers sensor characteristics, transducers, analog and digital interfacing, communication protocols (UART, SPI, I2C), microcontroller programming, wireless modules, and IoT applications. P2BL activities were mapped directly to these syllabus components without modifying the officially approved curriculum. Laboratory experiments were aligned with lecture topics, and the pitch–hackathon–prototype cycle was included as part of the internal evaluation scheme, ensuring full compliance with the university's structured curriculum.

Data Collection and Analysis

Data was collected through both quantitative and qualitative sources. Quantitative data included student scores across quizzes, labs, pitches, hackathons, and prototype expos, compiled into a composite performance index (CPI). Qualitative data were obtained from student reflections, peer evaluations, and evaluator feedback during the expo. These data were analyzed to examine the effectiveness of the P2BL framework in enhancing problem-solving, teamwork, and innovation skills. Descriptive statistics were used to summarize performance trends, while thematic analysis of qualitative feedback provided insights into student engagement and perceived benefits.

TABLE I
ASSESSMENT TOOLS IN P2BL FRAMEWORK

Assessment Tool	Purpose
Sessional Examinations & Quizzes	Theoretical Understanding
Regular Laboratory sessions	Practical skills and problem - solving
Pitch Presentation & Hackathon	Feasible solution, teamwork, and communication
Prototype development	Technical soundness
Peer / Faculty review	Teamwork experiences & Challenges

The analysis was conducted using a mixed-methods approach to capture both quantitative performance scores out of 100 for each assessment and qualitative parameters from students' learning experiences. The quantitative analysis involved student scores from quizzes, sessional examinations, laboratory rubrics, idea pitching, hackathon participation, and prototype evaluation that were compiled into a CPI value. The weightage of each tool is shown in Table 2. This CPI score is adopted here as it captures holistic performance across all assessments and makes statistical tests simpler instead of testing 5 separate variables. By analysing with CPI score, each component can still be analyzed separately if required.

TABLE II
ASSESSMENT TOOLS VS THEIR WEIGHTAGE

Assessment Tool	Weightage in %
Sessional Examinations & Quizzes	30
Regular Laboratory sessions	20
Pitch Presentation & Hackathon	20
Prototype Expo	30
Total CPI score	100

Descriptive statistics (mean, standard deviation, frequency distributions) were first used to summarize performance trends across the different assessment modes. To evaluate the impact of P2BL, comparative analyses were conducted. Independent-samples t-tests were applied where data from non-P2BL class was available for comparison. One-way ANOVA was employed to examine differences between groups (e.g., teams, gender, prior GPA levels) while controlling for baseline academic performance. Correlation analysis was used to explore relationships between different assessment modes (e.g., lab performance vs prototype creativity).

Qualitative data were drawn from student reflections, peer feedback, and evaluator comments from the project expo. A thematic coding approach was applied. Initial open coding was performed to identify recurring themes (e.g., teamwork, motivation, challenges, creativity). Codes were clustered into broader categories aligned with course learning outcomes (problem-solving, teamwork, innovation, communication). Representative student quotes were extracted to illustrate key themes. Triangulation with quantitative findings was performed to provide a comprehensive view of student learning experiences.

The combined analysis allowed for both statistical evidence of P2BL effectiveness and qualitative narratives that presents student learning gains. This integration ensured a holistic evaluation of the P2BL framework in the *IoT Sensors and Devices* course.

IV. RESULTS

To ensure reliability, internal consistency of assessment instruments was calculated. Cronbach's alpha for quiz items was $\alpha = 0.82$ and for laboratory rubrics was $\alpha = 0.85$, indicating strong reliability. Pitch, hackathon, and prototype evaluations were conducted by two independent evaluators; inter-rater reliability (Cohen's $\kappa = 0.79$) demonstrated substantial agreement. The descriptive statistics of student performance across different assessment components are presented in Table 3 and the comparison of P2BL and non-P2BL group is shown in fig.2. In the Quiz scores, the P2BL group (M = 78.4, SD = 8.2) outperformed the control group (M = 72.9, SD = 9.1). The higher mean score indicates that P2BL students had stronger conceptual understanding and retention of IoT fundamentals. Similarly, in Laboratory performance, P2BL students scored notably higher (M = 90.2, SD = 6.5) compared to the control group (M = 82.7, SD = 7.8). This suggests that P2BL contributed to improved practical skills, accuracy, and problem-solving in hands-on experimentation.

The Composite Performance Index (CPI), which integrates multiple assessments, was nearly identical between the two groups (P2BL: M = 73.7, SD = 7.4; Control: M = 73.9, SD = 6.7). This finding indicates that while P2BL enhanced performance in specific components such as quizzes and labs, the overall CPI did not differ significantly, possibly because the control group was evaluated only on conventional components, while P2BL students had additional tasks (pitching, hackathon, prototype expo) that added both opportunities and challenges.

Within the P2BL-specific assessments (Fig. 2), students demonstrated strong performance in Pitch & Hackathon activities (M = 81.0, SD = 7.2) and Prototype Expo (M = 85.6, SD = 6.1). These results highlight that P2BL fostered innovation, creativity, and teamwork, enabling students to successfully design and demonstrate IoT-based solutions. Overall, the results show that P2BL students achieved higher performance in theoretical and practical components (quiz and lab) compared to their lecture-based peers, while also excelling in innovation-driven activities such as pitching, hackathons, and prototype demonstrations—components absent in the control group. These findings are consistent with (Gunawan et al., 2025) and (Chang et al., 2024), who reported that project-based learning enhances higher-order cognitive skills, teamwork, and innovation capacity in undergraduate engineering education. Independent-samples t-tests revealed that the P2BL group of students performed significantly better than the lecture-based control group in both quizzes and laboratory assessments. In quizzes, P2BL students (M = 78.4, SD = 8.2) outscored their peers (M = 72.9, SD = 9.1), $t(118) = 3.50$, $p = 0.001$, indicating stronger conceptual understanding. Similarly, in laboratories, P2BL students (M = 90.2, SD = 6.5) achieved higher scores than the control group (M = 82.7, SD = 7.8), t (118) = 5.80, $p < 0.001$, demonstrating enhanced practical problem-solving and execution skills. In contrast, no significant difference was found in the Composite Performance Index (CPI), where P2BL (M = 84.5, SD = 5.9) and Control (M = 84.2, SD = 6.2) obtained similar results, t (118) = 0.15, p = 0.88. This outcome reflects that while P2BL improved performance in specific components, the inclusion of additional

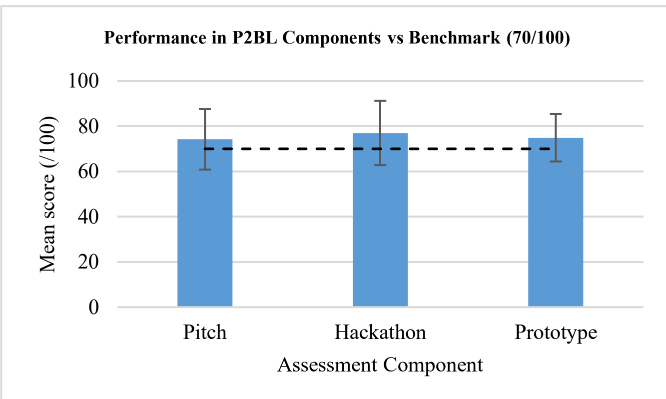

Fig. 3. Performance in Pitch, Hackathon, and Prototype vs Benchmark

authentic tasks such as pitching, hackathons, and prototype expos balanced the overall index. From the Table 4, it is confirmed that P2BL enhances both theoretical and hands-on learning outcomes, while also expanding assessment opportunities beyond traditional coursework. One-sample t-tests were performed to compare P2BL student performance against the benchmark of 70/100 for all three innovation-focused assessments. Since the Pitch, Hackathon, and Prototype Expo assessments were conducted only in the P2BL section and had no equivalent activities in the control group, performance was compared against a predefined benchmark score of 70/100, representing the minimum level of satisfactory achievement commonly used in engineering education. This approach allowed us to evaluate whether students in the P2BL framework not only completed the tasks but also achieved performance levels significantly above the expected competency threshold.

For the pitch assessment, the P2BL group (M = 74.2, SD = 13.4, n = 60) scored significantly higher than the benchmark, $t(59) = 2.45$, $p = 0.009$ (one-tailed). This indicates that students demonstrated strong skills in presenting innovative IoT solutions through idea pitching. On Similarly, hackathon performance (M = 77.0, SD = 14.2) also exceeded the benchmark, $t(59) = 3.79$, $p < 0.001$, suggesting that students effectively collaborated and problem-solved in time-constrained, real-world scenarios. The prototype scores (M = 74.9, SD = 10.5) were also significantly higher than the

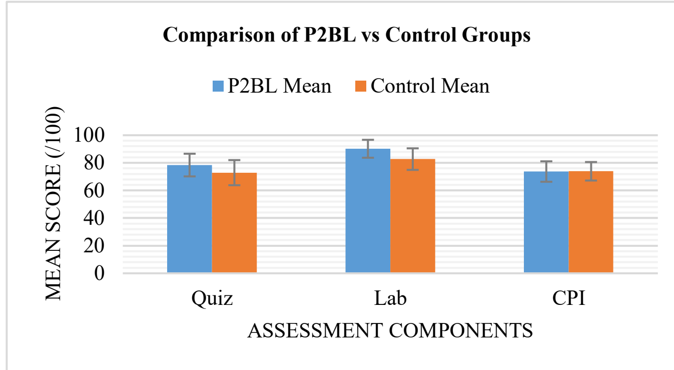

Fig. 2. Comparison of P2BL vs Control Groups

benchmark, $t(59) = 3.64$, $p < 0.001$. This demonstrates that most student teams were able to successfully integrate technical and creative aspects into functional IoT prototypes.

TABLE III
DESCRIPTIVE STATISTICS OF STUDENT PERFORMANCE

Assessment Component	Group	N	Mean	SD	Min	Max
Quiz	P2BL	60	78.4	8.2	60.0	97.0
	Control	63	72.9	9.1	50.0	96.0
Lab	P2BL	60	90.2	6.5	75.0	100
	Control	63	82.7	7.8	65.0	96.0
CPI	P2BL	60	73.7	7.4	58.2	93.2
	Control	63	73.9	6.7	57.0	89.0
Pitch & Hackathon	P2BL	60	81.0	7.2	62.0	95.0
Prototype Expo	P2BL	60	85.6	6.1	70.0	96.0

TABLE 1V
INDEPENDENT SAMPLE T-TESTS FOR P2BL AND CONTROL GROUPS

Assessment	Group	N	Mean	SD	t (df)	p-value
Quiz (/100)	P2BL	60	78.4	8.2	t (118) =3.50	0.001
	Control	63	72.9	9.1		
Lab (/100)	P2BL	60	90.2	6.5	t (118) =5.80	<0.001
	Control	63	82.7	7.8		
CPI (/100)	P2BL	60	84.5	5.9	t (118) =0.15	0.88
	Control	63	84.2	6.2		

Fig. 3. illustrates the mean scores obtained in the Pitch, Hackathon, and Prototype assessments, with error bars representing standard deviations. The dashed line indicates the benchmark of 70/100. As shown, the mean scores for all three components were above the benchmark, with Hackathon performance showing the largest margin.

TABLE V
CORRELATION OF PREDICTORS WITH PROJECT EXPO COMPONENT

Predictor vs Prototype Expo	r	t	p-value
Quiz	0.30	2.8	0.008
Lab	0.40	3.3	0.002
Pitch & Hackathon	0.80	9.8	<0.001

Correlation analysis within the P2BL cohort (n = 60) indicated that Prototype performance was strongly predicted by Pitch scores (r = 0.80, t = 9.8, p < .001), demonstrating a very strong positive association. Lab performance was moderately correlated with Prototype quality (r = 0.40, t = 3.3, p = .002), while Quiz scores showed a weaker but still significant relationship (r = 0.30, t = 2.8, p = .008). These findings suggest that innovation-driven activities such as pitching contributed most to final prototype quality, followed by practical laboratory skills, while theoretical quiz performance was a weaker predictor.

Simple linear regression equations were derived to examine how the assessments predicted final prototype performance. The regression of Prototype on Quiz & SE is given in (1).

$$prototype = 44.7 + 0.385\ Quiz \qquad (1)$$

Indicating that each one-point increase in Quiz & SE score was associated with a 0.39-point rise in Prototype score. For Laboratory scores, it is given in (2) that showed a stronger predictive effect, with each additional Lab point contributing 0.65 to the Prototype score.

$$prototype = 16.6 + 0.646\ Lab \qquad (2)$$

The Pitch & Hackathon assessment exhibited the highest predictive power, as in (3) explaining 64% of the variance (R^2 = 0.64).

$$prototype = 28.4 + 0.627\ Pitch \qquad (3)$$

These regression models highlight the differential role of assessments in enhancing prototype as one of the major components in P2BL process. While quizzes showed only a modest predictive relationship with prototypes, laboratory performance demonstrated a moderate contribution, underscoring the value of hands-on skills. The Pitch assessment emerged as the strongest predictor, suggesting that teams who articulated their ideas clearly and originally were more likely to deliver successful prototypes. This finding reinforces the view that unique, effective communication tasks within P2BL are crucial in bridging conceptual learning with innovative product development.

TABLE VI
ONE-WAY ANOVA RESULTS FOR PROTOTYPE SCORES

Factor	Groups Compared	Group Means	F(df)	p-value
GPA Band	Low	70.3	F (2,57) = 1.61	0.209
	Medium	77.6		
	High	79.3		
Gender	Male	75.0	F (1,64) = 2.17	0.146
	Female	80.1		

One-way ANOVAs were conducted to examine whether prototype performance differed across GPA bands or gender. Results shown in Table 6 indicate no significant effect of GPA, F (2,57) = 1.61, p = .209, despite a trend of higher means for medium- and high-GPA students. Similarly, gender-based differences were not statistically significant, F (1,64) = 2.17, p = .146, although female students (M = 80.1) scored slightly higher on average than male students (M = 75.0). These findings suggest that P2BL provided equitable prototype outcomes regardless of prior academic performance or gender.

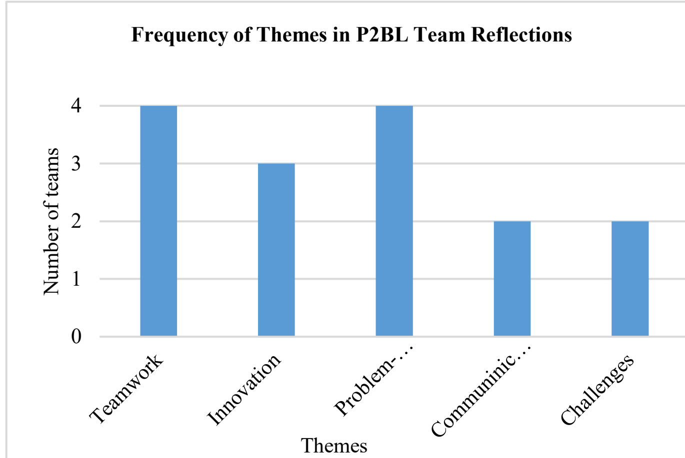

Fig. 4. Frequency of Themes in P2BL Team Reflections

Thematic analysis (Fig.4.) of reflections and feedback from 15 P2BL teams revealed four recurring themes: teamwork, innovation, problem-solving, and challenges, with communication emerging as a cross-cutting element across all activities. Students frequently emphasized the role of teamwork in facilitating collaboration and efficiency. For example, one team noted, *"Working in teams made us feel like a real engineering group,"* while another reflected, *"Dividing tasks by strengths improved team efficiency."* These comments align with the quantitative results where laboratory and peer-based tasks showed significant improvements for the P2BL cohort.

Innovation was another strong theme, particularly linked to hackathon and pitch activities. Teams described these experiences as stimulating creativity under time pressure (*"The hackathon pushed us to be more creative under time pressure"*) and encouraging originality (*"We realized the importance of innovation and originality in engineering work"*). This finding resonates with the correlation analysis, which showed that Pitch scores strongly predicted Prototype quality (r = 0.80).

Problem-solving was highlighted in reflections on prototype development and lab work. As one student stated, *"Prototype development helped us connect theory with practical application,"* underscoring the observed quantitative gain in laboratory performance. Challenges such as resource limitations and time management were also mentioned (*"Managing hackathon time taught us discipline"*), which explain the variability seen in prototype outcomes despite overall positive performance.

The results from both sections are presented separately. The P2BL group (n = 60) outperformed the control group (n = 63) in both Quiz and Laboratory components. As shown in Table 3, the P2BL group achieved higher Quiz scores (M = 78.4, SD = 8.2) than the control group (M = 72.9, SD = 9.1). Similarly, laboratory performance was higher for the P2BL section (M = 90.2, SD = 6.5) compared to the control section (M = 82.7, SD = 7.8). Independent-samples t-tests confirmed that these differences were statistically significant for Quiz, t(118) = 3.50, p = .001, and Laboratory performance, t(118) = 5.80, p < .001.

The CPI, however, showed no significant difference between the two groups (P2BL: M = 84.5, SD = 5.9; Control: M = 84.2, SD = 6.2), t(118) = 0.15, p = .88. This indicates that although the P2BL group performed better in conceptual and practical components, the inclusion of additional innovation-based assessments (pitch, hackathon, prototype) balanced the overall CPI.

Overall, the qualitative evidence triangulates with the quantitative analysis, showing that P2BL not only improved measurable outcomes in quizzes and labs but also fostered teamwork, creativity, and resilience in authentic project-based tasks.

V. DISCUSSION

The findings of this study offer important implications for engineering education, particularly in large Indian classrooms where practical exposure and innovation-driven activities are limited. The outcomes directly address the four research hypotheses (H1–H4), aligning each with measurable evidence and community benefits.

RQ1: Does P2BL enhance academic performance in IoT courses?

The higher quiz and laboratory scores demonstrate improved conceptual understanding and hands-on proficiency. This provides evidence that P2BL strengthens foundational knowledge essential for IoT-based industries and student readiness for internships .

RQ2: How does P2BL influence applied learning, problem-solving, and prototyping?

Innovation-focused assessments (pitch, hackathon, prototype expo) show that students not only understood IoT concepts but also used them to create functional solutions. This is critical for community-centered innovations such as smart agriculture, health monitoring, and campus automation systems.

RQ3: What professional competencies does P2BL develop?

Qualitative reflections revealed gains in teamwork, communication, creativity, and time-bounded problem-solving—skills highly sought by industry. Pitch scores being the strongest predictor of prototype performance indicates the importance of articulation and solution framing.

RQ4: How does student engagement mediate learning outcomes?

Frequent references to motivation, role distribution, and peer collaboration support the role of engagement as a mediator in P2BL success. This suggests that P2BL not only improves performance but also builds confidence and self-directed learning.

The P2BL model enables engineering graduates to propose community-relevant IoT solutions, addressing problems such as environmental monitoring, safety, healthcare, and energy conservation. The structured multimodal assessment ensures replicability across institutions, aiding nationwide efforts toward skill-based engineering education reform.

CONCLUSION

This study evaluated the impact of Project and Problem-Based Learning (P2BL) in the *IoT Sensors and Devices* course with respect to four hypothesized outcomes. H1 predicted that P2BL students would achieve higher overall performance than those taught traditionally. While P2BL students demonstrated significantly stronger outcomes in quizzes and laboratory assessments, the composite index was statistically similar across groups, indicating that P2BL advantages were concentrated in specific components rather than uniformly across all measures.

Consistent with H2, P2BL enhanced students' problem-solving and application-oriented learning, as evidenced by improved laboratory scores and reflections emphasizing hands-on experimentation and troubleshooting. H3 was strongly supported, with significant gains in pitch, hackathon, and prototype expo tasks, where students displayed teamwork, communication, and innovation. These authentic assessments also showed strong predictive relationships with prototype quality, particularly for pitch performance.

Finally, H4 was partially supported as qualitative evidence highlighted student engagement—through teamwork, motivation, and creativity—as a central factor connecting P2BL experiences with successful outcomes. Although engagement was not directly measured quantitatively, reflections and evaluator feedback consistently pointed to its mediating role in bridging course activities with enhanced professional skills.

Overall, the findings indicate that P2BL provides clear benefits in applied learning, teamwork, and innovation while offering equitable outcomes across academic and demographic groups. Embedding P2BL within existing curricula can therefore strengthen both academic performance and professional skill development in engineering education.

REFERENCES

Aisyah, S., & Novita, D. (2025). Teachers' perception of the implementation of project-based learning in early childhood education in Indonesia. Cogent Education, 12(1). https://doi.org/10.1080/2331186X.2025.2458663

Ashraf, M. H., Özpolat, K., Yalcin, M. G., & Shah, P. (2025). A project-based learning approach to supply chain mapping education. The International Journal of Management Education, 23(2), 101128. https://doi.org/10.1016/j.ijme.2024.101128

Boakye-Yiadom, F., Donkor, E. K., & Mensah, R. O. (2025). Exploring the role of project-based learning in higher education to promote indigenous knowledge through sculpture students' engagement with Ghanaian Adinkra symbols. Discover Global Society, 3(1), 4.

https://doi.org/10.1007/s44282-024-00135-8

Chang, Y., Choi, J., & Şen-Akbulut, M. (2024). Undergraduate Students' Engagement in Project-Based Learning with an Authentic Context. Education Sciences, 14(2), 168. https://doi.org/10.3390/educsci14020168

Fernandes, M. A. (2017). Project-based learning applied to an embedded systems course. International Journal of Electrical Engineering & Education, 54(3), 223–235. https://doi.org/10.1177/0020720916675830

Gunawan, W., Atiqoh, A., Wiyarno, Y., Fatirul, A. N., Sugiarni, S., & Mastoah, I. (2025). Enhancing Students' Problem-Solving Abilities: The Role of Project-Based Learning, Problem-Based Learning, and Learning Motivation. Jurnal Pendidikan Progresif, 15(1), 315–330. https://doi.org/10.23960/jpp.v15i1.pp315-330

Gutierrez-Berraondo, J., Iturbe-Zabalo, E., Arregi, N., & Guisasola, J. (2025). Influence on Students' Learning in a Problem- and Project-Based Approach to Implement STEM Projects in Engineering Curriculum. Education Sciences, 15(5), 534. https://doi.org/10.3390/educsci15050534

Hidayah, R. (2025). The Creativity Skills of Students in PjBL and CPjBL Model: An Experimental Study. Pakistan Journal of Life and Social Sciences (PJLSS), 23(1). https://doi.org/10.57239/PJLSS-2025-23.1.00219

Khan, M., Ibrahim, M., Wu, N., & Patil, R. (2020). Interdisciplinary Project Based Learning Approach for Machine Learning and Internet of Things. 2020 IEEE Integrated STEM Education Conference (ISEC), 1–6. https://doi.org/10.1109/ISEC49744.2020.9280619

Kong, S.-C., Cheung, M.-Y. W., & Tsang, O. (2024). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. Computers and Education: Artificial Intelligence, 6, 100214. https://doi.org/10.1016/j.caeai.2024.100214

Köpeczi-Bócz, T. (2024). The Impact of a Combination of Flipped Classroom and Project-Based Learning on the Learning Motivation of University Students. Education Sciences, 14(3), 240. https://doi.org/10.3390/educsci14030240

Lavado-Anguera, S., Velasco-Quintana, P.-J., & Terrón-López, M.-J. (2024). Project-Based Learning (PBL) as an Experiential Pedagogical Methodology in Engineering Education: A Review of the Literature. Education Sciences, 14(6), 617. https://doi.org/10.3390/educsci14060617

Lin, K.-Y., Wu, Y.-T., Hsu, Y.-T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. International Journal of STEM Education, 8(1), 1. https://doi.org/10.1186/s40594-020-00258-9

Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: how teachers implement projects in K-12 science education. Disciplinary and Interdisciplinary Science Education Research, 4(1), 2. https://doi.org/10.1186/s43031-021-00042-x

Maros, M., Korenkova, M., Fila, M., Levicky, M., & Schoberova, M. (2023). Project-based learning and its effectiveness: evidence from Slovakia. Interactive Learning Environments, 31(7), 4147–4155. https://doi.org/10.1080/10494820.2021.1954036

Mohammed, A., Zegeye, R., Dawed, H., & Tessema, Y. (2024). Implementation of Problem-Based Learning in Undergraduate Medical Education in Ethiopia: An Exploratory Qualitative Study. Advances in Medical Education and Practice, Volume 15, 105–119. https://doi.org/10.2147/AMEP.S443384

Naseer, F., Tariq, R., Alshahrani, H. M., Alruwais, N., & Al-Wesabi, F. N. (2025). Project based learning framework integrating industry collaboration to enhance student future readiness in higher education. Scientific Reports, 15(1), 24985. https://doi.org/10.1038/s41598-025-10385-4

Noguez, J., & Neri, L. (2019). Research-based learning: a case study for engineering students. International Journal on Interactive Design and Manufacturing (IJIDeM), 13(4), 1283–1295. https://doi.org/10.1007/s12008-019-00570-x

Perifanou, M., & Economides, A. A. (2025). Collaborative Uses of GenAI Tools in Project-Based Learning. Education Sciences, 15(3), 354. https://doi.org/10.3390/educsci15030354

Ricaurte, M., & Viloria, A. (2020). Project-based learning as a strategy for multi-level training applied to undergraduate engineering students. Education for Chemical Engineers, 33, 102–111. https://doi.org/10.1016/j.ece.2020.09.001