

# Integrating Problem-Based Learning and Practical Learning: A Mixed-Methods Study of First-Year Engineering Students' Self-Efficacy, Peer Evaluation, and Academic Adjustment

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**Abstract:** *This exploratory mixed-methods study examined the experiences of first-year engineering students in integrating problem-based learning (PBL) and practical learning. It also explored how these experiences relate to students' self-efficacy, peer evaluation, and early academic adjustment. The study involved 16 first-year engineering students enrolled in two project-based courses. Quantitative analyses assessed the reliability and construct validity of self-, peer-, and team-evaluation instruments, while qualitative data from 32 semi-structured interviews were analyzed using thematic analysis. The qualitative findings revealed several recurring themes, including authentic engagement in problem exploration, collaborative idea development, peer interaction, and emerging academic confidence. Quantitative results showed a relatively strong alignment between self-assessment and peer-assessment scores, whereas the relationship between individual self-perceptions and team-level evaluations was more variable. Given the small sample size and single-institution context, these findings should be interpreted with caution. Nevertheless, the study offers valuable insights into how integrated PBL and practical learning environments may enhance collaborative engagement and knowledge application among first-year university students. The implications for instructional design and multi-source evaluation practices in project-based learning contexts are discussed.*

**Keywords:** Problem-Based Learning; Practical Learning; Self-Efficacy; Peer Assessment; First-Year Students; Engineering Education

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## 1. Introduction

The first year of university represents a critical transition period for students' academic persistence and social integration in higher education. During this stage, students encounter new learning environments, increased academic autonomy, and unfamiliar social contexts. These adjustments can often lead to academic maladjustment, including reduced self-efficacy and limited interaction with faculty members. Such challenges are widely recognized as factors associated with lower academic persistence and delayed career development [1, 2]. In recent years, these transitional difficulties have been further intensified by the expansion of remote and non-face-to-face instruction during the COVID-19 pandemic, which has been linked to declines in student engagement and self-directed learning capacity [3].

At M University, a specialized institution located in M City, the adjustment process of first-year students is influenced by several distinctive institutional characteristics. One of the university's two major colleges requires students to wear uniforms and comply with relatively strict behavioral regulations. In addition, approximately 32.58% of newly admitted students come from metropolitan or special autonomous cities, which often requires relocation and adaptation to a new social and cultural environment [4]. These institutional and demographic factors, which are less common in general universities, may shape students' academic engagement and psychosocial adjustment in unique ways. Because successful adjustment during the first year has been

closely associated with student retention and institutional performance indicators, it represents a critical concern for universities.

At the same time, the rapid transformation associated with the Fourth Industrial Revolution (4IR) has intensified discussions about the competencies required for future learning and work. International policy reports emphasize self-directed learning and problem-solving ability as essential capacities for adaptability and lifelong learning in knowledge-based societies [5]. Within this context, Problem-Based Learning (PBL) has attracted considerable attention as a learner-centered instructional approach grounded in constructivist learning theory. A growing body of research suggests that PBL is often associated with improvements in students' autonomy, critical thinking, collaboration, and complex problem-solving abilities in higher education settings [6-10].

Alongside the growing adoption of PBL, practical learning—often described as hands-on or performance-based instruction—has become increasingly prominent in competency-based curricula. These instructional approaches provide opportunities for students to apply theoretical knowledge to authentic tasks and real-world contexts, which may in turn support early academic engagement and cognitive persistence among undergraduate learners [11, 12]. Prior studies in engineering education have reported that active learning strategies, including problem-based and hands-on instructional approaches, are associated with improvements in student learning outcomes and conceptual understanding [13]. For first-year students in particular, such approaches may contribute to the development of foundational academic self-efficacy and support their adjustment to university learning environments.

Despite substantial evidence demonstrating the educational benefits of problem-based learning, relatively little research has examined how PBL interacts with practical learning experiences to influence students' social and motivational development [14, 15]. This interaction may be especially important during the first year of university, when students are still developing academic confidence and forming new peer relationships.

The theoretical framework of this study draws on Bandura's social-cognitive theory of self-efficacy [16] and self-determination theory (SDT) [17]. Both perspectives emphasize the roles of autonomy, competence, and relatedness as important factors supporting motivation and learning. These theoretical foundations provide a useful lens for examining how integrated instructional approaches may influence students' perceptions of competence, collaborative experiences, and engagement in learning.

Building on these perspectives, the present study addresses several gaps in the existing literature. First, mixed-methods research examining the integration of PBL and practical learning remains limited. Second, relatively few studies have investigated multi-source evaluation systems that combine self-, peer-, and team-based assessments. Third, the alignment between instructional design, measurement tools, and analytical approaches within a constructivist framework has rarely been examined in a systematic manner.

Accordingly, the present study seeks to answer the following research questions:

- (a) How valid and reliable are the assessment tools used in PBL—practical learning environments?
- (b) How are self-, peer-, and team-assessment results related to one another?
- (c) How do students describe their learning experiences and developmental changes during these instructional activities?
- (d) How do qualitative findings help explain and contextualize the quantitative results?

## 2. Methods

### 2.1 Research Design

This study adopted a mixed-methods research design that integrates quantitative and qualitative approaches to examine how two instructional strategies—Problem-Based Learning (PBL) and practical learning—relate to students' academic self-efficacy, team engagement, and adjustment to the university environment. By combining statistical analysis with qualitative inquiry, the design was intended to provide a more comprehensive understanding of both measurable learning outcomes and students' experiential perspectives.

A sequential explanatory mixed-methods design was employed to first examine quantitative patterns and then use qualitative data to provide deeper interpretation of the findings [18]. In the initial phase, quantitative data were collected and analyzed to evaluate the reliability and construct validity of the assessment instruments. In the subsequent phase, semi-structured interviews were conducted with participating students to explore their learning experiences and perceptions in greater depth.

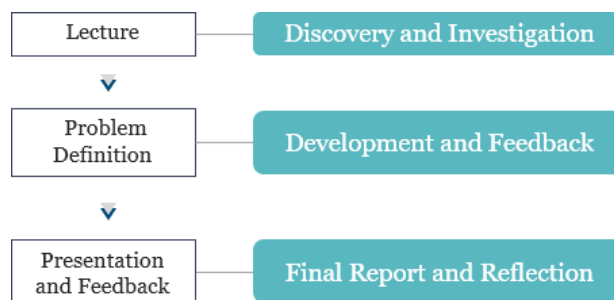
This two-stage design enabled the study to connect quantitative measurement results with qualitative insights derived from students’ narratives. All instruments and procedures were implemented using standardized protocols to support methodological transparency and reproducibility.

### 2.2 Participants and Instructional Context

The study involved 16 first-year undergraduate students majoring in engineering at M University in the Republic of Korea. All students were enrolled in two consecutive 15-week instructional modules offered during a single academic semester. The sample represented the full cohort of students registered in the program during the study period.

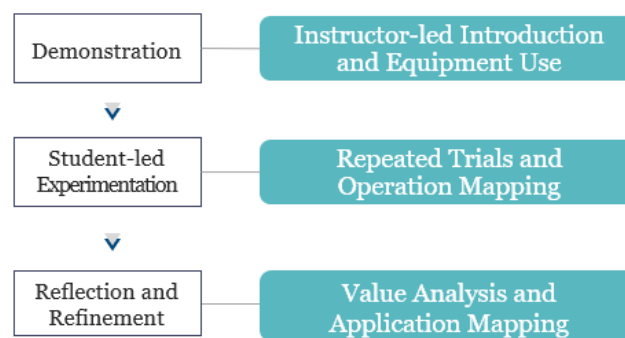
Among the participants, one student was female (6.3%), and the mean age of the group was 19.3 years. The low proportion of female participants reflects the gender composition of the cohort, as only one female student was enrolled in the program during the semester in which the study was conducted.

As part of the curriculum, students completed two mandatory project-based courses designed to integrate analytical and practical learning experiences. The first course, Applied Statistics, was delivered using a problem-based learning (PBL) approach. The instructional sequence involved problem identification, field investigation, hypothesis development, proposal preparation, presentation of results, and instructor feedback. The overall structure of the PBL instructional framework implemented in this course is illustrated in Figure 1.



**Figure 1.** PBL Framework

The second course, Smart Factory Lab, focused on practical learning activities emphasizing hands-on prototyping, iterative design processes, and collaborative problem solving among team members. Figure 2 presents the instructional framework of the practical learning process adopted in this course.



**Figure 2.** Practical Learning Framework

### 2.3 Assessment Tools

Three parallel Likert-type scales were developed to measure students’ perceptions of their learning experiences in the integrated PBL and practical learning environment. Each item was rated on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). The instruments were designed to capture three complementary dimensions of learning evaluation: self-assessment, peer assessment, and team evaluation.

The initial item pool consisted of 21 statements derived from previous studies on academic self-efficacy, collaborative learning, and peer evaluation in project-based learning contexts. To establish content relevance,

the items were reviewed by a panel of three faculty members with expertise in engineering education. Two rounds of expert review were conducted to refine the wording and eliminate redundant or ambiguous items.

Following expert validation, a pilot test was conducted with six students from a comparable engineering cohort to assess item clarity and response consistency. Based on the pilot feedback, minor revisions were made to improve wording and interpretability. The final instrument consisted of 18 items organized into three subscales.

The self-assessment scale (7 items) measured students' perceptions of their own contribution, engagement, and academic self-efficacy (e.g., "I actively contributed to problem-solving activities during the project").

The peer-assessment scale (7 items) evaluated team members' creativity, collaboration, and responsibility in group tasks (e.g., "This team member provided useful ideas for solving the problem").

The team evaluation scale (4 items) assessed students' evaluations of other teams' project outcomes in terms of logical structure, coherence, and practical applicability (e.g., "The presentation was logically organized and clearly explained").

Prior to the main analysis, the measurement properties of the scales were examined. Exploratory Factor Analysis (EFA) was conducted to assess construct validity, and internal consistency was evaluated using Cronbach's alpha. In addition, Pearson correlation analysis was performed to explore the relationships among the assessment dimensions.

Content validity was calculated using the Content Validity Index (CVI), which yielded a value of .92, indicating a high level of agreement among expert reviewers regarding the relevance of the measurement items.

#### 2.4 Qualitative Data Collection and Thematic Analysis

Two courses were implemented during the semester. The first course adopted a conventional seven-stage Problem-Based Learning (PBL) cycle [19], whereas the second course employed a studio-oriented practical learning model emphasizing iterative prototyping and collaborative design activities. All assessment instruments were administered after the completion of each course.

After the initial quantitative data collection, semi-structured individual interviews were conducted with each participant to obtain qualitative insights into students' learning experiences. Each student participated in two interviews over the course of the semester ( $n = 16$ ). The first interview was conducted prior to the final project presentations in order to capture students' reflections during the ongoing problem-solving process, whereas the second interview was conducted after the project presentations to explore students' perceptions of their learning outcomes and overall experience.

The interviews were designed to explore students' perceptions, learning challenges, and developmental reflections arising from their engagement in PBL and practical learning activities. Five guiding prompts were used to structure the interviews, drawing on cognitive processes associated with the revised Bloom's taxonomy. The interview questions are presented in Table 1.

**Table 1.** Interview Questions

No.	Semi-Structured Interview Questions
1	What aspects of the problem-identification process during your initial investigation were most significant or memorable to you?
2	How did you perceive the experience of formulating hypotheses or discussing solution strategies in response to the identified issue?
3	In what ways did your prior knowledge support or influence your approach to solving the problem?
4	Based on what you already knew, what additional questions or areas did you feel compelled to explore further?
5	How has this experience informed your future approach to similar tasks or problem-based projects?

The interview protocol was developed based on core elements of the PBL learning process, including problem diagnosis, knowledge exploration, and reflective redesign [19, 20]. All interviews were audio-recorded and subsequently transcribed for analysis.

Qualitative data were analyzed using thematic analysis following the six-phase procedure outlined by Braun and Clarke [21]. The analysis proceeded through six phases: familiarization with the data, initial coding, development of candidate themes, review of themes, definition and naming of themes, and narrative synthesis.

To enhance the credibility and trustworthiness of the qualitative findings, several strategies were employed, including investigator triangulation, the constant comparative method, and member checking with selected participants.

## 2.5 Quantitative Analysis, Qualitative Analysis and Integration

For the quantitative analysis, the internal consistency of the measurement scales was evaluated using Cronbach's  $\alpha$ , composite reliability (CR), and McDonald's  $\omega$ . Construct validity was examined through exploratory factor analysis (EFA) using maximum-likelihood extraction with oblimin rotation. The suitability of the data for factor analysis was assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity. Pearson correlation analysis with 95% confidence intervals was conducted to examine relationships among the assessment dimensions, providing additional interpretive context given the small sample size.

The qualitative dataset consisted of verbatim transcripts derived from the semi-structured interviews. In total, the interview corpus contained approximately 68,314 words. Thirty-two interviews were conducted (16 students  $\times$  2 sessions), each lasting approximately 15–16 minutes on average, producing roughly 2,135 words per interview.

The interviews were conducted at two points during the semester. The first interview took place prior to the final project presentations in order to capture students' reflections during the ongoing problem-solving and project development process. The second interview was conducted after the project presentations to examine students' perceptions of their learning outcomes and their overall experience in the integrated PBL and practical learning environment.

Qualitative data were analyzed using thematic analysis following the six-phase procedure outlined by Braun and Clarke [21]. The analysis proceeded through six phases: familiarization with the data, initial coding, development of candidate themes, review of themes, definition and naming of themes, and narrative synthesis. Two researchers independently coded the transcripts and compared their interpretations to ensure analytical consistency. Inter-coder reliability was high ( $\kappa = .84$ ), and thematic saturation was reached during the analysis of the eleventh transcript.

To integrate the quantitative and qualitative findings, a joint-display matrix was constructed. This matrix aligned quantitative domains with qualitative themes in order to facilitate meta-inferences regarding the learning processes observed in the integrated instructional model [22].

## 2.6 Ethical Considerations

The study protocol was reviewed and approved by the Institutional Review Board of M University (Approval No. 2025-01). All procedures complied with ethical standards for research involving human participants, and all identifying information was anonymized using alphanumeric codes.

## 3. Results

### 3.1 Quantitative Findings

#### 3.1.1 Reliability and Construct Validity

The internal consistency of the three assessment instruments—Self-Assessment, Peer-Assessment, and Team Evaluation—was examined using IBM SPSS Statistics 24. Cronbach's  $\alpha$  coefficients were calculated to evaluate the reliability of each scale.

As presented in Table 2, the Self-Assessment scale (7 items) and the Peer-Assessment scale (7 items) both yielded Cronbach's  $\alpha$  values of .94, indicating a high level of internal consistency. The Team Evaluation scale (4 items) showed slightly lower but still acceptable reliability, with item-level  $\alpha$  values ranging from .78 to .92 and an overall mean  $\alpha$  of .82.

Construct validity was examined using exploratory factor analysis (EFA). The Kaiser–Meyer–Olkin measure of sampling adequacy was .89, and Bartlett's test of sphericity was statistically significant ( $\chi^2 = 215.6$ ,  $df = 105$ ,  $p < .001$ ), indicating that the data were appropriate for factor analysis.

A single-factor solution was retained for each instrument. Factor loadings ranged from .71 to .88 across the three scales. Average communality values ranged between .52 and .67, suggesting that the extracted factor structures accounted for a meaningful proportion of variance in the observed variables. These results indicate

that the measurement instruments demonstrate acceptable reliability and construct coherence within the context of this exploratory study.

**Table 2.** Reliability and Factor Analysis Results of the Assessment Scales

Scale	Items	$\alpha$	CR	$\omega$	KMO	Bartlett $\chi^2$ (df)	Factor Loadings	Mean Communality	Variance Explained
Self-Assessment	7	.94	.95	.94	.90	294.1(21) p < .001	.71–.88	.67	62.8%
Peer-Assessment	7	.94	.95	.95	.88	276.4(21) p < .001	.72–.86	.63	71.5%
Team Evaluation	4	.82	.83	.83	.79	66.7(6) p < .001	.71–.85	.52	64.4%

All factor loadings exceeded .70, supporting the interpretability of a single-factor structure for each scale within this exploratory dataset.

### 3.1.2 Correlation Analysis

Pearson correlation analysis was conducted to examine relationships among the three assessment dimensions (Table 3).

A strong positive correlation was observed between Self-Assessment and Peer-Assessment scores ( $r = .82$ ,  $p < .001$ ), suggesting a high degree of alignment between students' self-perceptions and peer evaluations in the project context.

The relationship between Self-Assessment and Team Evaluation scores was moderate in magnitude ( $r = .47$ ) but did not reach statistical significance ( $p = .069$ ). Given the limited sample size ( $N = 16$ ), this result should be interpreted with caution.

A moderate positive relationship was also observed between Peer-Assessment and Team Evaluation scores ( $r = .53$ ,  $p = .032$ ), indicating that peer evaluations tended to correspond with perceptions of overall team performance.

Taken together, these results indicate a tendency toward convergence between self- and peer-evaluations within the present dataset while team-level evaluations appear to capture a somewhat distinct dimension of collaborative performance within the project environment.

**Table 3.** Correlations among Self-, Peer-, and Team-Assessment Scores

Relationship	r	95% CI	p
Self-Assessment – Peer-Assessment	.82	[.56, .94]	< .001
Self-Assessment – Team Evaluation	.47	[-.06, .79]	.069
Peer-Assessment – Team Evaluation	.53	[.02, .81]	.032

### 3.2 Qualitative Findings and Thematic Interpretation

The interview transcripts were analyzed using the six-phase thematic analysis procedure outlined by Braun and Clarke [21]. Through iterative coding and comparison of emerging patterns, five themes were identified that reflect students' experiences during the integrated PBL and practical learning activities. Pseudonyms (Student A–F) are used to maintain participant anonymity.

#### Theme 1: Authentic Engagement in Problem Exploration

Several students emphasized that the early stages of the project encouraged them to engage more directly with real-world problems. Field investigation and data collection exposed students to contextual complexities that were not immediately apparent during initial discussions. One participant described how encountering the real environment altered their understanding of the problem:

“When we started collecting information on site, we realized the situation was more complicated than we expected. Seeing the actual environment made us think more seriously about possible solutions.” (Student A)

These accounts suggest that the problem exploration phase contributed to a stronger sense of involvement in the learning task.

#### Theme 2: Collaborative Refinement of Ideas through Dialogue

Participants frequently described how discussions with teammates helped expand or refine their ideas. Initial proposals were often revised through dialogue with other group members. As one student noted:

“When someone suggested a different perspective, our original idea changed quite a lot. Talking together helped us see possibilities we had not considered before.” (Student B)

Such exchanges appeared to support the iterative development of project ideas and encouraged students to consider alternative approaches to the identified problem.

#### Theme 3: Application and Extension of Prior Knowledge

Students also reported drawing on previously learned knowledge when working on their projects. In particular, several participants described applying statistical tools or analytical techniques introduced in class. One participant explained:

“Using the statistical software we learned in class helped us organize our data. I also looked for additional tutorials online to understand the analysis better.” (Student C)

These experiences indicate that the project context provided opportunities for students to apply prior knowledge while extending their technical skills through additional self-directed learning.

#### Theme 4: Development of Social Connectedness

A number of participants highlighted the social dimension of the project activities. Working closely with peers over an extended period allowed students to develop stronger interpersonal relationships. One student reflected:

“Before this project I did not know many people in my class. Working together on the project helped us become more comfortable with each other.” (Student D)

Another participant noted that collaborative work sometimes helped resolve earlier interpersonal difficulties:

“At first I was unsure about working with one of my teammates, but during the project we started to understand each other better.” (Student E)

These comments suggest that team-based project activities contributed to the development of social connections among students.

#### Theme 5: Changes in Academic Confidence

Some participants reported that completing the project influenced their confidence in their academic abilities. For example, one student described reconsidering earlier academic plans after experiencing a successful project outcome:

“When our project worked out better than I expected, I started to think that I might be able to continue studying in this field.” (Student F)

Although such accounts represent individual experiences rather than general patterns, they illustrate how project participation may influence students’ perceptions of their own capabilities.

These qualitative findings provide insight into how students experienced the integrated learning activities. Several patterns emerged from the interviews. First, many participants described a heightened sense of engagement during the problem exploration process, particularly when projects involved direct interaction with real-world contexts. Second, collaborative discussions appeared to support the refinement of ideas by allowing students to consider multiple perspectives during hypothesis development and solution planning. Third, students frequently reported applying previously learned knowledge—such as statistical tools or software—to project tasks, sometimes extending their skills through additional self-directed learning. Fourth, team-based project work often contributed to the development of social connections among participants, which some students associated with a more positive perception of their first-year university experience. Finally, several students described increased confidence in their ability to participate in academic tasks following the completion of the project activities.

When considered alongside the quantitative results reported in Section 3.1, these qualitative accounts suggest a degree of convergence between students’ perceived individual contributions and peer evaluations within the project context. Rather than demonstrating direct instructional effects, the findings illustrate how students interpreted their experiences within the integrated PBL and practical learning environment.

### 3.3 Meta-Inference

To integrate the findings across methodological strands, a joint-display analysis was conducted linking the quantitative assessment patterns (SA-PA-TE) with the themes identified in the qualitative analysis. The alignment between self- and peer-assessment scores corresponds with interview accounts describing collaborative dialogue and shared evaluation of individual contributions during the projects.

From a theoretical perspective, several themes appear consistent with constructs commonly discussed in constructivist and self-determination frameworks, including autonomy in problem exploration, competence development through knowledge application, and relatedness through peer collaboration. These patterns do not establish causal relationships but suggest possible mechanisms through which integrated PBL and practical learning activities may support students' engagement in project-based learning contexts.

## 4. Discussion

This study examined how first-year engineering students experienced an instructional model that combines problem-based learning (PBL) with practical project activities. By integrating quantitative assessment data with qualitative interview findings, the analysis sought to better understand how students interpreted their individual engagement, peer collaboration, and team performance within this learning environment.

The quantitative findings indicated a strong positive relationship between self-assessment and peer-assessment scores. This pattern suggests that students' perceptions of their own contributions were generally consistent with the evaluations provided by their teammates. Similar tendencies have been reported in studies of collaborative learning environments, where peer feedback can support students in reflecting on their own participation and learning processes [23-25]. In particular, research on socially shared metacognition suggests that interaction among team members may contribute to shared monitoring of group progress and individual effort [23].

By contrast, the association between self-assessment and team evaluation was weaker and did not reach statistical significance. This result may indicate that students' perceptions of their own effort do not always correspond directly with judgments about overall team performance. Previous studies of team-based learning environments have suggested that individual participation and collective outcomes may be influenced by different factors, such as task coordination, group organization, and patterns of interaction among members [26, 27]. Consequently, the relationship between individual and team-level evaluations may be more complex than a simple linear association.

The moderate relationship observed between peer assessment and team evaluation provides additional insight into this dynamic. Peer evaluations often reflect observations of participation, communication, and cooperation within a team, which may also influence how group performance is perceived overall [24]. Studies on team interaction and collaborative metacognition similarly note that peer-based evaluation systems can capture aspects of team functioning that are not always visible through individual self-reports alone [27].

The qualitative findings help contextualize these statistical patterns. Many participants described becoming more engaged during the initial stages of problem exploration, particularly when projects required interaction with real-world contexts. Such experiences reflect a central principle of problem-based learning, in which students investigate authentic problems and construct understanding through inquiry and collaboration [19, 20]. Previous research has suggested that engagement with realistic problems may contribute to improvements in conceptual understanding and student motivation in higher education settings [6-8].

Students also highlighted the importance of discussion with teammates when refining ideas and considering potential solutions. Through dialogue, students often reconsidered their initial assumptions and incorporated alternative perspectives into their projects. This observation aligns with earlier research indicating that collaborative reasoning and negotiation are central elements of effective problem-based and project-based learning environments [10], [28].

In addition, several participants reported applying knowledge previously acquired in coursework while working on their projects. In some cases, students sought additional resources or tutorials to better understand the tools required for analysis. Such experiences suggest that project-based learning activities may provide opportunities for knowledge transfer and self-directed learning. Active learning research in engineering education has similarly found that hands-on tasks can facilitate deeper understanding when students are required to apply theoretical concepts in practical contexts [13, 14].

Another theme emerging from the interviews concerned the social dimension of the projects. Many participants described developing closer relationships with their peers during the collaborative process. For

students in their first year of university, such interactions may contribute to a stronger sense of belonging within the academic community. Previous studies have emphasized that peer interaction and social integration are important factors influencing students' early adjustment to university life [1-3].

Some students also noted that successfully completing the project influenced their confidence in their academic abilities. From a theoretical perspective, such experiences may be interpreted through Bandura's concept of mastery experiences as a key source of self-efficacy development [16]. Similarly, self-determination theory suggests that learning environments that support autonomy, competence, and relatedness can foster sustained motivation and engagement [17].

Taken together, the findings provide preliminary insight into how learning environments integrating PBL with practical project activities may relate to several aspects of early university learning. These include opportunities for collaborative engagement, application of prior knowledge, and the development of confidence in academic tasks. Prior meta-analytic research has also indicated that problem-based learning can contribute to improvements in critical thinking and learner autonomy compared with more traditional instructional approaches [7], [15].

From an instructional perspective, incorporating structured peer evaluation and collaborative project work into introductory engineering courses may provide students with opportunities to reflect on their own learning processes while participating in collective problem-solving. Such experiences may be particularly valuable during the first year of university, when students are still developing both academic skills and collaborative learning practices.

Finally, the exploratory nature of the present study highlights the need for further research. Studies involving larger samples and multiple institutional contexts may help clarify how integrated PBL and practical learning environments influence students' learning experiences and collaborative development over time [29]. Rather than providing definitive evidence of instructional effects, the present findings offer exploratory insights into how first-year students interpret collaborative project-based learning experiences in an integrated instructional setting. The findings should therefore be interpreted as exploratory observations derived from a small cohort rather than as evidence of generalizable instructional effects.

#### 4.1 Limitations and Future Research

Several limitations should be considered when interpreting the findings of this study.

First, the small sample size ( $N = 16$ ) limits the statistical power of the quantitative analyses and restricts the generalizability of the findings. Although the reliability and factor analyses suggested acceptable measurement properties, the exploratory nature of the study requires cautious interpretation of the observed relationships.

Second, the gender distribution of the sample was highly imbalanced, with only one female participant (approximately 6%). This reflects the gender composition of the cohort in the program during the study period but may influence interpretations of social interaction and collaboration patterns.

Third, the research was conducted at a single specialized institution. Institutional characteristics—including program structure and learning culture—may influence the observed patterns. Replication in other institutional contexts would therefore be valuable.

Finally, the study did not include a control group. As a result, the findings cannot establish causal relationships between the instructional approach and student outcomes. Future studies could employ quasi-experimental or longitudinal designs across multiple institutions to further examine how integrated PBL and practical learning environments influence students' academic development. Future studies involving larger samples and multiple institutional contexts may help clarify the extent to which these patterns are observed in broader engineering education environments.

## 5. Conclusions

This exploratory study examined how first-year engineering students experienced an instructional approach that integrates problem-based learning (PBL) with practical project activities. Using a mixed-methods design, the study examined patterns in multi-source assessment data alongside students' narrative accounts of their project experiences.

The quantitative results indicated a strong alignment between students' self-assessments and peer evaluations, while the relationship between individual self-perceptions and team-level evaluations appeared less

consistent. Although these patterns should be interpreted cautiously given the small sample size, they suggest that students' perceptions of their own contributions may not always correspond directly with evaluations of overall team performance.

The qualitative findings provided additional context for these patterns. Students frequently described becoming more engaged during the process of defining and exploring project problems, particularly when projects involved interaction with real-world contexts. Participants also emphasized the role of collaborative dialogue in shaping project ideas and reported applying previously learned knowledge while developing new skills through project activities. Several students further noted that working closely with peers contributed to the formation of social connections and, in some cases, increased confidence in their academic abilities.

Taken together, the findings illustrate how students interpreted their experiences within integrated PBL and practical learning activities during their first year of university, including collaborative engagement, application of knowledge, and the development of academic confidence. Rather than establishing causal instructional effects, the results highlight how students interpret and make meaning of project-based learning experiences within a team-based academic environment.

From a pedagogical perspective, the study suggests that incorporating structured peer feedback and collaborative project work into introductory engineering courses may offer opportunities for students to reflect on their learning processes while engaging in authentic problem-solving tasks. Such learning environments may be particularly relevant for first-year students who are still adapting to university-level study and collaborative learning practices.

Given the exploratory nature of the present study, future research should examine similar instructional models with larger samples and across multiple institutional contexts. Longitudinal designs may also help clarify how early project-based learning experiences influence students' academic development and collaborative competencies over time.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

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