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SHORT PAPER

# Teaching of Physics in Engineering from Problem-Based and Project-Based Learning Approaches

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**ABSTRACT**

Within the scope of this research, an evaluation was conducted on the problem-based learning (PBL) and project-based learning (PrBL) methods in teaching physics to mechanical and electrical engineering students at a public university in Peru. Two groups, each consisting of 15 and 16 students, were carefully selected to ensure uniformity in academic, socioeconomic, and emotional aspects. The measurement of academic performance was conducted both at the beginning and the end of the period. The statistical analysis using the t-student test revealed that the PrBL method was significantly more effective than PBL. These findings underscore the association between the choice of learning methods and the specific scientific area being taught, emphasizing the superiority of the PrBL approach in this educational context. This discovery suggests that implementing learning strategies that incorporate a project-based approach can be a valuable option to enhance academic performance in scientific disciplines.

**KEYWORDS**

problem-based learning (PBL), project-based learning (PrBL), learning achievement, academic achievement, academic performance

## 1 INTRODUCTION

In the context of the evolution of learning and its perspectives in management education, [13] conducted a study to identify the profile of academic research on blended learning (BL) worldwide and to propose a research agenda on the subject. The study found that recent literature has reported positive outcomes in terms of performance and student satisfaction in blended learning. However, there is still much to be explored and understood about BL due to its recent emergence.

In this sense, [15] examined the role of organizational learning culture as a mediating and moderating variable between transformational leadership and employee performance. The evidence from the findings indicated that transformational

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leadership is significantly associated with employee performance and organizational learning culture.

Furthermore, the organizational learning culture is closely linked to employee performance. In addition, the organizational learning culture plays a mediating and moderating role between transformational leadership and employee performance.

The purpose of the study is to enhance the teaching-learning process of physics in the professional careers of mechanical and electrical engineering at a public university in Peru. The study evaluated problem-based learning (PBL) and project-based learning (PrBL) methods in a section divided into two groups of 15 and 16 students, aiming to contribute to the development of graduates who are well-prepared for successful integration into the job market.

In that order of ideas, [16] expresses that industry requirements for engineering graduates evolve and demand changes in the educational approach used. Experiential learning, with its focus on hands-on experience, is the most suitable response to the new demands in education. PrBL and PBL are recognized as highly successful and innovative methods within the educational approach, particularly in engineering education. A special focus on PrBL is desirable because it introduces students to professional engineering practice and is the most effective way to meet the needs of the industry.

Regarding multimodal learning analytics, [14] expressed that it provides new tools and techniques to capture various types of data from intricate learning activities in dynamic learning environments. It is emphasized that novel and promising methods, such as neural networks and traditional regression procedures, can be employed to categorize data in multimodal learning analytics. This contributes significantly to the advancement of techniques for automatically identifying crucial aspects of student success in PrBL and learning environments. Ultimately, this can assist teachers in offering suitable and timely support to students in these critical areas.

It is important to highlight the points made by [2], who state that in traditional learning, there is a lack of motivation to learn and problem-solving skills.

## 2 METHODOLOGY

### 2.1 Study population

The study was conducted at a public university in Peru, involving five professional programs: Civil Engineering, Mechanical and Electrical Engineering, Food Industry Engineering, Forestry and Environmental Engineering, and Medical Technology with a specialization in Clinical Laboratory and Pathological Anatomy. The total enrollment for the 2022-I academic semester was 1999 students. The mechanical and electrical engineering career, with 414 students, was specifically chosen due to its notable failure rate in basic and applied sciences.

### 2.2 Research design

Focusing on the significance of the Physics course in the education of Mechanical and Electrical Engineers, a section in the third stage of the program was chosen. This section comprised 31 students and was randomly divided into two groups: 15 students in one group and 16 students in the other. Each group was exposed to different teaching methodologies, with one group receiving PBL and the other receiving project-based learning.

## 2.3 Data collection

To measure academic performance, an instrument was developed and validated through expert judgment. The instrument underwent a reliability test through a pilot test using Cronbach's alpha statistic. Academic performance was assessed at various points: initial condition (pre-test), evaluation after the first unit (first average), evaluation after the second unit (second average), evaluation after the third unit (third average), final grade of the subject (final average), and final condition (post-test).

## 2.4 Data analysis

Descriptive statistics were used to analyze the collected data. The t-test for independent samples facilitates comparisons between groups, while the t-test for related samples allows comparisons within groups.

## 2.5 Conceptual framework

The purpose of this study was to evaluate the methods of PBL and PrBL. A section of the physics course from the Mechanical and Electrical Engineering program at a public university in Peru was selected for the study. This section of 31 students was divided into two groups of 15 and 16 students each for teaching PBL and PrBL, respectively (see Figure 1).

Both groups were assessed using rubrics: a pre-test, the first average, the second average, the third average, the post-test, and the final average. The data obtained were processed using descriptive statistics, t-tests for independent samples, and t-tests for related samples.

The results of the statistical tests were analyzed, interpreted, and discussed in relation to the null and alternative hypotheses of equality and difference in effects between the methods. This analysis enabled the identification of the method the produced that most favorable indicators of learning achievement.

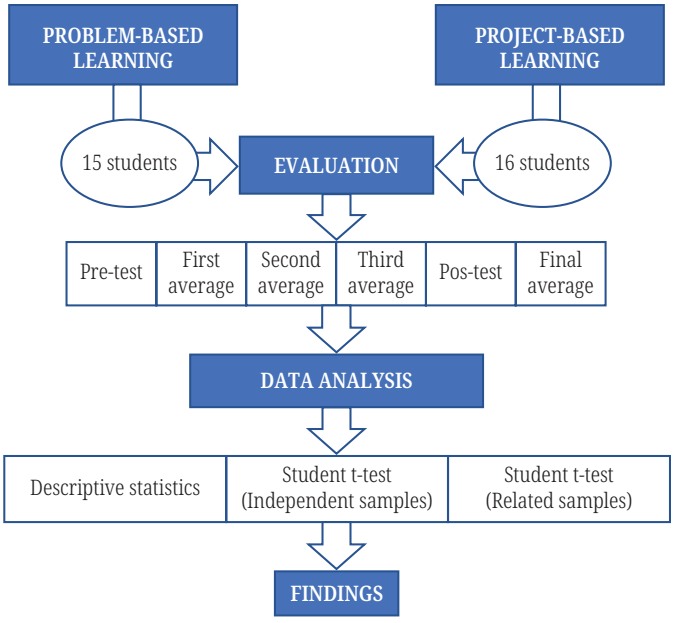


**Fig. 1.** Conceptual framework

*Source:* own elaboration.

# 3 RESULTS

## 3.1 Results obtained from the comparison between the learning methods

Results obtained from the comparison between the learning methods are presented in Table 1.

**Table 1.** Comparison of learning methods

| Variable | Student t-Test | | Observation |
|---|---|---|---|
| | t | P-Value | |
| Pre-test | 0.44 ns | 0.6615 | Equals |
| First average | –1.15 ns | 0.2593 | Equals |
| Second average | –1.14 ns | 0.2662 | Equals |
| Third average | –0.41 ns | 0.6871 | Equals |
| Pos-test | –0.44 ns | 0.6602 | Equals |
| Final average | –0.69 ns | 0.4975 | Equals |

*Notes:* ns: not significant (P > 0.0500); *: significant (P < 0.0500); **: highly significant (P < 0.0100).

The statistical tests indicate that there is no significant difference in academic performance between the two learning methods. Although the results are not statistically significant, it is noteworthy that performances achieved through the PrBL method were consistently higher in each measured instance.

## 3.2 Results of the comparison within the problem-based learning method

Table 2 shows the results of the comparison within the problem-based learning method.

**Table 2.** Comparison within the problem-based learning method

| Variable | Student t-Test | | Observation |
|---|---|---|---|
| | t | P-Value | |
| Pre-test vs First average | 1.67 ns | 0.1201 | Equals |
| Pre-test vs Second average | –1.33 ns | 0.2076 | Equals |
| Pre-test vs third average | –1.01 ns | 0.3344 | Equals |
| Pre-test vs Pos-test | –0.49 ns | 0.6309 | Equals |
| Pre-test vs Final average | –1.11 ns | 0.2876 | Equals |

*Notes:* ns: not significant (P > 0.0500); *: significant (P < 0.0500); **: highly significant (P < 0.0100).

Within the PBL method, no significant differences were observed between the pre-test and subsequent assessments. However, the negative test statistics suggest that as PBL was implemented, students gradually improved their performance.

## 3.3 Results of the comparison within the project-based learning method

Finally, Table 3 presents the results of the comparison within the project-based learning method.

**Table 3.** Comparison within the project-based learning approach

| Variable | Student t-Test | | Observation |
|---|---|---|---|
| | t | P-Value | |
| Pre-test vs First average | 0.32 ns | 0.7560 | Equals |
| Pre-test vs Second average | –3.82** | 0.0017 | Different |
| Pre-test vs third average | –2.79* | 0.0138 | Different |
| Pre-test vs Pos-test | –1.51 ns | 0.1528 | Equals |
| Pre-test vs Final average | –2.99** | 0.0092 | Different |

*Notes:* ns: not significant (P > 0.0500); *: significant (P < 0.0500); **: highly significant (P < 0.0100).

Within the PrBL method, statistically significant differences were observed in the comparisons between the pre-test and the second, third, and final averages. This indicates that as the course progressed, higher performances were achieved. The negative test statistics indicate a significant improvement in performance.

## 4 DISCUSSION

When comparing the two methods in terms of the academic performance achieved by the students, the test statistic was not significant (refer to Table 1). This suggests that there is no significant difference between the two methods. However, it is important to note that the negative sign in the calculated statistic reflects that the performances achieved through the PrBL method were higher. This was evident in the first average, second average, third average, post-test, and final average. These results align with ones expressed in [7], [2], [16].

The aforementioned elements of judgment indicate that the PrBL method represents a valuable strategic alternative to ensure that students achieve the expected knowledge, a statement similar to that expressed by [4], [9], [11], [1], [6].

Upon comparing the results obtained from the PBL method (refer to Table 2), where samples were compared assuming related samples because each student in the group generated an observation at the beginning, during the execution of the research execution, and at the end, no significant differences were observed in the performances at different measurement points (second average, third average, post-test, and final average) compared to the pre-test. However, the negative value of the test statistic indicates that students improved their performance as they were taught using PBL. In this sense, the improvement in students' performance noted during the gradual adoption of the PBL approach aligns with the findings of [3], [5], [17], [12], [8], [10].

Regarding the results obtained from the application of the PrBL method (refer to Table 3), we observed significant differences in paired samples through a statistical test. The comparisons between the second average, third average, and final average against the pre-test showed higher performances as the subject was developed. This finding aligns with [7], [2], [16].

In this sense, we can infer that both groups of students experienced an improvement in academic performance as they engaged in project-based and PBL methods. However, the rate of improvement in performance was notably higher in the project-based method.

Regarding the hypothesis formulated in this study, we can affirm that it is not supported by the results obtained. The hypothesis stated that the PBL method is more effective than PrBL. However, this research led us to reject that hypothesis

because the results indicate the opposite, showing that PrBL is more effective than problem-based learning.

The processing, analysis, and interpretation of the information gathered during the study execution provide crucial insights indicating the feasibility of implementing teaching-learning strategies. These strategies integrate key elements from both PrBL and PBL methods, ensuring the convergence of both approaches to promote didactic mechanisms that facilitate learning outcomes. This scenario aligns with the multimodal vision that should have the teaching-learning process exposed by [14].

## 5 CONCLUSIONS

Project-based learning leads to higher academic performance compared to PBL. Statistically, significant differences in performance were observed between the two approaches.

It is possible to implement teaching-learning strategies that combine key elements from both the PrBL method and the PBL method. This integration ensures the coexistence of both approaches to promote didactic mechanisms that facilitate learning achievement. This approach aligns with the multimodal vision that the teaching-learning process should embody.

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