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Project-Based Learning in Malaysian Pre-University Mechanical Engineering: A Descriptive Survey of Lecturer Facilitation and Student Participation

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ABSTRACT

Project-based learning (PjBL) is widely promoted in engineering education because it connects disciplinary knowledge with authentic design activity, collaboration, technical problem solving, documentation, and reflective learning. However, implementation quality depends not only on assigning students a project, but also on how lecturers facilitate learning and how students participate in the project process. This article reports a single-site descriptive survey of PjBL implementation in the second-semester mechanical engineering design project at Kolej Matrikulasi Kejuruteraan Kedah, Malaysia. The study involved 52 mechanical engineering students from the 2022/2023 academic session who completed a 19-item Malay-language questionnaire adapted from a prior PjBL implementation framework. Descriptive analysis showed high perceived lecturer facilitation ($M = 4.58$) and high student participation ($M = 4.68$), with an overall dimension-based implementation mean of 4.63. Student participation was especially strong in information searching, report writing, workshop activity, lecturer consultation, expert engagement, and project presentation. Lecturer facilitation was also rated highly for discussion, guidance, technical support, monitoring, and assessment. The main implementation weakness was lecturer encouragement to complete projects ($M = 3.44$, $SD = 1.62$), suggesting that motivational scaffolding was less consistent than technical and procedural support. The article contributes a context-specific implementation profile of PjBL in Malaysian pre-university mechanical engineering and argues that technically strong project supervision should be complemented by systematic motivational, autonomy-supportive, and formative feedback practices. The findings should be interpreted as descriptive implementation evidence rather than causal evidence of PjBL effectiveness.

Keywords: Project-Based Learning; Engineering Education; Mechanical Engineering; Matriculation Programme; Lecturer Facilitation; Student Participation; Motivational Scaffolding; Malaysia

INTRODUCTION

Engineering education is increasingly expected to prepare learners not only to remember disciplinary knowledge, but also to apply knowledge to uncertain design situations, communicate decisions, manage practical constraints, and collaborate in problem-solving environments. Recent reviews of engineering education argue that active and experiential pedagogies such as problem-based learning, project-based learning, and challenge-based learning have become central to this shift because they require learners to engage with authentic tasks and integrated competencies (Chen et al., 2021; Lavado-Anguera et al., 2024; Sukacke et al., 2022). Evidence from STEM education also suggests that active learning can improve participation and learning opportunities when the activities are deliberately designed and supported (Nguyen et al., 2021; Theobald et al., 2020).

Project-based learning (PjBL) is particularly relevant to engineering because engineering work normally involves iterative problem definition, design decision making, fabrication or modelling, testing, documentation, teamwork, and presentation to evaluators or stakeholders (Guo et al., 2020; Helle et al., 2006; Prince & Felder, 2006). Recent systematic reviews emphasise that PjBL can support cognitive, affective, professional, and real-world skills, but they also caution that its benefits depend strongly on implementation design, instructor facilitation, assessment practices, and institutional support (Chen et al., 2021; Guo et al., 2020; Lavado-Anguera et al., 2024; Ramirez de Dampierre et al., 2024). Thus, the existence of a project task does not by itself guarantee high-quality PjBL.

The Malaysian Matriculation Programme provides a pre-university pathway for students preparing for bachelor-level study at higher education institutions, including students intending to progress into science and engineering fields (Government of Malaysia, n.d.). Within the engineering matriculation context, the mechanical engineering subject at engineering matriculation colleges has incorporated PjBL in the second-semester design project since 2010. In this curriculum component, students undertake a design project that contributes to continuous assessment, requiring them to combine technical reasoning, practical workshop activity, reporting, consultation, and presentation.

Despite the long-standing use of PjBL in this setting, there is limited empirical evidence on the level of PjBL implementation in engineering matriculation colleges, particularly in relation to the roles enacted by lecturers and students. This gap matters because PjBL implementation quality depends on the interaction between structured lecturer facilitation and active student participation (Chen et al., 2021; Nguyen et al., 2021; Sukacke et al., 2022). If lecturers provide technical advice but insufficient motivational support, or if students complete projects without meaningful agency, the curriculum may be labelled as project-based without fully realising the pedagogical value of PjBL.

The central problem addressed in this article is therefore not whether PjBL exists in the curriculum, but how students perceive the implementation roles of lecturers and learners in an actual mechanical engineering project. This distinction is important because recent reviews of PjBL and engineering education call for stronger attention to implementation processes, evaluation models, instructor roles, and learner participation, not only to final performance outcomes (Chen et al., 2021; Guo et al., 2020; Ramirez de Dampierre et al., 2024). A descriptive implementation profile can help institutions identify which elements of PjBL are working well and which require targeted improvement.

The aim of the study is to examine the perceived level of PjBL implementation in a Malaysian pre-university mechanical engineering setting based on lecturer facilitation and student participation. The study is guided by two research questions: first, what is the perceived level of lecturer facilitation in the implementation of PjBL? Second, what is the perceived level of student participation in the implementation of PjBL? The article contributes by providing descriptive empirical evidence from an underrepresented pre-university engineering context, by presenting a consistent role-based implementation profile of lecturer facilitation and student participation, and by identifying motivational scaffolding as a practical priority for improving PjBL quality.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Project-Based Learning in Engineering Education

PjBL is commonly defined as an active and student-centred pedagogy in which learners acquire and apply knowledge through sustained work on meaningful projects. Unlike short classroom exercises, PjBL normally involves an extended task, a problem or design challenge, inquiry activity, collaboration, product development, reflection, and presentation (Blumenfeld et al., 1991; Krajcik & Blumenfeld, 2006). In engineering education, this approach is frequently valued because it resembles professional practices in which technical knowledge must be applied to real or simulated design constraints (Lavado-Anguera et al., 2024; Pereira et al., 2017; Prince & Felder, 2006).

The literature portrays PjBL as promising but implementation-sensitive. Guo et al. (2020) found that higher education PjBL research commonly measures affective, cognitive, and behavioural outcomes, but also noted that questionnaire-based measures of student perceptions remain common. Chen et al. (2021) reviewed engineering PBL/PjBL implementation and showed that challenges occur at teacher, student, institutional, and cultural levels. Lavado-Anguera et al. (2024) further argued that engineering PjBL contributes to real-world skills when linked to professional environments, integrated curricula, interdisciplinarity, technology, and sustainability. These reviews support the need to examine how PjBL is enacted in specific contexts rather than assuming that all project activities represent equivalent implementation quality.

Recent engineering education literature also emphasises that active learning requires deliberate instructional design. Sukacke et al. (2022) argued that teachers adopting active learning methods must move from teacher-centred delivery towards the role of instructional designers of student-centred education. Ramirez de Dampierre et al. (2024) similarly highlighted the need for evaluation models that can assess implementation, competencies, and improvement cycles in PjBL and CDIO-related engineering programmes. For a pre-university mechanical engineering project, these arguments imply that PjBL should be evaluated not only by whether students produce a project, but also by whether facilitation, participation, feedback, and assessment practices are sufficiently structured.

For pre-university learners, PjBL has additional pedagogical value because it can introduce students to engineering design before they enter degree-level study. Students can experience how abstract concepts become meaningful through design decisions, fabrication, documentation, and communication. At the same time, pre-university learners may lack mature project-management, workshop, documentation, and self-regulation skills. This makes lecturer facilitation and student participation especially important for ensuring that PjBL is challenging but not pedagogically unsupported (Chen et al., 2021; Nguyen et al., 2021; Sukacke et al., 2022).

Lecturer Facilitation, Scaffolding, and Feedback

A common misconception is that student-centred learning reduces the importance of the lecturer. In high-quality PjBL, the lecturer's role becomes less transmissive but more pedagogically complex. Lecturers must design or refine project conditions, clarify expectations, guide students without removing ownership, provide technical and procedural support, facilitate discussion, monitor progress, and assess both process and product (Helle et al., 2006; Nguyen et al., 2021; Sukacke et al., 2022). In this sense, the lecturer functions as facilitator, coach, scaffold, feedback provider, and evaluator.

Scaffolding theory is particularly relevant to this role. Vygotsky's (1978) account of learning through social interaction and the zone of proximal development suggests that learners can perform beyond their independent capability when supported by more knowledgeable others. Wood et al. (1976) further conceptualised scaffolding as support that enables learners to complete tasks they could not yet complete alone. In PjBL, scaffolding may include guiding questions, project milestones, technical demonstrations, safety reminders, formative feedback, and structured opportunities for reflection (Blumenfeld et al., 1991; Hattie & Timperley, 2007; Krajcik & Blumenfeld, 2006).

Feedback is another central component of lecturer facilitation. Hattie and Timperley (2007) argued that feedback is most useful when it helps learners understand learning goals, current progress, and next steps. In PjBL, feedback is not limited to final grading; it should occur during planning, design, fabrication, documentation, and presentation preparation (Ramirez de Dampierre et al., 2024). This is consistent with active-learning implementation literature showing that instructors need explanation, facilitation, and planning strategies to reduce uncertainty and support positive student responses (Nguyen et al., 2021).

Lecturer facilitation also has a motivational dimension. Self-determination theory proposes that learners are more likely to sustain engagement when learning environments support autonomy, competence, and relatedness (Deci & Ryan, 2000; Ryan & Deci, 2020). Recent meta-analytic evidence indicates that SDT-based educational interventions can support autonomy, competence, and intrinsic motivation (Wang et al., 2024). In PjBL, this suggests that technical guidance alone is insufficient; students also need encouragement, confidence-building, meaningful choice, and acknowledgement of effort as they encounter uncertainty, project setbacks, and time pressure.

Student Participation and Agency in PjBL

Student participation in PjBL includes active involvement in project selection or refinement, information searching, consultation, teamwork, workshop activity, written reporting, engagement with external expertise, and presentation of project outcomes. These behaviours matter because PjBL depends on learners doing the intellectual, social, and practical work of inquiry and production (Guo et al., 2020; Krajcik & Blumenfeld, 2006; Lavado-Anguera et al., 2024). A project that is almost entirely lecturer-directed may produce a physical artefact, but it may not cultivate learner agency, self-regulation, or professional confidence.

Student agency should not be treated as an assumed characteristic. It is a capability that develops through structured opportunities and appropriate support. Students who are new to open-ended engineering design may need help interpreting project requirements, locating credible information, planning tasks, managing time, handling tools safely, documenting design decisions, and communicating outcomes (Chen et al., 2021; Nguyen et al., 2021). High student participation therefore does not mean the absence of lecturer support; rather, it may indicate that support has enabled learners to take active roles.

The relationship between lecturer facilitation and student participation is reciprocal. Lecturer scaffolding can strengthen student agency, while active student participation gives lecturers evidence of where further guidance is needed (Helle et al., 2006; Sukacke et al., 2022). Effective PjBL implementation is therefore best understood as a coordinated interaction between structured support and learner responsibility. This article adopts that interactional view in interpreting lecturer-role and student-role indicators.

CONCEPTUAL FRAMEWORK

The conceptual framework for this article integrates social constructivism, scaffolding theory, self-determination theory, formative feedback, and engineering-oriented PjBL. Figure 1 depicts the expected relationship among the engineering design project, lecturer facilitation, student participation, and perceived PjBL implementation quality. Table 1 is retained as an operationalisation table for the two measured dimensions.

The framework assumes that implementation quality is shaped by two interacting role dimensions. Lecturer facilitation includes discussion, guidance, technical support, monitoring, encouragement, feedback, and assessment. Student participation includes project ownership, information searching, workshop activity, expert engagement, lecturer consultation, reporting, and presentation. These dimensions are interpreted as role-based indicators of implementation quality, not as direct measures of learning achievement or causal impact (Guo et al., 2020; Ramirez de Dampierre et al., 2024).

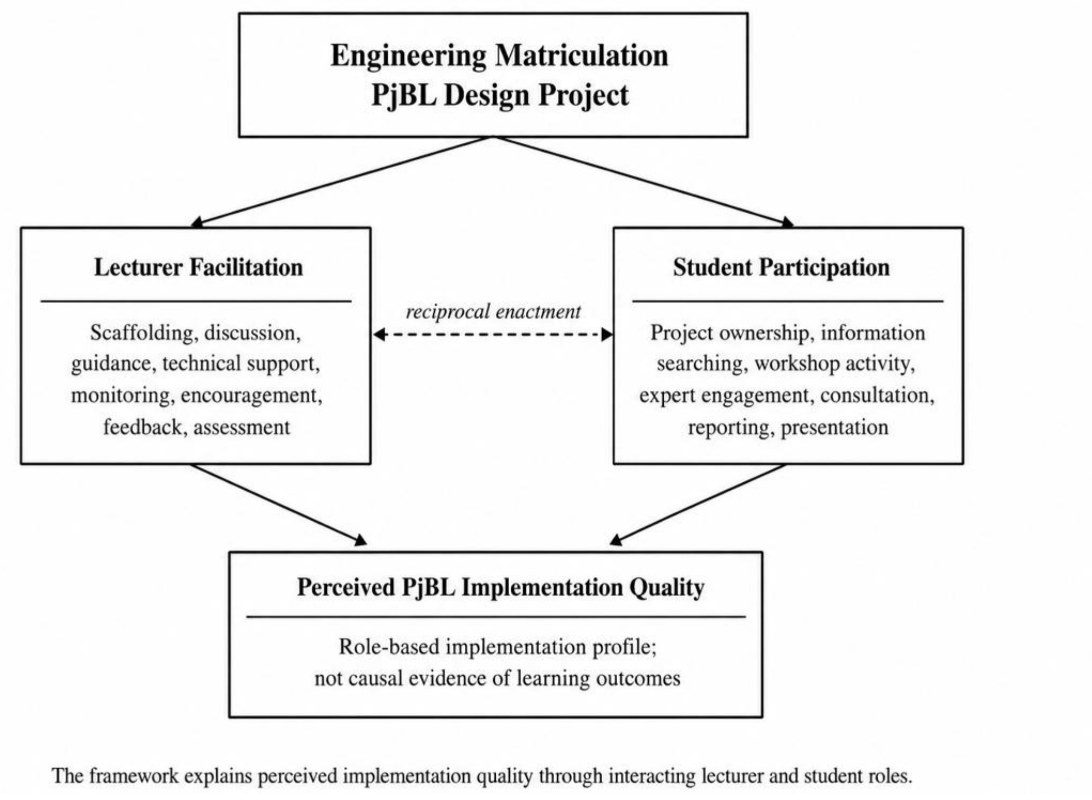

Figure 1. Conceptual framework of perceived PjBL implementation in pre-university mechanical engineering

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The framework positions lecturer facilitation and student participation as mutually reinforcing dimensions within a mechanical engineering design project. It explains perceived implementation quality, not causal learning outcomes. This distinction is important because the present study uses descriptive self-report data and does not include direct measures of design quality, achievement, or competence development.

Table 1. Operationalisation of PjBL implementation dimensions in the study

Dimension	Implementation focus	Theoretical interpretation
Lecturer facilitation	Discussion, guidance, technical support, monitoring, encouragement, feedback, and assessment	Scaffolding, formative feedback, autonomy support, and social mediation of learning
Student participation	Project selection, information searching, workshop activity, expert engagement, lecturer consultation, reporting, and presentation	Student agency, active learning, collaborative knowledge construction, and authentic engineering participation
Implementation profile	Combined pattern of lecturer and student roles in the design project	Role-based evidence of how PjBL is enacted in a specific institutional setting

METHODOLOGY

Research Design and Setting

The study used a descriptive quantitative survey design. This design was appropriate because the purpose was to profile students' perceptions of PjBL implementation rather than to test causal effects, compare experimental groups, or evaluate learning outcomes. Descriptive implementation studies can be useful when an instructional approach is already embedded in a curriculum and the immediate research need is to identify perceived strengths and weaknesses in enactment (Creswell & Creswell, 2018; Guo et al., 2020; Ramirez de Dampierre et al., 2024).

The setting was Kolej Matrikulasi Kejuruteraan Kedah (KMKK), a Malaysian engineering matriculation college. The focal activity was the second-semester mechanical engineering design project, which formed part of the continuous assessment structure. The project required students to engage in design-related tasks, obtain guidance from lecturers, participate in practical workshop activity, prepare reports, and present project outcomes to evaluators. The study is therefore best understood as a single-site descriptive implementation survey embedded in an institutional case context.

Participants and Sampling

The respondents were 52 second-semester mechanical engineering students from the 2022/2023 academic session who had direct experience of the PjBL design project. The sample was treated as an accessible whole-cohort implementation sample within the institutional context rather than as a probability sample intended to represent all engineering matriculation students in Malaysia. This framing is methodologically more appropriate than claiming broad statistical generalisability from a single-site sample (Creswell & Creswell, 2018).

The study's sampling logic was purposive and context-bound: students were selected because they were the relevant participants who had experienced the project-based learning activity being examined. The findings should be interpreted as an institutional implementation profile and as a basis for practice improvement, not as evidence that can be generalised without qualification to all matriculation colleges or engineering programmes. This caution is consistent with recent PjBL reviews that emphasise contextual variation in implementation and evaluation (Chen et al., 2021; Guo et al., 2020; Lavado-Anguera et al., 2024).

Instrument and Measures

Data were collected using a Malay-language questionnaire adapted from the PjBL implementation framework developed by Mohd Noramdzan Mohd Yusof (2021). The instrument contained 19 items organised into two dimensions: lecturer role and student role. Eleven items measured students' perceptions of lecturer facilitation, including assistance, discussion, guidance, project selection support, encouragement, technical expertise, monitoring, and assessment. Eight items measured student participation, including discussion with lecturers, project-title responsibility, information searching, report writing, workshop work, collaboration with experts, lecturer consultation, and presentation of project outcomes.

Responses were recorded using a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Mean scores were interpreted using three levels: low, moderate, and high. The instrument's content relevance is supported by its alignment with a prior PjBL implementation framework and with the actual roles expected in the mechanical engineering design project (Mohd Noramdzan Mohd Yusof, 2021). Accordingly, the findings are interpreted cautiously as descriptive implementation indicators rather than as psychometrically validated scale scores.

As the available dataset consisted of aggregated item-level statistics, reliability coefficients, confidence intervals, factor structure, and item-total correlations could not be recalculated. The analysis is therefore limited to descriptive item-level and construct-level implementation patterns (Creswell & Creswell, 2018; Guo et al., 2020).

Table 2. Instrument structure

Dimension	Items	Number of items	Response scale
Lecturer role	Items 1-11	11	1 = strongly disagree to 5 = strongly agree
Student role	Items 12-19	8	1 = strongly disagree to 5 = strongly agree

Data Collection and Analysis

The questionnaire was administered using Microsoft Forms, and the survey link was distributed through the relevant student communication channel. Responses were exported to Microsoft Excel for descriptive analysis. For each item, the mean and standard deviation were calculated. Construct means were then computed by averaging all reported item means within each dimension. The lecturer-role dimension was based on 11 items, and the student-role dimension was based on eight items. The overall implementation profile was calculated as the unweighted average of the two construct means, with an additional item-weighted mean reported for transparency.

No inferential statistics were conducted because the study was not designed to compare groups or test hypotheses. The analysis therefore remains descriptive and should be interpreted as an implementation profile. This analytic choice is appropriate because PjBL implementation research often involves context-specific evaluation, and stronger causal claims would require comparison groups, longitudinal data, direct outcome measures, or mixed-methods triangulation (Guo et al., 2020; Ramirez de Dampierre et al., 2024).

Table 3. Interpretation of mean scores

Mean range	Interpretation
1.00-2.33	Low
2.34-3.66	Moderate
3.67-5.00	High

Note. The interpretation categories follow Mohd Noramdzan Mohd Yusof (2021).

Validity, Reliability, Trustworthiness, and Ethics

The study's validity is primarily supported through content alignment. The questionnaire items were derived from a prior framework on PjBL implementation among engineering students and reflected the lecturer and student roles involved in the mechanical engineering design project. Item-level reporting further strengthens interpretive transparency because readers can identify both strong and weaker implementation indicators rather than relying only on overall means (Mohd Noramdzan Mohd Yusof, 2021; Ramirez de Dampierre et al., 2024).

Nevertheless, the available aggregated data do not allow recalculation of internal consistency, exploratory factor analysis, item-total correlations, or confidence intervals. For this reason, the study is positioned as a descriptive implementation survey rather than a validation study. Future studies should retain and analyse raw response data so that reliability and construct validity evidence can be reported (Creswell & Creswell, 2018; Guo et al., 2020).

Ethically, the study involved student survey responses concerning an educational activity. Participation was voluntary, responses were analysed in aggregate form, and student identities were protected. The study is therefore presented as a low-risk educational survey of perceived PjBL implementation.

RESULTS

Lecturer Role in PjBL Implementation

The lecturer-role dimension recorded a high perceived implementation level, with an overall mean of 4.58. Students rated lecturer discussion with students as the strongest item (M = 4.77, SD = 0.54), followed by lecturer assistance in solving project problems and lecturer assessment of projects (both M = 4.73). These results suggest that students perceived lecturers as actively involved in guiding, monitoring, technically supporting, and evaluating the design project. This pattern is consistent with PjBL literature emphasising that instructors remain central to planning, facilitation, feedback, and assessment even in student-centred learning environments (Nguyen et al., 2021; Sukacke et al., 2022).

The lowest lecturer-role item was lecturer encouragement for students to complete the project (M = 3.44, SD = 1.62), which falls within the moderate level and also shows the widest dispersion. This pattern is substantively important. It indicates that students generally perceived strong technical and procedural facilitation, but their perceptions of motivational encouragement were less consistent. The item is therefore treated as the main implementation-improvement signal in the study, particularly because motivation and autonomy support are central to sustained engagement in challenging learning tasks (Ryan & Deci, 2020; Wang et al., 2024).

Table 4. Mean and standard deviation for lecturer role in PjBL implementation

Item	Lecturer role indicator	Mean	SD	Level
1	Lecturers helped students solve project problems	4.73	0.56	High
2	Lecturers helped students obtain external information, including internet sources	4.62	0.59	High
3	Lecturers discussed with students to complete the project	4.77	0.54	High
4	Lecturers provided guidance in completing the project	4.69	0.61	High
5	Lecturers helped students prepare the written report	4.67	0.54	High
6	Lecturers acted as facilitators in completing the project	4.67	0.58	High
7	Lecturers helped students choose the project	4.69	0.57	High
8	Lecturers encouraged students to complete the project	3.44	1.62	Moderate
9	Lecturers used technical expertise to help students complete the project	4.67	0.54	High
10	Lecturers monitored project progress	4.63	0.59	High
11	Lecturers evaluated the project well	4.73	0.48	High
Construct mean		**4.58**		**High**

Student Role in PjBL Implementation

The student-role dimension also recorded a high perceived implementation level. Based on the eight reported item means, the student-role construct mean is 4.68. This value is consistent with the item-level results, all of which ranged from 4.60 to 4.71. The highest-rated student-role items were information searching, report writing, and workshop activity (each M = 4.71, SD = 0.49). These findings indicate that students perceived themselves as actively involved in both intellectual and practical components of the design project, which aligns with the active participation expected in authentic PjBL (Guo et al., 2020; Lavado-Anguera et al., 2024).

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The lowest student-role item was responsibility for selecting the project title (M = 4.60, SD = 0.63), but this result still falls within the high level. The narrow range of item means suggests a consistently positive participation profile across consultation with lecturers, collaboration with experts, written reporting, workshop practice, and project presentation. Student participation marginally exceeded lecturer facilitation, indicating that students perceived themselves as active contributors to the PjBL process rather than passive recipients of lecturer direction.

Table 5. Mean and standard deviation for student role in PjBL implementation

Item	Student role indicator	Mean	SD	Level
12	Students discussed with lecturers to complete the project	4.69	0.54	High
13	Students were responsible for selecting the project title	4.60	0.63	High
14	Students searched for information in the project-completion process	4.71	0.49	High
15	Students prepared the written project report	4.71	0.49	High
16	Students conducted workshop tasks such as welding during project completion	4.71	0.49	High
17	Students cooperated with experts during project implementation	4.69	0.50	High
18	Students met lecturers throughout project completion	4.67	0.51	High
19	Students presented project outcomes to evaluators	4.65	0.51	High
	Construct mean	**4.68**		**High**

Note. The student-role mean was computed from the eight reported item means: (4.69 + 4.60 + 4.71 + 4.71 + 4.71 + 4.69 + 4.67 + 4.65) / 8 = 4.68.

Overall PjBL Implementation Profile

The overall dimension-based mean for PjBL implementation was 4.63, indicating a high level of implementation. The lecturer-role mean was 4.58, while the student-role mean was 4.68. This pattern suggests a strongly enacted PjBL environment in which students perceived both substantial lecturer facilitation and active student participation. Student participation marginally exceeded lecturer facilitation, while the key improvement issue was located within the lecturer-facilitation dimension, specifically the variability and moderate rating for motivational encouragement.

Table 6. Overall PjBL implementation level

Implementation dimension	Mean	Level
Lecturer facilitation	4.58	High
Student participation	4.68	High
Overall dimension-based mean	4.63	High
Item-weighted mean across all 19 items	4.62	High

Note. The overall dimension-based mean is the unweighted average of the two construct means. The item-weighted overall mean across all 19 items is also reported for transparency; both calculations indicate a high implementation level.

DISCUSSION

A Strong Implementation Profile with Active Student Participation

The findings show that PjBL implementation in the KMKK mechanical engineering design project was perceived positively by students. Both lecturer facilitation and student participation were rated at a high level, with the student-role dimension slightly exceeding the lecturer-role dimension. This suggests that the project was not experienced merely as a lecturer-led assignment. Students perceived themselves as active participants in key PjBL processes, including searching for information, preparing written reports, undertaking workshop tasks, consulting lecturers, engaging with experts, and presenting outcomes. Such participation is consistent with core PjBL principles that emphasise inquiry, production, collaboration, reflection, and authentic communication (Blumenfeld et al., 1991; Guo et al., 2020; Krajcik & Blumenfeld, 2006).

This finding is important because authentic PjBL requires student participation across cognitive, practical, and communicative domains. The high ratings for information searching and report writing suggest that students engaged with knowledge-building and documentation processes. The high rating for workshop activity suggests that the learning experience included practical engineering engagement rather than being limited to theoretical discussion. The high rating for presentation indicates that students were required to communicate project outcomes to evaluators, a practice that aligns with the professional communication expectations of engineering education and the emphasis on real-world skills identified in recent engineering PjBL reviews (Lavado-Anguera et al., 2024; Ramirez de Dampierre et al., 2024; Sukacke et al., 2022).

At the same time, the result should be interpreted carefully. The study measures students' perceived participation, not independently observed participation quality or actual learning outcomes. High self-reported participation does not prove that all groups achieved equivalent design quality, technical competence, teamwork effectiveness, or conceptual understanding. This caution is consistent with Guo et al. (2020), who noted that PjBL studies often use perception-based affective measures, and with Ramirez de Dampierre et al. (2024), who called for stronger evaluation models in engineering PjBL. The value of the present finding lies in documenting that students perceived the structural opportunities for active participation as strong within this institutional setting.

Lecturer Facilitation as Technical and Procedural Scaffolding

The lecturer-role findings indicate that students viewed lecturers as important facilitators of the project process. High scores for discussion, guidance, project selection support, technical expertise, monitoring, report assistance, and assessment suggest that lecturers provided substantial technical and procedural scaffolding. This aligns with the view that effective PjBL requires carefully structured support, especially when learners are at a pre-university stage and may not yet have mature engineering design experience (Chen et al., 2021; Helle et al., 2006; Nguyen et al., 2021).

The strong rating for lecturer-student discussion is particularly meaningful. Discussion allows lecturers to diagnose misconceptions, prompt design reasoning, guide students towards credible information, and help teams make practical decisions. In mechanical engineering project work, discussion can also support safety, feasibility, material selection, workshop planning, and documentation quality. In this respect, the findings are consistent with social constructivist and scaffolding perspectives, which emphasise learning through guided interaction with more knowledgeable others (Vygotsky, 1978; Wood et al., 1976).

The high ratings for technical expertise and monitoring further suggest that lecturers contributed to implementation quality by keeping projects within feasible engineering and assessment boundaries. This is especially important in pre-university engineering contexts, where students need enough autonomy to learn through project work but also enough structure to avoid unsafe, unrealistic, or poorly documented project practices. Recent active-learning reviews show that instructor planning and facilitation strategies are crucial because students can respond negatively when active learning is poorly explained, insufficiently guided, or weakly organised (Nguyen et al., 2021; Sukacke et al., 2022).

The Motivational Scaffolding Gap

The most important improvement signal in the results is the lecturer encouragement item. Although the overall lecturer-role dimension was high, encouragement recorded only a moderate mean and the largest standard deviation. This pattern indicates an uneven motivational experience: some students may have felt well encouraged, whereas others may have perceived encouragement as insufficient or inconsistent. The finding is analytically valuable because it prevents the article from making a simplistic claim that all aspects of implementation were equally strong.

The difference between technical support and motivational support can be understood through self-determination theory. Students may receive adequate guidance on how to complete a task, but they also need learning conditions that support competence, autonomy, and relatedness (Deci & Ryan, 2000; Ryan & Deci, 2020). Encouragement contributes to these psychological needs by helping students persist through uncertainty, view setbacks as part of design learning, and feel that their effort is recognised. Recent meta-analytic evidence further suggests that SDT-based interventions in education can improve students' intrinsic motivation, autonomy, and competence, which makes motivational support relevant to educational design rather than merely interpersonal preference (Wang et al., 2024).

The practical implication is that lecturer professional development should not focus only on project supervision, technical advice, and assessment procedures. It should also include motivational scaffolding strategies such as structured progress affirmation, autonomy-supportive questioning, constructive feedback after setbacks, group-level encouragement, and reflection prompts that help students recognise learning progress. Such strategies are consistent with active-learning implementation guidance that emphasises explanation, facilitation, and planning to support student affective and behavioural responses (Nguyen et al., 2021). Strengthening this area may improve the consistency of students' PjBL experience even when technical facilitation is already strong.

Positioning the Study within the Wider PjBL Literature

The findings are broadly consistent with literature suggesting that PjBL can support active learning and professional skill development when implementation is well structured. Reviews of PjBL in higher education and engineering education have shown that project work is associated with cognitive, affective, behavioural, and professional outcomes, but they also caution that implementation quality varies considerably across contexts (Chen et al., 2021; Guo et al., 2020; Lavado-Anguera et al., 2024). The present study contributes by showing how role-based implementation indicators can identify both strengths and weaknesses within a functioning PjBL curriculum.

The study also differs from research that focuses mainly on learning outcomes. Rather than claiming that PjBL improved achievement or competence, this article focuses on implementation conditions. This narrower claim is appropriate because the study does not include pre-test/post-test data, comparison groups, rubric-based design scores, or longitudinal tracking. This analytic restraint strengthens the credibility of the article because the conclusions remain aligned with the available descriptive data and with calls for better implementation evaluation in engineering PjBL (Guo et al., 2020; Ramirez de Dampierre et al., 2024).

This interpretation contributes to the wider PjBL literature by showing that role-based implementation profiles can identify both strong participation structures and specific areas requiring pedagogical improvement. In this case, the central implementation issue concerns the need to complement strong technical and participatory structures with more consistent motivational scaffolding. Other institutions may use a similar role-based profile to examine whether PjBL implementation is technically supported, motivationally supportive, and participatory.

Contributions

Theoretical and Conceptual Contribution

The study contributes to PjBL scholarship by extending discussion of implementation quality to a Malaysian pre-university mechanical engineering setting, a context that remains less visible than school-based, university-based, or degree-level engineering PjBL research. Conceptually, it integrates the original role-based PjBL implementation framework with social constructivism, scaffolding theory, self-determination theory, and formative feedback. This integration clarifies that PjBL implementation should be understood through the interaction between lecturer facilitation, student participation, technical guidance, learner agency, motivational support, and assessment practices (Chen et al., 2021; Guo et al., 2020; Ryan & Deci, 2020; Wang et al., 2024).

Practical, Institutional, and Policy Contribution

Practically, the study identifies a strongly perceived implementation profile in which lecturers provided substantial technical and procedural support while students reported active participation in information searching, workshop activity, reporting, expert engagement, consultation, and presentation. At the same time, the moderate and highly variable rating for lecturer encouragement highlights motivational scaffolding as the key area for improvement. For lecturers and curriculum leaders, the findings suggest that effective PjBL support should combine technical supervision, formative feedback, structured milestones, autonomy-supportive questioning, consistent encouragement, and transparent assessment. For institutions and policy makers, the study shows the value of monitoring PjBL through role-based implementation indicators rather than assuming quality from the presence of a project component alone (Nguyen et al., 2021; Ramirez de Dampierre et al., 2024; Sukacke et al., 2022).

Methodological and Future Research Contribution

Methodologically, the study demonstrates how a modest single-site descriptive survey can generate useful implementation evidence when the claims are carefully bounded. The article uses item-level and construct-level descriptive indicators to identify implementation strengths and improvement priorities, providing a baseline for future multi-site studies across Malaysian engineering matriculation colleges. Future research should add raw-data reliability analysis, construct validation, student interviews, classroom or workshop observations, project artefact assessment, and outcome measures so that implementation profiles can be linked more directly to learning quality and engineering competencies (Creswell & Creswell, 2018; Guo et al., 2020; Ramirez de Dampierre et al., 2024).

Implications

Academic Implications

Academically, the article shows the importance of distinguishing implementation evidence from outcome evidence. PjBL research should not assume that project activities automatically produce learning gains. Instead, researchers should examine how projects are enacted, which lecturer and student roles are present, and where implementation weaknesses occur (Chen et al., 2021; Guo et al., 2020). The item-level profile used in this study offers a practical way to identify such patterns and to avoid overly general claims about PjBL effectiveness.

Practitioner Implications

For practitioners, the findings support the continuation of structured facilitation practices in the mechanical engineering design project. Lecturers should maintain strong discussion, guidance, monitoring, technical support, report assistance, and assessment practices. At the same time, they should strengthen motivational scaffolding by providing consistent encouragement, autonomy-supportive feedback, and progress-focused dialogue. This is especially important when students face technical setbacks, group-management problems, or uncertainty about project feasibility (Nguyen et al., 2021; Ryan & Deci, 2020; Wang et al., 2024).

Institutional and Policy Implications

At institutional level, PjBL should be supported through lecturer development, clear assessment rubrics, workshop access, project milestone schedules, and mechanisms for formative feedback. Policy makers should avoid treating PjBL as a simple curriculum label. Instead, implementation guidelines should specify the expected facilitation, participation, feedback, assessment, and quality-monitoring practices required for high-quality project work (Ramirez de Dampierre et al., 2024; Sukacke et al., 2022). Periodic implementation audits can help institutions maintain quality and identify areas for improvement.

Societal Implications

At a broader level, strengthening PjBL in pre-university engineering education can help prepare students for disciplines and occupations that require adaptability, collaboration, communication, technical problem solving, and creativity. While the present study does not measure these outcomes directly, the high participation profile suggests that students were exposed to learning activities relevant to such competencies. This implication should be treated as pedagogically plausible rather than empirically proven, consistent with the article's descriptive design and with the wider literature on active learning and engineering skills (Lavado-Anguera et al., 2024; Theobald et al., 2020).

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

Limitations

Several limitations must be acknowledged. First, the study was conducted in a single engineering matriculation college and involved 52 mechanical engineering students. The findings provide a useful institutional implementation profile, but they should not be generalised to all matriculation colleges or engineering programmes without further evidence. Recent reviews of PjBL in engineering education emphasise that implementation varies by course, curriculum, project type, institutional support, and culture (Chen et al., 2021; Lavado-Anguera et al., 2024).

Second, the study relied on self-reported student perceptions. Such data are useful for understanding perceived implementation quality, but they may be influenced by response bias, social desirability, student satisfaction, or limited awareness of alternative PjBL models. The results should therefore be complemented in future studies with classroom observation, lecturer interviews, project artefact analysis, and assessment rubrics (Guo et al., 2020; Ramirez de Dampierre et al., 2024).

Third, the available data were aggregated at item level, which prevented recalculation of reliability coefficients, confidence intervals, factor structure, item-total correlations, and subgroup analyses. The findings should therefore be read as descriptive implementation indicators rather than as evidence from a validated psychometric scale or an effectiveness evaluation.

Fourth, the study measured perceived implementation roles rather than direct learning outcomes. It therefore cannot establish whether high perceived lecturer facilitation and student participation led to stronger technical competence, design quality, critical thinking, teamwork, motivation, or academic achievement. The findings should be read as evidence of implementation profile, not as proof of learning impact (Guo et al., 2020; Ramirez de Dampierre et al., 2024).

Fifth, the study records do not report a formal ethics approval or exemption reference number. This limitation is relevant to transparency, although the study involved a low-risk educational survey, voluntary participation, aggregate reporting, and protection of student identities.

Future Research Directions

Future research should replicate the study across multiple engineering matriculation colleges in Malaysia to determine whether the implementation profile observed at KMKK is typical or context-specific. A larger multi-site sample would allow stronger reliability testing, construct validation, subgroup comparison, and potentially multivariate analysis. Such work would respond to current calls for more robust implementation and evaluation models in engineering PjBL (Chen et al., 2021; Ramirez de Dampierre et al., 2024).

Future studies should also connect PjBL implementation indicators with objective or rubric-based outcomes such as design quality, technical documentation, oral presentation performance, problem-solving capability, teamwork, creativity, and academic achievement. Longitudinal research would be especially valuable for examining whether pre-university PjBL experience supports students' transition into engineering degree programmes (Guo et al., 2020; Lavado-Anguera et al., 2024).

Mixed-methods research would further strengthen understanding of the motivational scaffolding gap identified in this study. Interviews or focus groups could explore why some students perceived lecturer encouragement less positively and what kinds of encouragement they find most useful during project work. Such evidence would support more precise lecturer development and curriculum improvement, especially when guided by self-determination theory and active-learning facilitation strategies (Nguyen et al., 2021; Ryan & Deci, 2020; Wang et al., 2024).

CONCLUSION

This study examined students' perceptions of PjBL implementation in the second-semester mechanical engineering design project at Kolej Matrikulasi Kejuruteraan Kedah. The findings show high perceived implementation for both lecturer facilitation (M = 4.58) and student participation (M = 4.68), with an overall dimension-based implementation mean of 4.63. These results suggest that the project environment was perceived as strongly supportive of active student participation and structured lecturer facilitation.

The article's main contribution lies in providing a transparent, context-specific implementation profile of PjBL in Malaysian pre-university mechanical engineering. The findings show that student participation was one of the strongest dimensions of the implementation profile. The most important area for improvement is lecturer encouragement, which received a moderate and highly variable rating despite strong scores for technical support, guidance, discussion, monitoring, and assessment.

Overall, the study contributes a focused implementation profile of PjBL in a Malaysian pre-university engineering context. Its value lies in documenting how lecturer facilitation and student participation are enacted in a specific institutional setting, while identifying motivational scaffolding as a practical priority for strengthening PjBL quality. Future institutional improvement should therefore preserve the strong technical and participatory structures already evident in the programme while strengthening consistent encouragement, autonomy-supportive feedback, and formative dialogue throughout the project cycle.

Declarations

Ethics approval and consent to participate: The study involved a low-risk educational survey. Participation was voluntary, responses were analysed in aggregate form, and student identities were protected.

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Data availability: De-identified raw data are not publicly available due to institutional and ethical restrictions. Aggregated descriptive data are reported in this article.

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