The Effectiveness of Problem-Based Learning and Project-Based Learning on Cadet Problem-Solving Skills in Vocational Aviation Education

Parjan[1], Lady Silk Moonlight[2], Maulana Ania Silvia [3], Faoyan Agus Furyanto[4], Ahmad Musadek[5], Anton Budiarto[6]
[1,2,3,4,5,6] Politeknik Penerbangan Surabaya, Indonesia

Article Info

Article history:

Received : November 12, 2025
Revised : December 03, 2025
Accepted : December 24, 2025

Keywords:

Problem-Solving Skills
Problem-Based Learning
Project-Based Learning
Quasi-Experimental Design

ABSTRACT

Problem-solving skills are essential competencies for vocational graduates in aviation education, where professional tasks are characterized by high risk, time pressure, and technological complexity. This study examined the effectiveness of Problem-Based Learning (PBL), Project-Based Learning (PJBL), and a combined PBL–PJBL approach in improving the problem-solving skills of cadets at the Surabaya Aviation Polytechnic. A quantitative method with a quasi-experimental design was employed. A total of 100 first-year cadets were selected through purposive sampling and assigned to four groups: PBL, PJBL, combined PBL–PJBL, and a control group. Data were collected using a validated and reliable questionnaire administered as pretest and posttest, and analyzed using one-way ANOVA, Tukey's HSD post hoc test, and N-Gain analysis. The results indicate that all experimental learning models significantly improved cadets' problem-solving skills compared to the control group. The combined PBL–PJBL model demonstrated the strongest overall effect, yielding the highest statistical improvement and a very large effect size. When examined as single-method implementations, PBL produced higher learning gains than PJBL, indicating greater practical efficiency in developing problem-solving skills. These findings suggest that while PBL alone is an effective and efficient instructional approach, integrating PBL and PJBL provides a more comprehensive learning experience that maximizes problem-solving development in aviation vocational education. The study highlights the importance of aligning instructional strategies with the cognitive and operational demands of aviation training contexts.

Corresponding Author:

Parjan
Study Program of Airport Electrical Engineering, Politeknik Penerbangan Surabaya, Indonesia
Email: parjan.poltekbangsby@gmail.com

1. INTRODUCTION

Problem-solving skills are a crucial competence for vocational graduates, particularly in aviation education, where professionals must respond to complex, technology-driven, and dynamic work environments (Antonietti et al., 2022). Alongside rapid technological advancement and increasing workplace complexity, problem-solving skills are now widely recognized as essential for workforce readiness. This condition is directly relevant to cadets at the Surabaya Aviation Polytechnic, who will encounter operational contexts characterized by digital systems, procedural rigor, and high safety demands. Therefore, vocational education institutions must adopt effective learning approaches that prepare cadets to face these challenges.

Problem-Based Learning (PBL) and Project-Based Learning (PJBL) are two instructional models that have been shown to significantly influence the development of problem-solving skills (Liu et al., 2024; McGrath & Yamada, 2023). Both models emphasize contextual and authentic learning experiences, allowing cadets to engage with real-world situations. Studies in vocational education indicate that these approaches help learners prepare for increasingly complex and technology-based workplace problems (Magagula & Awodiji, 2024; Winkler et al., 2021; Yu et al., 2022). For example, research conducted in Taiwan highlights that vocational education in STEM fields places strong emphasis on problem-solving skills to address the demands of more complex work environments (Lee et al., 2023).

Within vocational education, PBL and PJBL have also been identified as effective in developing broader 21st-century skills, including critical thinking, collaboration, and adaptability (Alsmadi et al., 2024; McGrath & Yamada, 2023; Winkler et al., 2021). PBL focuses on learning through structured engagement with real-world problems, enabling cadets to identify issues, collect relevant information, and formulate solutions independently (Moon & Chang, 2024; Satwika et al., 2018). Evidence from other disciplines, such as pharmacy education, shows that PBL enhances both problem-solving and teamwork skills (Shimomura & Utsumi, 2025). Similarly, studies in physics and computer education demonstrate that PBL contributes to improved analytical skills and helps address disparities in learning outcomes, including gender-related gaps in understanding (Boye & Agyei, 2023; Kanyesigye et al., 2022; Liu & Pásztor, 2022; Ottenbreit-Leftwich et al., 2021).

In contrast, PJBL emphasizes the integration of theoretical knowledge with practical application through extended project work, enabling learners to solve problems within realistic and meaningful contexts (Alexandersen et al., 2025). Its effectiveness has been reported in engineering (Rehman et al., 2024), biotechnology (Novalia et al., 2025), and social psychology education (Alexandersen et al., 2025; Dias-Oliveira et al., 2024). Both PBL and PJBL support the development of collaboration, creativity, and adaptability, which are increasingly necessary in complex and evolving work environments (Liu & Pásztor, 2022; Novalia et al., 2025). Consequently, these models are considered capable of improving learners' understanding of content while equipping them with relevant and applicable skills for professional practice (Badia-Valiente & Gil-Castell, 2025).

Although numerous studies have examined the effectiveness of PBL and PJBL in improving problem-solving and related skills, most existing research investigates these models separately and primarily in non-aviation vocational or general STEM education contexts (Alsmadi et al., 2024; McGrath & Yamada, 2023; Winkler et al., 2021). Empirical studies that directly compare PBL and PJBL within the same learning context remain limited, particularly in aviation vocational education. Moreover, despite the complementary nature of both models, there is a lack of research examining whether a combined implementation of PBL and PJBL produces greater improvements in problem-solving skills than the application of a single model alone. This gap is especially critical given the complex, procedural, and technology-intensive characteristics of aviation training environments.

To address this gap, the present study employs a quasi-experimental design to examine the effects of PBL, PJBL, and their combination on cadets' problem-solving skills. A quasi-experimental approach allows for controlled comparison without random assignment while still ensuring internal validity (Moon & Chang, 2024; Chang et al., 2022; Yan et al., 2024). Data were analyzed using one-way ANOVA to test for differences among instructional groups (Kłos et al., 2021; Fu & Tan, 2024; Winkler et al., 2021; Yu et al., 2022), followed by Tukey's HSD post hoc test to identify specific group differences (Mierzwicki et al., 2024; Young et al., 2023; Agbangba et al., 2024). Normality and homogeneity assumptions were assessed using the Shapiro–Wilk and Levene's tests, respectively.

Learning improvement was further evaluated using N-Gain analysis, which measures the degree of improvement in problem-solving skills across instructional conditions (Christman et al., 2024). Through this design, the study aims to provide empirical evidence on the relative and combined effectiveness of PBL and PJBL in aviation vocational education, contributing to the development of more effective instructional strategies aligned with the demands of an increasingly complex and technology-driven aviation industry (Alex et al., 2024; Hassan et al., 2024; Yu et al., 2022).

2. METHOD

This study employed a quantitative approach using a quasi-experimental design with a non-randomized control group. The design involved the use of intact classes and therefore did not include random assignment of participants. This approach was selected due to institutional constraints while still allowing for systematic comparison of instructional effects. The primary objective of the study was to examine the effects of Problem-Based Learning (PBL), Project-Based Learning (PJBL), and a combined PBL–PJBL approach on the problem-solving skills of cadets at the Surabaya Aviation Polytechnic.

Prior to the implementation of the instructional interventions, a literature study was conducted to identify prevailing findings, methodological approaches, and limitations in previous research related to PBL and PJBL, particularly within vocational and technology-oriented education contexts. This review informed the selection of the learning models and supported the positioning of problem-solving skills as the central outcome variable of the study.

The research focused on first-year cadets at the Surabaya Aviation Polytechnic, as this cohort was considered to have relatively similar academic backgrounds and limited prior exposure to aviation-specific vocational training. This focus was intended to reduce variation in baseline competence and to allow a clearer examination of instructional effects on problem-solving skills. The population consisted of 100 first-year cadets, all of whom were included in the study through purposive sampling to ensure relevance to the research objectives (Carrera et al., 2025).

The sample was divided into four groups, each consisting of 25 cadets: a group taught using the PBL model, a group taught using the PJBL model, a group taught using a combination of PBL and PJBL, and a control group that received conventional instruction. Although participants were not randomly assigned, all groups were drawn from the same cohort level, used identical instruments, and followed the same instructional timeframe. These procedural controls were intended to minimize baseline differences and support internal validity within the constraints of a quasi-experimental design. Data were collected using a self-report questionnaire administered online through Google Forms. The instrument consisted of 24 items measured on a four-point Likert scale ranging from strongly disagree (1) to strongly agree (4). To reduce response bias and detect inattentive responding, several negatively worded items were included and reverse-coded during the scoring process. The questionnaire was administered as a pretest to assess cadets' initial problem-solving skills and again as a posttest following the completion of the instructional interventions.

The quality of the research instrument was evaluated through validity and reliability testing prior to inferential analysis. Item validity was confirmed using corrected item–total correlations and significance testing, with all items meeting the accepted thresholds. Reliability analysis showed that the PBL instrument demonstrated very high internal consistency (Cronbach's alpha = 0.889), while the PJBL instrument demonstrated acceptable reliability (Cronbach's alpha = 0.757). These results indicate that the questionnaire was sufficiently valid and reliable for measuring problem-solving skills, despite its self-report format. All questionnaire responses were coded numerically and entered into SPSS version 25 for analysis. Negatively worded items were reverse-coded prior to computing composite scores. Before testing the main hypotheses, assumption testing was conducted to ensure the suitability of parametric analysis. Normality of the data distribution was assessed using the Shapiro–Wilk test, while homogeneity of variance across groups was evaluated using Levene's test. The results of these tests indicated that the data met the required assumptions for further analysis.

To examine differences in problem-solving skills across instructional models, a one-way ANOVA was conducted. This analysis was used to determine whether significant differences existed among the PBL, PJBL, combined PBL–PJBL, and control groups. When significant effects were identified, Tukey's HSD post hoc test was applied to identify specific group differences. In addition, N-Gain analysis was used to measure the magnitude of improvement in problem-solving skills between the pretest and posttest scores and to compare the effectiveness of the learning models. Through this analytical approach, the study sought to provide a clear comparison of the relative and combined effects of PBL and PJBL on cadets' problem-solving skills within an aviation vocational education context.

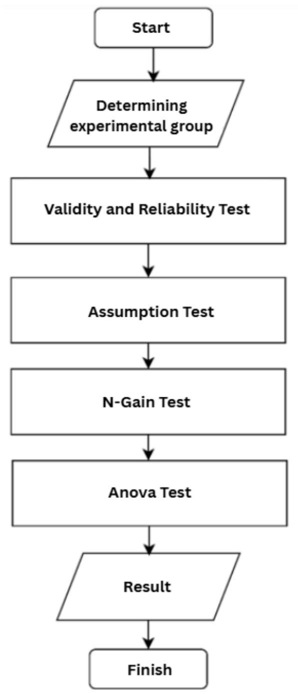

Fig. 1. Data Analysis Flowchart

1) *Determining the experimental groups*

The initial stage of the analysis began with determining the groups to be selected as samples. These groups consisted of four groups: a group using the PBL model, a group using the PJBL model, a group using a combination of PBL and PJBL models, and a control group. Each group was then given a pretest using the same instrument as the posttest. Before administering the posttest, the sample groups first participated in learning using the established model.

2) *Validity and Reliability Test*

Measurements for each variable were taken first. Next, validity testing was applied to each question to confirm that the instrument measured accurately. Then, reliability testing was conducted to ensure consistency in the instrument's measurement results.

3) *Assumption Test*

Before proceeding with the ANOVA test, the model used must meet several basic assumptions to ensure the validity of the analysis results. The Wilk-Shapiro test for normality is performed to check whether the data are normally distributed. Furthermore, a homogeneity test is required to ensure that the variances between groups are uniform, which is an important assumption in ANOVA analysis.

4) *N-Gain Test*

The N-Gain (Normalized Gain) test is used to measure the extent of improvement in problem-solving ability between the pretest and posttest. Using a predetermined formula, this test allows researchers to determine the effectiveness of the learning model in improving cadets' problem-solving skills. The results of the N-Gain test are used to compare the effectiveness of each learning model applied to each group, providing a clearer picture of the impact of each model. The following formula can be used to calculate N-Gain:

$$N - Gain = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

Measures improvement in ability by comparing the difference between the posttest and pretest scores to the difference between the maximum score and the pretest score. The resulting score reflects the effectiveness of changes in cadet skills during the testing period.

5) *ANOVA Test*

ANOVA (Analysis of Variance) is a statistical technique used to compare the average variance of more than two groups. ANOVA was used in this study to determine the extent of improvement in problem-solving ability before and after implementing the PBL and PJBL methods through a one-way ANOVA test. One-way ANOVA is a one-way analysis used to test the influence of multiple populations on a test using a single factor. In this study, problem-solving ability was measured at three levels: low, medium, and high.

The process involves comparing the variation between treatment groups with the variation within each group. If the calculation results show that the variation between groups is greater than the variation within groups, then the hypothesis stating that there are no differences between the groups is rejected. Conversely, if the comparison shows no significant differences, the hypothesis is accepted. If significant differences are found, further tests are conducted to compare the different groups in more detail.

6) *Result*

The results of the ANOVA test in the previous stage were used to identify the effect of each learning model on problem-solving skills. To determine the most effective learning model, a post-ANOVA test using Tukey's HSD was conducted to further compare differences between the different groups.

3. RESULTS AND DISCUSSION

3.1 RESULTS

A. Validity and Reliability Test

1) Validity Test

Table 1. Validity Test PBL and PJBL

Aspects	Criteria	PBL	PJBL
Correlation with total	r > 0.3	All items valid (r > 0.3)	All items are valid (r > 0.3)
Significance (Sig.)	Sig. < 0.05	All items valid (Sig. < 0.05)	All items valid (Sig. < 0.05)
Lower correlation in PBL	PBL4, PBL11 (r = 0.429, r = 0.438)	Valid despite lower correlation	-
Lower correlation in PJBL	PJBL1, PJBL10 (r < 0.3)	-	Valid despite lower correlation

Prior to hypothesis testing, the validity and reliability of the research instrument were examined. The validity test results presented in Table 1 indicate that all items in both the PBL and PJBL instruments met the required criteria, with corrected item–total correlation values exceeding 0.30 and significance values below 0.05. Although several items, such as PBL4 and PBL11, showed relatively lower correlation values, they remained above the acceptable threshold and were therefore retained. Similarly, all PJBL items were declared valid despite a small number showing lower correlations.

2) Reliability Test

Table 2. Reliability Test PBL and PJBL

Instrument	Cronbach's Alpha	Number of Items	Conclusion
PBL	0.889	12	Very good
PJBL	0.757	13	Fairly good

Reliability analysis further confirmed the internal consistency of the instruments. As shown in Table 2, the PBL instrument demonstrated very high reliability, with a Cronbach's alpha value of 0.889, indicating excellent consistency in measuring problem-solving skills. The PJBL instrument showed acceptable reliability with a Cronbach's alpha of 0.757, which exceeds the minimum threshold of 0.70. These findings indicate that both instruments were sufficiently reliable for subsequent analysis.

B. Assumption Test

1) Normality Test

Table 3. Normality Test PBL and PJBL

Statistics	Kolmogorov-Smirnova (Sig.)	Shapiro-Wilk (Sig.)
Mean_PBL	0.042	0.932
Mean_PJBL	0.066	0.601
Mean_PBL_PJBL	0.052	0.724

Before conducting inferential statistical tests, assumption testing was performed. Normality testing using the Kolmogorov–Smirnov and Shapiro–Wilk tests (Table 3) showed that all variables had significance values greater than 0.05, indicating that the data were normally distributed. Homogeneity testing using Levene's test (Table 4) revealed that the variance across groups was homogeneous, as all p-values exceeded 0.05. These results confirm that the data met the assumptions required for one-way ANOVA.

2) Homogeneity Test

Table 4. Homogeneity Test PBL and PJBL

	Group	Mean	Std. Deviation	Levene's Test p-value (Sig.)
Mean_PBL	PBL	3.3996	0.06142	0.360
	PJBL	3.2080	0.06315	0.407
	PBL_PJBL_ combination	3.3789	0.09172	0.275
	Control	3.1743	0.08587	
Mean_PJBL	PBL	3.1898	0.07741	0.407
	PJBL	3.3889	0.07711	0.652
	PBL_PJBL_ combination	3.3814	0.05976	0.444
	Control	3.2056	0.07624	
Mean_PBL_PJBL	PBL	39.5227	0.46335	0.275
	PJBL	39.5833	0.59940	0.340
	PBL_PJBL_ combination	40.5717	0.58673	0.292
	Control	38.2771	0.67807	

Table 4 shows the results of the homogeneity test for the 4 groups. The test uses Levene's Test, which shows that the p-value (Sig.) for each group is greater than 0.05, which indicates that the variance between groups is homogeneous. For the variance of mean_PBL, the p-value ranges between 0.275 and 0.407; for mean_PJBL, the p-value ranges between 0.407 and 0.652; and for mean_PBL_PJBL, the p-value ranges between 0.275 and 0.340. Thus, the data between groups on each variable can be considered to have uniform variance.

C. N-Gain Test

Table 5. N-Gain Test PBL and PJBL

Variable	N	Min.	Max.	Mean	Std. Deviation
NGain_PBL	100	0.02	0.57	0.3642	0.11565
NGain_PJBL	100	0.04	0.56	0.3505	0.11358

The N-Gain analysis was conducted to examine the magnitude of improvement in problem-solving skills between the pretest and posttest. As shown in Table 5, both the PBL and PJBL groups experienced moderate improvement. The PBL group achieved a slightly higher mean N-Gain value (0.3642) compared to the PJBL group (0.3505). The relatively similar standard deviations suggest that improvement was consistently distributed across participants. These results indicate that while both instructional models effectively enhanced problem-solving skills, PBL showed marginally higher efficiency in producing learning gains when applied as a single method.

D. ANOVA Test

Table 6. ANOVA Test

Learning Model	Sum of Squares	df	Mean of Squares	F	Sig.
PBL	0.983	3	0.328	53.774	0.000
PJBL	0.870	3	0.290	55.670	0.000
PBL and PJBL Combination	70.244	3	23.415	67.440	0.000

To examine differences in problem-solving skill improvement across learning Tmodels, a one-way ANOVA was conducted. The results presented in Table 6 show that all learning models produced statistically significant effects. The PBL model yielded an F value of 53.774 ($p < 0.001$), and the PJBL model yielded an F value of 55.670 ($p < 0.001$), indicating that both models significantly improved cadets' problem-solving skills compared to baseline conditions. Notably, the combined PBL–PJBL model produced the highest F value ($F = 67.440$, $p < 0.001$), indicating that this instructional approach generated the strongest overall statistical effect. To complement statistical significance, effect size analysis using eta-squared (η^2) was conducted. In addition to statistical significance, the eta-squared effect size (η^2) was used to determine the extent of the learning model's effect on cadets' problem-solving abilities based on the ANOVA results obtained previously. The η^2 value was calculated using the following formula:

$$\eta^2 = \frac{SS_{between}}{SS_{total}}$$

$$\eta^2 = \frac{70.244}{0.983+0.870+70.244} = 0.97$$

The η^2 value for the combined PBL–PJBL model was 0.97, indicating a very large effect. This result suggests that a substantial proportion of the variance in problem-solving skill improvement was associated with the combined instructional model, reinforcing its statistical dominance over single-method approaches.

E. Post Hoc with Tukey HSD

1) Tukey's HSD Test Result in the PBL Group

Table 7. Tukey's HSD PBL Group

Group Comparison	Mean Difference	Sig.
PBL vs Control	0.22532*	0.000
PBL vs PJBL	0.19164*	0.000
PBL vs PBL and PJBL Combination	0.02073	0.000

Post hoc comparisons using Tukey's HSD test were conducted to identify specific group differences. As shown in Table 7, the PBL group demonstrated significantly higher problem-solving scores than both the control group and the PJBL group ($p < 0.001$). However, the difference between the PBL group and the combined PBL–PJBL group was very small, indicating that while the combined model achieved higher overall scores, PBL alone performed at a comparable level in practical terms.

The Tukey HSD results for the PJBL group (Table 8) showed that PJBL was significantly more effective than the control group but significantly less effective than PBL. No statistically meaningful difference was found between PJBL and the combined PBL–PJBL group, suggesting that PJBL contributes positively when integrated with PBL but is less effective as a standalone approach.

Further analysis of the combined PBL–PJBL group (Table 9) revealed significant differences compared to all other groups, including PBL, PJBL, and the control group ($p < 0.001$). This confirms that the integrated instructional model achieved the highest overall improvement in problem-solving skills.

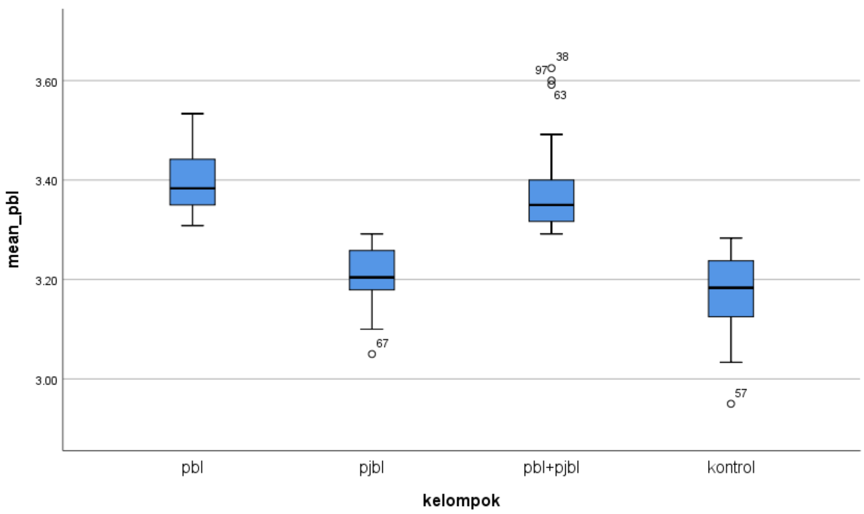

Fig. 2. Boxplot PBL Group

In Figure 2. PBL boxplot, it can be seen that the PBL group has the highest average of 3.40, although there are several outliers with values of 67 and 38. The PJBL group has an average of 3.20, with outliers at values 63 and 70. The combination of PBL and PJBL groups. The combination of PBL and PJBL groups In Figure 2. PBL boxplot, it can be seen that the PBL group has the highest average of 3.40, although there are several outliers with values of 67 and 38. The PJBL group has an average of 3.20, with outliers at values 63 and 70. The combination of PBL and PJBL groups.

2) *Tukey's HSD Test Result in the PJBL Group*

Table 8. Tukey's HSD PJBL Group

Group Comparison	**Mean Difference**	**Sig.**
PJBL vs PBL	-0.19912*	0.000
PJBL vs Control	0.18333*	0.000
PJBL vs PBL and PJBL Combination	-0.00750	0.980

[b] *$p < 0.005$

Table 8 shows a significant difference between PJBL and PBL, with PBL proving more effective in improving problem-solving skills than PJBL. Furthermore, the comparison between the two groups also showed a significant difference, with PJBL being more effective in improving problem-solving skills than the group not receiving the learning intervention. However, no significant difference was found between PJBL and the combination of PBL and PJBL, indicating that both learning models provided nearly equal skill improvement.

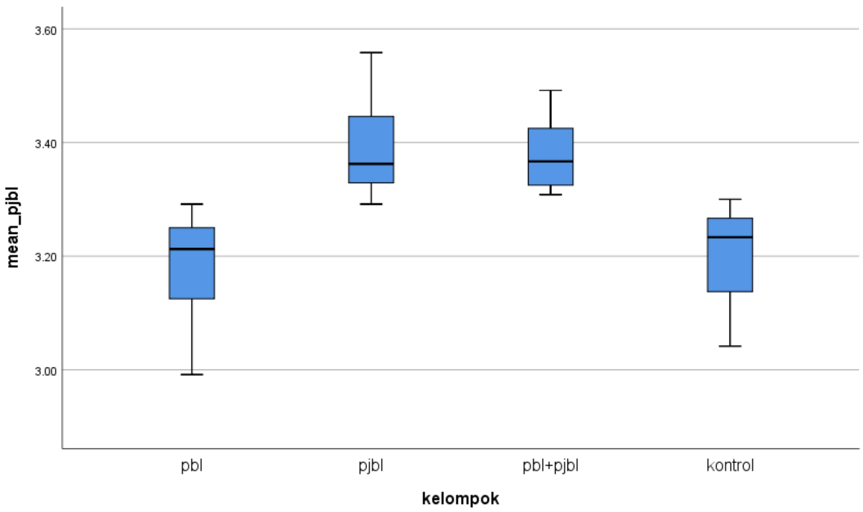

Fig. 3. Boxplot PJBL Group

Figure 3, a PJBL boxplot, shows that the PBL group had the highest average score of 3.19, with a narrow distribution. The PJBL group had an average of 3.39, although there was one outlier at 38. The combination of PBL and PJBL group showed an average of 3.38, which was higher than both PBL and the Control group. Meanwhile, the Control group had an average of 3.21, with an outlier at 63.

3) *Tukey's HSD Test Result in the PBL and PJBL Combination Group*

Table 9. Tukey's HSD PBL and PJBL Combination Group

Group Comparison	Mean Difference	Sig.
PBL and PJBL Combination vs Control	1.24564*	0.000
PBL and PJBL Combination vs PBL	1.04894*	0.000
PBL and PJBL Combination vs PJBL	0.98833	0.000

[c]*p < 0.005

Table 9 shows a significant difference between the combination of PBL with PJBL and the control group, indicating that the combination of PBL with PJBL was more effective in improving problem-solving skills compared to the control group. Furthermore, a significant difference was also found between the combination of PBL with PJBL and PBL. The combination of PBL with PJBL proved more effective in improving skills than PBL alone. Finally, between the combination of PBL with PJBL and PJBL, there was a significant difference, indicating that the combination of PBL with PJBL was more effective than PJBL alone.

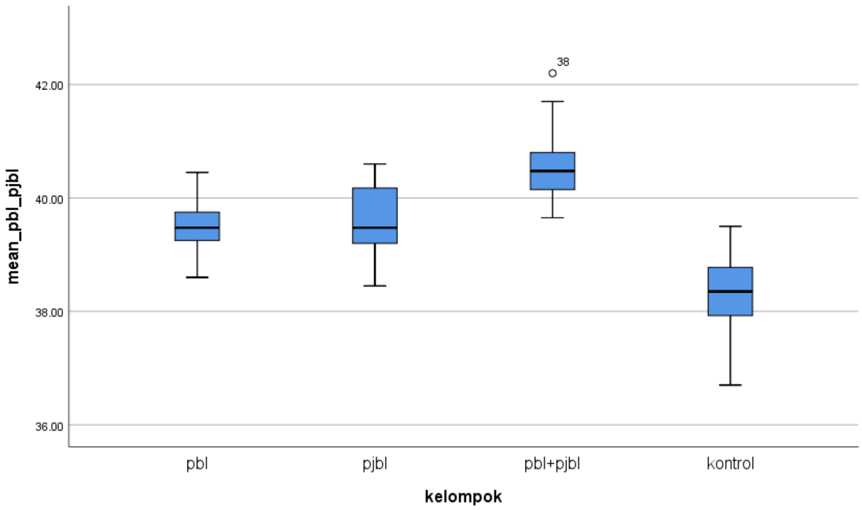

Fig. 4. Boxplot PBL and PJBL Combination Group

Figure 4 shows a boxplot of the combination of PBL with PJBL, showing that the PBL group had an average of 39.52, although there was one outlier at 38. The PJBL group had an average of 39.58, with an outlier at 63. The combination of PBL with the PJBL group had the highest average, at 40.57, with one outlier at 70. Meanwhile, the control group had an average of 38.28, with an outlier at 57.

3.2 DISCUSSION

The findings of this study indicate that the combined learning outcomes of the PBL and PJBL methods yielded superior results compared to either single-method implementation or the control class. This result can be understood as the effect of integrating two complementary learning processes. In this integration, PBL plays a central role in developing analytical and conceptual problem-solving skills, while PJBL supports the application of those analytical skills through structured task completion and project execution. The combination allows cadets not only to understand problems theoretically but also to operationalize solutions in practice, which is essential in vocational education contexts.

Although the combined PBL–PJBL model produced the strongest overall outcomes, analysis of the single-method implementations indicates that PBL is superior to PJBL in improving problem-solving skills. This advantage can be explained by the specific characteristics of aviation vocational education. Aviation tasks are inherently time-critical, high-risk, and decision-intensive, requiring rapid situational assessment and strict adherence to standard operating procedures. In aviation practice, problems frequently arise related to aircraft systems, departure and arrival processes, safety management, flight risks, and passenger-related issues. These conditions demand immediate decision-making and analytical reasoning rather than prolonged procedural execution. PBL exposes cadets to realistic and frequently occurring problem scenarios, enabling them to simulate the cognitive demands they will encounter in real operational settings and to practice making justified decisions under pressure.

Cadets who received PBL demonstrated significantly stronger problem-solving performance because the PBL approach encourages engagement with open-ended and ill-structured problems. Through problem-based assignments, cadets are required to identify relevant information, evaluate alternative solutions, and justify their decisions independently, which increases their cognitive involvement in the learning process. This finding is consistent with previous research indicating that PBL enhances engagement and problem-solving performance by requiring learners to actively construct knowledge rather than follow predetermined procedures (Gao et al., 2022). The need to engage in independent learning beyond classroom sessions further increases cognitive load, which in turn promotes deeper understanding and greater responsibility for mastering key concepts.

The educational context of cadets at the Surabaya Aviation Polytechnic also contributes to the observed differences between PBL and PJBL. Cadets live in a dormitory-based environment characterized by dense schedules, repetitive institutional activities, and a strong emphasis on discipline. Under such conditions, learning approaches that require extended time frames and intensive coordination—such as PJBL—can be less flexible when implemented independently. PJBL relies heavily on hands-on project completion and adherence to fixed procedural steps, which may reduce opportunities for rapid decision-making and spontaneous analytical reasoning. As a result, PJBL as a single method may place greater demands on time and logistical coordination without proportionally increasing problem-solving intensity.

Nevertheless, when PBL and PJBL are combined, their respective strengths compensate for these limitations. The analytical reasoning fostered through PBL is reinforced by the applied practice emphasized in PJBL, allowing cadets to connect theoretical problem analysis with practical implementation. This integration not only enhances problem-solving skills but also improves communication between cadets and instructors, as conceptual reasoning is translated into observable project outcomes. Through repeated exposure to both problem analysis and task execution, cadets develop more comprehensive competencies that align with professional demands in aviation.

The effectiveness of the combined PBL and PJBL approach in improving problem-solving skills and learner engagement is consistent with previous studies reporting that integrated instructional models outperform single-method approaches, and that PBL tends to yield stronger outcomes than PJBL when applied independently (Fang et al., 2026; Pimdee et al., 2024). In the context of aviation vocational education, where cognitive flexibility, rapid decision-making, and operational accuracy are essential, the combination of PBL and PJBL represents a pedagogically sound strategy for preparing cadets to face real-world professional challenges.

4. CONCLUSION

Based on the research results, it was concluded that the integrated PBL and PJBL learning model proved to be the most effective method compared to single methods or control classes in improving problem-solving skills in cadets at the Politeknik Penerbangan Surabaya. The results of the Tukey HSD follow-up test also showed that when the learning model only applies a single method, PBL is more effective than PJBL. This indicates that as a single method, PBL is more efficient, but the combination of PBL and PJBL can provide additional benefits in more comprehensive learning. These findings emphasize the importance of choosing the right learning model, especially in vocational education with aviation vocations, to improve the skills needed in the increasingly complex world of work. This study has limitations in the limited research subjects. This study only focused on first-year cadets, so it has not yet obtained a picture of the effectiveness of learning models with a broader scope with a combination of various higher education levels. This research instrument also used a questionnaire distributed through a self-reporting Google Form, which has the potential to contain respondent perception bias. The results of this study provide implications that the curriculum needs to integrate PBL and PJBL in learning activities at the Politeknik Penerbangan Surabaya. Lecturers in charge of each course will also need to be given special training in the implementation of PBL and PJBL learning models in the future so that learning is more optimal and aligned with education with a focus on aviation. In addition to training provided to lecturers, coordination among lecturers is also needed in the preparation of cadet learning designs that emphasize solving real-life problems that often occur in the world of aviation, so that problem-solving skills are not only learned theoretically in education but can become provisions for cadets to face real problems that occur. With this, problem-solving skills will certainly continue to improve and the learning obtained is more applicable and contextual in a professional career in the world of aviation.

ACKNOWLEDGEMENTS
This work was supported by the Politeknik Penerbangan Surabaya.

REFERENCES

Agbangba, C. E., Sacla Aide, E., Honfo, H., & Glèlè Kakai, R. (2024). On the use of post-hoc tests in environmental and biological sciences: A critical review. *Heliyon*, *10*(3), e25131. https://doi.org/10.1016/j.heliyon.2024.e25131

Alex, A. F., Dudhe, R., & Vinoth, R. (2024). Design optimization of hemodialyzer membrane modelled in chemical reaction module using statistical algorithms and ANOVA testing. *South African Journal of Chemical Engineering*, *48*, 417–424. https://doi.org/10.1016/j.sajce.2024.03.007

Alexandersen, L., Klemsdal, L., & Kjekshus, L. E. (2025). Bridging the relevancy gap in higher education via project-based learning: The significance of the personal experience of learning from conflict. *Social Sciences and Humanities Open*, *11*. https://doi.org/10.1016/j.ssaho.2025.101451

Alsmadi, H., Kandasamy, G., Al Kafri, A., & Zahirah, K. F. (2024). Empowering computing students through multidisciplinary project based learning (PBL): Creating meaningful differences in the real world. *Social Sciences and Humanities Open*, *10*. https://doi.org/10.1016/j.ssaho.2024.101180

Antonietti, C., Cattaneo, A., & Amenduni, F. (2022). Can teachers' digital competence influence technology acceptance in vocational education? *Computers in Human Behavior*, *132*. https://doi.org/10.1016/j.chb.2022.107266

Badia-Valiente, J. D., & Gil-Castell, O. (2025). ChEngBoost: Vitaminised and gamified problem-based learning of chemical engineering bases in biotechnology. *Education for Chemical Engineers*, *53*, 62–70. https://doi.org/10.1016/j.ece.2025.07.006

Boye, E. S., & Agyei, D. D. (2023). Effectiveness of problem-based learning strategy in improving teaching and learning of mathematics for pre-service teachers in Ghana. *Social Sciences and Humanities Open*, *7*(1). https://doi.org/10.1016/j.ssaho.2023.100453

Carrera, L., Tagliaferri, F., Albertini, A., Sironi, S., & Invernizzi, M. (2025). A comparative study of wind tunnel and flux chamber for diffuse emission sampling: Experimental evaluation and theoretical approach. *Chemosphere*, *375*. https://doi.org/10.1016/j.chemosphere.2025.144242

Chang, H. Y., Binali, T., Liang, J. C., Chiou, G. L., Cheng, K. H., Lee, S. W. Y., & Tsai, C. C. (2022). Ten years of augmented reality in education: A meta-analysis of (quasi-) experimental studies to investigate the impact. *Computers and Education*, *191*. https://doi.org/10.1016/j.compedu.2022.104641

Christman, E., Miller, P., & Stewart, J. (2024). Beyond normalized gain: Improved comparison of physics educational outcomes. *Physical Review Physics Education Research*, *20*(1). https://doi.org/10.1103/PhysRevPhysEducRes.20.010123

Dias-Oliveira, E., Pasion, R., Vieira da Cunha, R., & Lima Coelho, S. (2024). The development of critical thinking, team working, and communication skills in a business school–A project-based learning approach. *Thinking Skills and Creativity*, *54*. https://doi.org/10.1016/j.tsc.2024.101680

Fang, F., Bu, B., & Jiang, W. (2026). Combining Problem-Based Learning Methods With the WeChat Platform in Teaching Ophthalmology: Randomized Controlled Trial. *JMIR Medical Education*, *12*. https://doi.org/10.2196/65279

Fu, P., & Tan, Z. (2024). Block-wise primal-dual algorithms for large-scale doubly penalized ANOVA modeling. *Computational Statistics and Data Analysis*, *194*. https://doi.org/10.1016/j.csda.2024.107932

Gao, X., Wang, L., Deng, J., Wan, C., & Mu, D. (2022). The effect of the problem based learning teaching model combined with mind mapping on nursing teaching: A meta-analysis. *Nurse Education Today*, *111*, 105306. https://doi.org/10.1016/j.nedt.2022.105306

Hassan, A., Samy, G., Hegazy, M., Balah, A., & Fathy, S. (2024). Statistical analysis for water quality data using ANOVA (Case study – Lake Burullus influent drains). *Ain Shams Engineering Journal*, *15*(4). https://doi.org/10.1016/j.asej.2024.102652

Kanyesigye, S. T., Uwamahoro, J., & Kemeza, I. (2022). Data collected to measure the impact of problem-based learning and document physics classroom practices among Ugandan secondary schools. *Data in Brief*, *44*. https://doi.org/10.1016/j.dib.2022.108534

Kłos, J., Nicholson, J. W., & Czarnecka, B. (2021). Glass-ionomer dental cements as novel solid-state buffers. *Journal of Materials Research and Technology*, *15*, 3570–3574. https://doi.org/10.1016/j.jmrt.2021.09.115

Lee, Y. F., Altschuld, J. W., Tseng, P. K., & Hung, H. S. (2023). Assessing Study Skill Needs for Information Technology and Computer Science Students in Technical and Vocational Universities. *Heliyon*, *9*(10). https://doi.org/10.1016/j.heliyon.2023.e20915

Liu, P., Liu, K., Li, J., Zhao, Y., & Wang, G. (2024). Predictive analysis and correlational exploration of public and academic attention in secondary vocational education. *Heliyon*, *10*(4). https://doi.org/10.1016/j.heliyon.2024.e25947

Liu, Y., & Pásztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. *Thinking Skills and Creativity*, *45*. https://doi.org/10.1016/j.tsc.2022.101069

Magagula, M. M., & Awodiji, O. A. (2024). The implications of the fourth industrial revolution on technical and vocational education and training in South Africa. *Social Sciences and Humanities Open*, *10*. https://doi.org/10.1016/j.ssaho.2024.100896

McGrath, S., & Yamada, S. (2023). Skills for development and vocational education and training: Current and emergent trends. *International Journal of Educational Development*, *102*. https://doi.org/10.1016/j.ijedudev.2023.102853

Mierzwicki, J. T., Kline, J., Schach, B., & Vandenberg, L. (2024). Loneliness improved by either telephone or video communications in community-dwelling older adults. *Archives of Gerontology and Geriatrics Plus*, *1*(2), 100011. https://doi.org/10.1016/j.aggp.2024.100011

Moon, S., & Chang, S. J. (2024). Comparing the effects of patient safety education using design thinking and case based learning on nursing students' competece and professional socialization: A quasi-experimental design. *Heliyon*, *10*(9). https://doi.org/10.1016/j.heliyon.2024.e29942

Novalia, R., Marini, A., Bintoro, T., & Muawanah, U. (2025). Project-based learning: For higher education students' learning independence. *Social Sciences and Humanities Open*, *11*. https://doi.org/10.1016/j.ssaho.2025.101530

Ottenbreit-Leftwich, A. T., Kwon, K., Brush, T. A., Karlin, M., Jeon, M., Jantaraweragul, K., Guo, M., Nadir, H., Gok, F., & Bhattacharya, P. (2021). The impact of an issue-centered problem-based learning curriculum on 6th grade girls' understanding of and interest in computer science. *Computers and Education Open*, *2*. https://doi.org/10.1016/j.caeo.2021.100057

Pimdee, P., Sukkamart, A., Nantha, C., Kantathanawat, T., & Leekitchwatana, P. (2024). Enhancing Thai student-teacher problem-solving skills and academic achievement through a blended problem-based learning approach in online flipped classrooms. *Heliyon*, *10*(7), e29172. https://doi.org/10.1016/j.heliyon.2024.e29172

Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom. *Heliyon*, *10*(23). https://doi.org/10.1016/j.heliyon.2024.e39988

Shimomura, Y., & Utsumi, M. (2025). Exploring Instructor-Led Team Formation and Task Assignment to Enhance Group Dynamics in Pharmacy Problem-Based Learning. *American Journal of Pharmaceutical Education*, *89*(4). https://doi.org/10.1016/j.ajpe.2025.101377

Winkler, R., Söllner, M., & Leimeister, J. M. (2021). Enhancing problem-solving skills with smart personal assistant technology. *Computers and Education*, *165*. https://doi.org/10.1016/j.compedu.2021.104148

Yan, Z., Liu, Q., & Chen, Y. (2024). Examining the impact of flipped learning on second language development: A quasi-experiment in higher education. *Heliyon*, *10*(13). https://doi.org/10.1016/j.heliyon.2024.e33593

Young, P., Luch, A., & Laux, P. (2023). Impact of phosphine and of sulfuryl fluoride fumigation on walnut quality. *Journal of Stored Products Research*, *100*. https://doi.org/10.1016/j.jspr.2022.102059

Yu, Z., Guindani, M., Grieco, S. F., Chen, L., Holmes, T. C., & Xu, X. (2022). Beyond t test and ANOVA: Applications of mixed-effects models for more rigorous statistical analysis in neuroscience research. *Neuron*, *110*(1), 21-35. https://doi.org/10.1016/j.neuron.2021.10.030

BIOGRAPHIES OF AUTHORS

	**Parjan** was born in Sragen, Indonesia, in 1977. His educational background includes a Bachelor of Applied Engineering in Airport Electrical Engineering from the Indonesian Aviation College, a Master of Aeronautical and Astronautical Engineering from the Bandung Institute of Technology (ITB), and a Doctorate in Vocational Education from the State University of Surabaya. His research interests include aspects of aviation, management, and technology, such as seaplane flight operations planning and its environmental impact, the use of light fire extinguishers in airport terminals, web-based firefighting tactics applications, robotic simulation (FITERN), job satisfaction, the application of RFID technology, ESP32-based systems, lost and found recording applications, and the development of digital learning media for airport firefighters (ARFF). He can be reached via email at parjan.poltekbangsby@gmail.com
	**Lady Silk Moonlight** was born in Surabaya, Indonesia, in 1987. She earned her Bachelor's degree (S1) in Informatics Engineering from Trunojoyo University in 2009 and her Master's degree (S2) in Informatics Engineering from Bandung Institute of Technology (ITB) in 2013. Her research interests include information technology, artificial intelligence, information systems, computer science, digital image processing, and computer networks. She is a Lecturer in the Study Program of Air Navigation Engineering, Surabaya Aviation Polytechnic. She has served as Head of the Technology, Information, Data and Multimedia Unit, Head of the Library Unit, Head of the Study Program of Aviation Communication, and currently she is the Head of Study Program of Air Transport Management, Surabaya Aviation Polytechnic, Indonesia. She can be contacted via email: lady@poltekbangsby.ac.id
	**Maulana Anifa Silvia** was born in Madiun, Indonesia, in 1984. She received a Bachelor's degree in Accounting from Bhayangkara University, Surabaya in 2008 and a Master's degree in Management from Bhayangkara University, Surabaya in 2013. Her research interests include economic, management, accounting, business, digital bussines, education, logistic, transportation, and aviation. She is a lecturer in D3 Air Transport Management, Surabaya Aviation Polytechnic, Indonesia. She can be contacted via email: silvi@poltekbangsby.ac.id
	**Faoyan Agus Furyanto** was born on August 19th, 1984, in Banjarnegara, and is a civil servant at the Surabaya Aviation Polytechnic. In 2009, he received a bachelor's degree in English education from the Open University. In addition, in 2012, he received a master's degree in English education from Sebelas Maret University. He finished his doctorate at Yogyakarta State University. He is an aviation English lecturer under the Ministry of Transportation of the Republic of Indonesia. He can be contacted at email: faoyan_agusfuryanto@dephub.go.id
	**Ahmad Musadek** was born in Cilacap, Indonesia, in 1968. He earned a Bachelor's degree (S1) in Informatics Engineering from Muhammadiyah University of Jakarta in 2001 and a Master's degree (S2) in Informatics Engineering Management from Sepuluh Nopember Institute of Technology (ITS) in 2008. His research interests include information technology and air transportation services. He is a Lecturer in the Diploma 3 Study Program in Air Transportation Management, Surabaya Aviation Polytechnic. Previously, he served as Head of the Information Technology, Data and Multimedia Unit, and Head of the Diploma 3 Study Program in Air Transportation Management at Surabaya Aviation Polytechnic, Indonesia. He can be contacted via email: ahmad.5dk@poltekbangsby.ac.id

Anton Budiarto is a lecturer at Politeknik Penerbangan Surabaya (Surabaya Aviation Polytechnic) with expertise in Air Management and Transportation. He completed his formal education up to the master's level, earning a Master's degree in Transportation (S2) from the Bandung Institute of Technology (ITB). He has participated in Anti-Terrorism training in Singapore and the Inland Waterways Transport program at the Université de Liège, Belgium, which expanded on aspects of safety, security, and integrated transportation systems. He has served as Head of the Aviation Management Department and Assistant Director II. He can be contacted via email: anton.atkpsby@gmail.com