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PAPER

Problem-Based Learning and Knowledge of Digital Electronics among Engineering Students

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ABSTRACT

This paper aims to explore the relationship between problem-based learning (PBL) and the digital electronics course for engineering students at a private university with a population of 97 students. The study utilized a deductive and correlational hypothetical method with a non-experimental and quantitative design. As a result, the statistically significant relationship between PBL and the digital electronics course is verified. A relationship coefficient equal to *Rho* = 0.780 and $p < 0.01$, confirms the proposed alternative hypothesis. This result provides a robust quantitative perspective on how the integration of PBL positively influences engineering students' acquisition of digital electronics knowledge. The contribution lies in empirical support for the effectiveness of the PBL approach, providing educators and engineering professionals with a solid foundation for enhancing pedagogical strategies and fostering more effective and practical learning in the discipline.

KEYWORDS

digital electronics, knowledge, problem-based learning (PBL)

1 INTRODUCTION

Knowledge of digital electronics is a discipline that generates significant achievements today. It involves the constant study of electronic components, leading to discoveries and technological revolutions that continuously reshape society. This motivates students to acquire this knowledge and develop solutions for everyday challenges [1]. This is why the present study was born out of observations that align with professional and social realities. It aims to address the need for university education to serve as an intermediary, ensuring that students receive comprehensive professional training and can seamlessly transition between the educational and professional spheres without encountering significant gaps.

In [2], there is a mention of the necessity for a new vision and model of higher education that should be student-centered. This suggests a significant lack of major reforms and policies in many countries, especially in South America. The aim is to be

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able to serve students of different classes and diversities while maintaining consistency in the content, methods, experiences, and means of transmitting knowledge.

In terms of investment in education, at 0.1% of gross domestic product (GDP), Peru has the worst results in South America, reflecting a society that neglects and does not emphasize the quality of education. This indicator shows that students lack the necessary resources to enhance their learning effectively. More specifically, it is challenging for them to study, research, and produce, which leads to many difficulties in escaping poverty. Inequality in society results in various forms of injustice [3–5]. Numerous studies conducted around the world, notably by the World Economic Forum (WEF), the Organization for Economic Co-operation and Development (OECD), and the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), highlight the challenges in higher education, basic education, technological preparation, and significant deficiencies in the field of innovation.

Another challenge is that the state does not ensure that teachers meet the new quality standards for teaching and research [6]. It does not support them with resources and economic funding for good pedagogical and academic training of their teachers due to low salaries. There is no synergy between the national development plan and the universities. The universities fail to identify priority areas for scientific and technological development, resulting in poor-quality teaching for the students and, consequently, poor-quality learning in the acquisition of knowledge [7].

The World Bank focuses on evaluating education in general. To this end, Article 4 of the World Declaration on Education for All states that education should focus on acquisition and actual learning outcomes rather than giving exclusive attention to enrollment and certification, with assessment being the primary reason [8] [9].

Given the context explained above, the aim of this paper is to assess the extent of problem-based learning (PBL) and to evaluate knowledge in the field of digital electronics. To achieve this goal, our main contribution is the implementation of a hypothetical-deductive and correlational method based on a non-experimental and quantitative design.

The structure of this paper is as follows: Section 2 presents a review of the literature on creating pedagogy strategies through PBL. Section 3 presents the methodological aspects of the study. Section 4 presents the main results. Section 5 discusses the relevance of the proposed approach.

2 RELATED WORK

In [10], initial investigations were conducted on developing teaching strategies using PBL. The instruments used to obtain information included questionnaires with closed and open-ended questions, observation documents, and an interview guide. The investigation concluded that the use of PBL methodology for teaching enables better development in terms of collaboration, reasoning, and as activity. It also fosters greater creativity and feedback through teacher intervention. However, this development was unsatisfactory because the correct steps of PBL were not followed.

In the study proposed by the authors of [11], PBL is an active pedagogical approach that promotes self-directed learning, enhances knowledge retention, and improves educational performance. PBL was introduced in conservative dentistry with 91 student volunteers out of 119. Ultimately, an anonymous satisfaction survey was conducted using a 4-level Likert scale. Statistical analysis revealed that students highly appreciated the general concept of PBL (3.4/4), the scientific interest (3.4/4), and the pedagogical value (3.1/4) of the sessions. The organization and execution scored 3.2 out of 4. In conclusion, all students expressed a desire for PBL to be incorporated into their training.

In [12], which focuses on cooperative problem-based learning (CPBL), digital technology was used to implement a program in two secondary schools in the Iskandar region of Malaysia. Results suggest that student-centered, problem-based cooperative learning promotes environmental awareness, fosters deep STEM (science, technology, engineering, and mathematics) learning, and enhances 21st century skills. Students were observed using search engines to obtain information and messaging platforms such as WhatsApp and Telegram to communicate and support each other within the learning community. In addition, the CPBL introduced students to software and technology, raising their awareness of the importance of low-carbon production.

In reference [13], the authors proposed quantitative research and utilized a quasi-experimental method. The study was conducted on 61 vocational students in the clinical refraction course. The results showed an increase in critical, collaborative, communicative, and creative thinking skills in solving exercises in the clinical refraction course. Additionally, there was the creation of an engaging learning atmosphere and greater enthusiasm for participating in learning activities.

According to [14], the study on the effectiveness of teaching ordinary differential equations using the PBL method for mechanical engineering students at the SENAI CIMATEC university center resulted in a high number of students passing the course. In particular, the students embraced the use of the PBL method due to the more concentrated participation of working groups, which enhanced the exchange of ideas and actions, leading to intellectual and social development, and fostering enthusiasm. In electronic and mechanical engineering education, the authors of the article [15] came to the same conclusions.

Therefore, the primary research problem is: What is the relationship between PBL and knowledge of digital electronics among engineering students in 2023? Regarding the specific issues, the following question is posed: What is the relationship between PBL and general concepts of electricity in the knowledge of engineering students specializing in digital electronics in 2023? What relationship exists between PBL and instrumentation in the electronic laboratory to understand the digital electronics career of engineering students in 2023? What relationship exists between PBL and the introduction to digital electronics in engineering students' knowledge of the digital electronics career in 2023? What is the relationship between PBL and micro-programmable circuits in engineering students' understanding of the digital electronics field in 2023?

3 METHODOLOGY

The positivist paradigm was used in accordance with [16], which refers to the manifestation of the representation of reality and objectivity as the only means of achieving knowledge. The approach used is quantitative [17], taking into account validity, reliability, objectivity, experimentation and the predominant use of instruments, such as questionnaires with closed questions of fact or opinion and tests of objective and critical elements in research. Data analysis is carried out using descriptive and inferential statistics. The hypothetic-deductive method was used, which enables new knowledge to be derived from other, already established knowledge, by gradually subjecting it to deductions [18].

3.1 Variable identification

Two variables are identified here:

- **Variable #1 "Problem-based learning (PBL)":** This variable can be utilized to assess an empirical educational proposal designed to address the core issues of vocational training, such as lack of motivation, surface-level learning, learning and the gap between school instruction and real-world application [19].

– **Variable #2 "Knowledge of the subject of digital electronics":** This variable defines electrical systems from the perspective of electrons. Electronic components and circuits (including passive and active components as well as programmable integrated circuits) cater to the requirements of educational exploration and research. The goal is to construct, design, troubleshoot, program, and simulate diverse electronic systems [20].

3.2 Variable operationalization

To operationalize variable # 1, a 50-question questionnaire was prepared, containing indicators of the 4 dimensions: student-centered, active learning, collaborative learning, and critical reasoning (refer to Table 1 and see Figure 1).

To operationalize variable #2, a 20-question questionnaire was prepared to evaluate dimensions and indicators related to general concepts of electricity, instrumentation, introduction to digital electronics, and micro-programmable circuits (refer to Table 2 and see Figure 2).

Table 1. Operationalization matrix for variable #1

Dimension	Indicators	Items	Scale and Values	Levels and Range
Student Centered	Interest in the student	From 1 to 11	1: Totally Disagree 2: In disagreement 3: Neutral 4: Ok 5: Totally agree	Low [50–116] Half [117–183] High [184–250]
	Interest in learning goals			
	Interest in student responsibility			
	Interest in their own learning			
Active Learning	He is constantly active	From 12 to 26		
	Perform cognitive process			
	Perform psychomotor process			
	Build your learning			
	Participate in the process			
Collaborative Learning	Exchange knowledge they acquire skills	From 27 to 47		
	Participation of all students			
	Work as a team in the groups formed			
	Group leaders become tutors			
Critical Thinking	It is formative	From 48 to 50		
	The reasoning is given			
	Oriented to the learning process			
	Gain critical reasoning skills			

Table 2. Operationalization matrix for variable #2

Dimension	Indicators	Items	Scale and Values	Levels and Ranks
General concepts of electricity	Identify the parts of an electrical circuit	From 1 to 5	1: OK 0: Incorrect	Bad: [00–10] Regular: [11–15] Well: [16–20]
	Relates the magnitudes of a circuit with its corresponding unit of measurement			
Instrumentation in the electronic laboratory	Solve exercises on resistivity	From 6 to 10		
	Do Ohm's law exercises			
	Describes the most relevant management characteristics of measuring instruments			
	Recognizes the measurement instruments used in basic electronic circuits			
Introduction to digital electronics	Use the multimeters properly	From 11 to 15		
	Performs with precision and safety the fundamental electrical magnitudes			
	Operates with different numbering systems			
	Recognize the advantage of digital systems			
	Use Boolean algebra for the use of basic gates			
	Study the operation of a combinational circuit			
Micro programmable circuits	Implements the operation of the basic gates	From 16 to 20		
	Examine the operation of a combinational circuit			
	Recognizes electronic circuit simulation programs			
	Identify the structure of a microcontroller			
	Details the logic associated with the programmable elements (memories, ports, among others)			
	Describes basic applications with programmable elements			
	Make simple application programs			

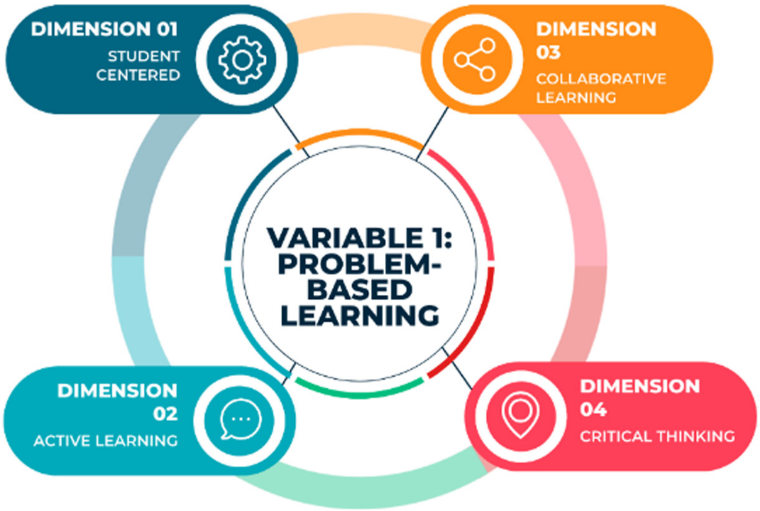

Fig. 1. Dimensions of variable #1 (student-centered, active learning, collaborative learning and critical thinking)

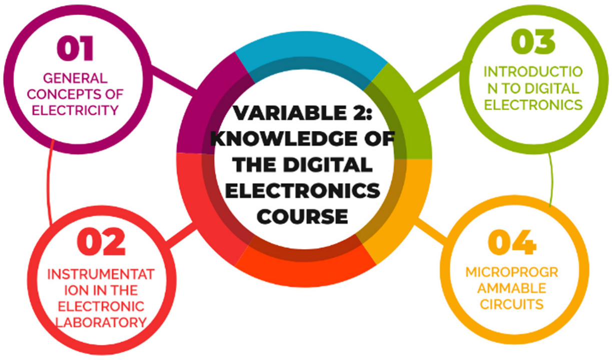

Fig. 2. Dimensions of variable #2 (general concepts of electricity, instrumentation, introduction to digital electronics, micro-programmable circuits)

3.3 Type of investigation

Concept definition. It is of a substantive nature because PBL was introduced to describe and explain the knowledge and reality of the digital electronics course. So [21] indicated that substantive research aims to address significant issues. It is focused on describing, explaining, predicting, or changing reality. This type of research seeks to identify general principles and laws to develop a scientific theory.

3.4 Research design

The research design corresponds to the non-experimental, cross-sectional type because the study variables were not manipulated or tested. It is also cross-sectional because the instrument was applied only once. According to [22], the analysis and interrelation are as follows:

3.5 Population

The population for the research conducted is presented in Table 3. According to [23], the population is defined as the total number of research participants, quantified by a set *N* of units that took part in the research. The entire population, consisting of 97 students, was used for the sample. According to [24], the model consists of a specific representative subset drawn from the population, from which data is collected and delimited.

Table 3. Table of the total population

			Total Population
1	Systems Engineering III cycle (A1)	35	97
2	Systems Engineering III cycle (B1)	32	
3	Systems Engineering III cycle (C1)	30	

3.6 Techniques and instruments

Instrument V1 problem-based learning: To conduct the reliability test, the results of the surveyed questionnaires from the students were utilized and then stored in Excel. The statistical analysis used was Cronbach's alpha for ordinal measurement scales.

Table 4 and Figure 3 show that Cronbach's alpha reliability statistic has a value of 0.868, which is considered good, indicating that the instrument is reliable.

Table 4. Reliability statistics

Cronbach's Alpha	Number of Items
0.868	50

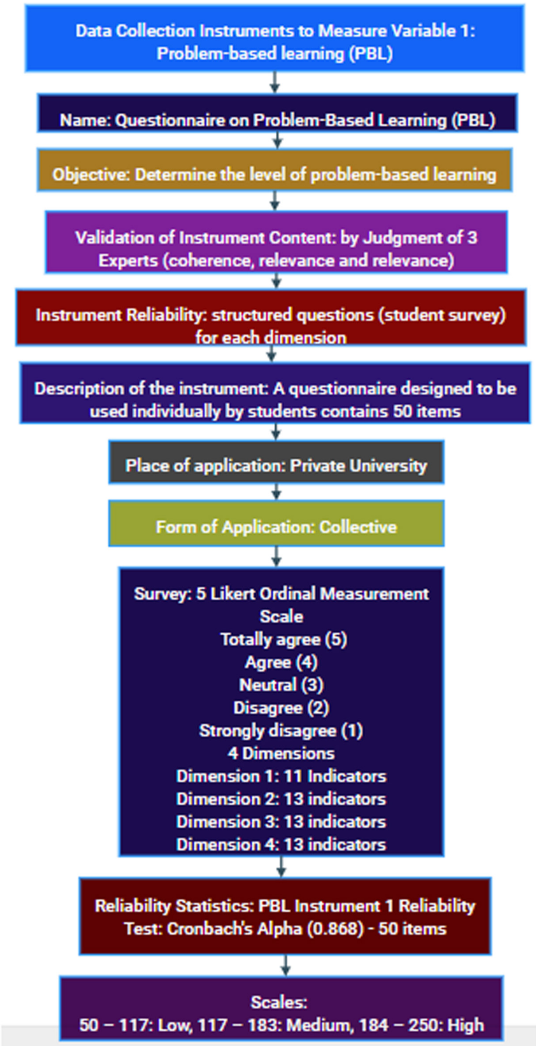

Fig. 3. Techniques and instruments for variable 1

Instrument V2: Knowledge of the digital electronics course: Description of the instrument: It is a printed evaluation test designed for individual use by students. The test has 20 items, and the responses are dichotomous. Each item answered correctly is equivalent to one point, each item answered incorrectly is equivalent to minus one point, and each item left unanswered is equivalent to zero points. The correctly answered scores are added, which would be their corresponding note (score).

Instrument validation: The internal consistency reliability of the instrument was evaluated using the Kuder-Richardson coefficient (KR-20), yielding a result of 0.836, which indicates that the instrument is reliable. According to [25] [26], he maintains that the Kuder-Richardson (KR-20) test is based on reliability in two halves that are generally considered equivalent or parallel.

Table 5 shows that the value of KR20 is 0.836, indicating very good reliability for the test conducted on the 20 items of the instrument. The final measurement scale will be constructed using scales, which will be designed based on the following correspondence intervals.

Table 5. KR20 Reliability statistics

Kuder–Richardson Statistics	
Rho	**Number of Elements**
0.836	20

Table 6 displays the high, medium, and low values of the variable "knowledge of the digital electronics course" along with their corresponding values for each dimension. Similarly, Figure 4 illustrates the process of validating the techniques and instruments of variable 2.

Table 6. Scales of the variable "knowledge of the subject of digital electronics"

Quantitative					
General	**Dimension 1**	**Dimension 2**	**Dimension 3**	**Dimension 4**	**Levels**
16 – 20	4 – 5	4 – 5	4 – 5	4 – 5	Well
11 – 15	2 – 3	2 – 3	2 – 3	2 – 3	Regular
00 – 10	0 – 1	0 – 1	0 – 1	0 – 1	Bad

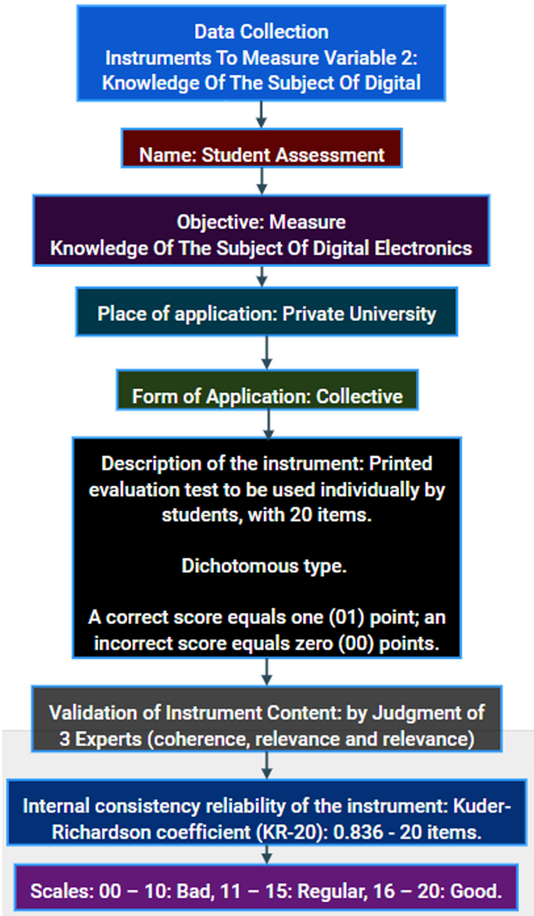

Fig. 4. Techniques and instruments for variable 2

3.7 Data analysis method

The data was analyzed using descriptive statistics, including frequency tables and figures. In terms of inferential statistics, hypothesis tests were conducted. Once the data collected from the surveys is typed and organized, it will be tabulated and classified by creating percentage distribution tables along with corresponding figures to facilitate interpretation.

4 MAIN RESULTS

4.1 Descriptive statistics

Variable 1: Problem-based learning: Table 7 and Figure 5 display the percentage values and the bar chart of the PBL variable. It can be seen that out of the 97 students, 0.0% have a low level, 45.4% have an average level, and 54.6% have a high level. Furthermore, a 100% value is observed, with no missing data.

Table 7. Levels of the PBL variable

Levels	Number of Students	Percentages
Low	0	0.0
Half	44	45.4
High	53	54.6
Total	97	100.0

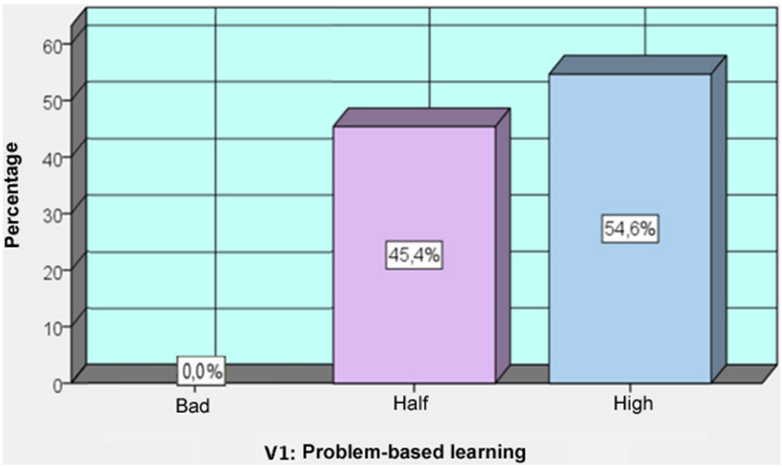

Fig. 5. Bar chart of the PBL variable

Dimension D1V1: Student-centered dimension: Table 8 and Figure 6 display the percentage values and histogram of the student-centered dimension of the PBL variable. Specifically, 97 students were assessed: 0.0% of them have a low level, 83.5% have an average level, and 16.5% have a high level. The total percentage amounts to 100%. No data loss is reported.

Table 8. Levels of the student-centered dimension

Levels	Number of Students	Percentages
Low	0	0.0
Half	81	83.5
High	16	16.5
Total	97	100.0

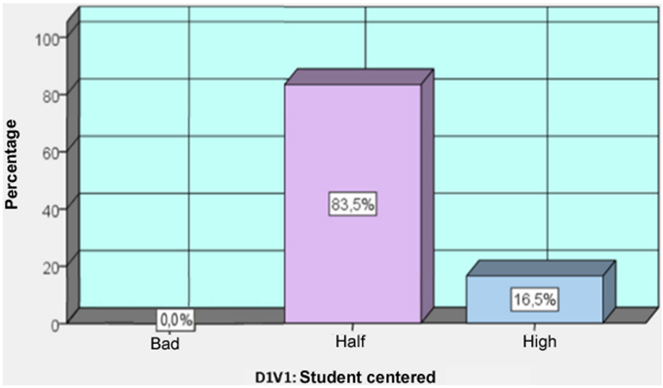

Fig. 6. Bar chart of the student-centered dimension

Dimension D2V1: Active learning dimension: In Table 9 and Figure 7, the percentage values and bar chart of the active learning dimension of the PBL variable are shown. Of the 97 students who were assessed, 0.0% had a low level, 14.4% had an average level, and 85.6% had a high level. No missing data is presented.

Table 9. Levels of the active learning dimension

Levels	Number of Students	Percentages
Low	0	0.0
Half	14	14.4
High	83	85.6
Total	97	100.0

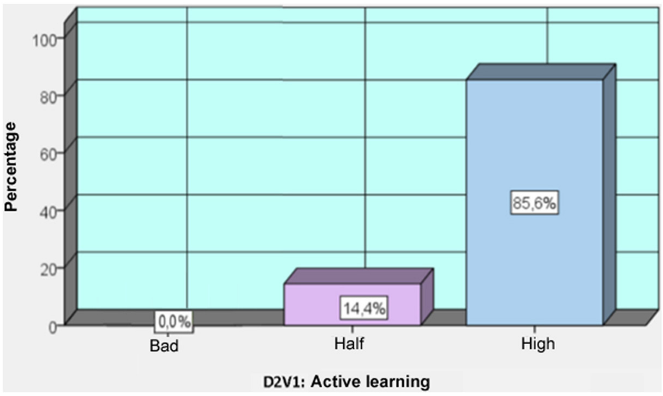

Fig. 7. Bar chart of the active learning dimension

Dimension D3V1: Dimension collaborative learning: Table 10 and Figure 8 display the percentage values and the bar chart with their corresponding percentages of the collaborative learning dimension of the PBL variable. To summarize, we observe that out of the 97 students, 0.0% have a low level, 3.1% exhibit an average level, and 96.9% exhibit a high level. Additionally, no data loss is reported.

Table 10. Levels of the collaborative learning dimension

Levels	Number of Students	Percentages
Low	0	0.0
Half	3	3.1
High	94	96.9
Total	97	100.0

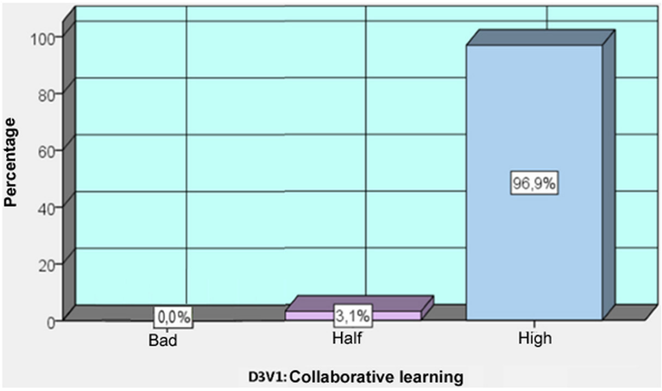

Fig. 8. Bar chart of the collaborative learning dimension

Dimension D4V1: Critical reasoning dimension: Table 11 and Figure 9 display the percentage values and histogram of the critical reasoning dimension of the PBL variable. Specifically, 97 students were assessed: 0.0% have a low level, 69.1% have an average level, and 30.9% have a high level. No data loss is reported.

Table 11. Levels of the critical reasoning dimension

Levels	Number of Students	Percentages
Low	0	0.0
Half	67	69.1
High	30	30.9
Total	97	100.0

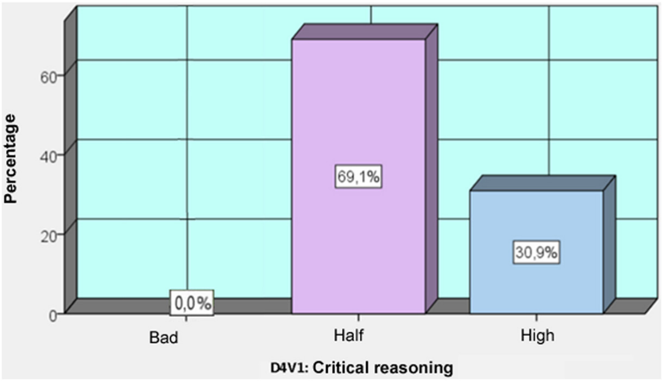

Fig. 9. Bar chart of the critical reasoning dimension

Variable 2: Knowledge of the subject of digital electronics: Table 12 and Figure 10 display the percentage values representing the level of knowledge of the subject of digital electronics. It can be seen that out of the 97 students, 0.0% have a low level, 17.5% have a normal level, and 82.5% have a good level. No missing data is presented.

Table 12. Levels of knowledge of digital electronics

Levels	Number of Students	Percentages
Bad	0	0.0
Regular	17	17.5
Well	80	82.5
Total	97	100.0

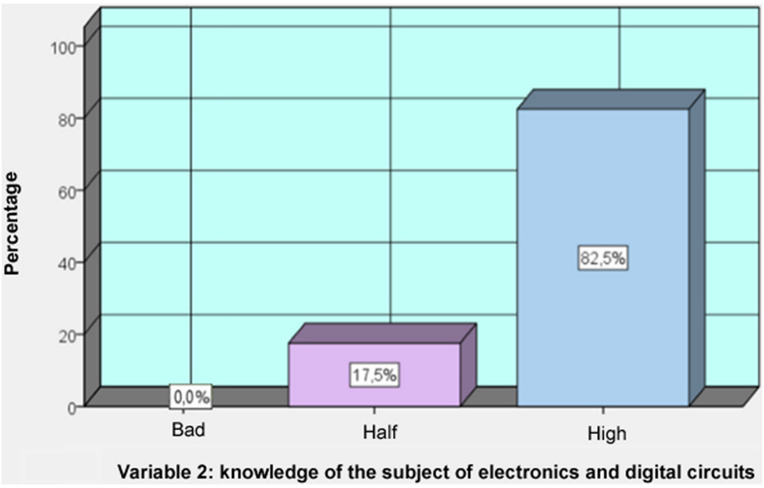

Fig. 10. Bar chart of the "knowledge of the subject of digital electronics" dimension

Dimension D1V2: Dimension of the general concepts of electricity: Table 13 and Figure 11 display the percentage values and a bar chart illustrating the percentage values of the general electrical concepts dimension. It is observed that 0.0% have a poor level, 38.1% present a regular level, and 61.9% present a good level. No missing data is presented.

Table 13. Levels of the "general electrical concepts" dimension

Levels	Number of Students	Percentages
Bad	0	0.0
Regular	37	38.1
Well	60	61.9
Total	97	100.0

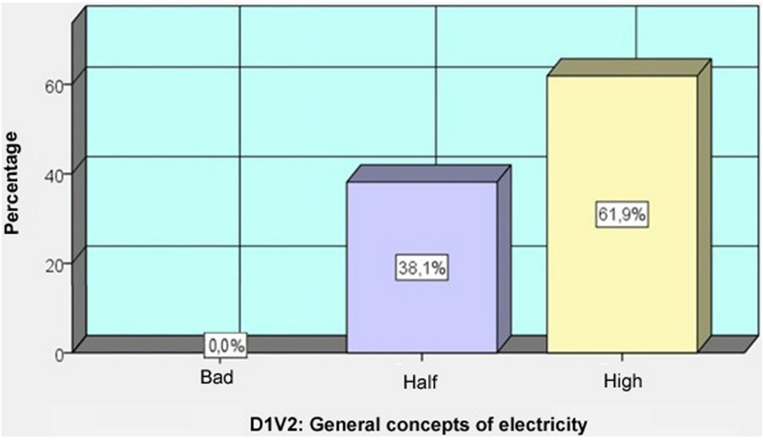

Fig. 11. Bar chart of the "general electrical concepts" dimension

Dimension D2V2: Dimension of the variable "instrumentation in the electronics laboratory": In Table 14 and Figure 12, the percentage values and the bar chart displaying the percentage values of the instrumentation dimension in the electronics laboratory are presented. It is observed that 0.0% have a low level, 16.5% present a regular level, and 83.5% present a good level. In addition, there is no missing data.

Table 14. Levels of the variable "instrumentation in the electronics laboratory"

Levels	Number of Students	Percentages
Bad	0	0.0
Regular	16	16.5
Well	81	83.5
Total	97	100.0

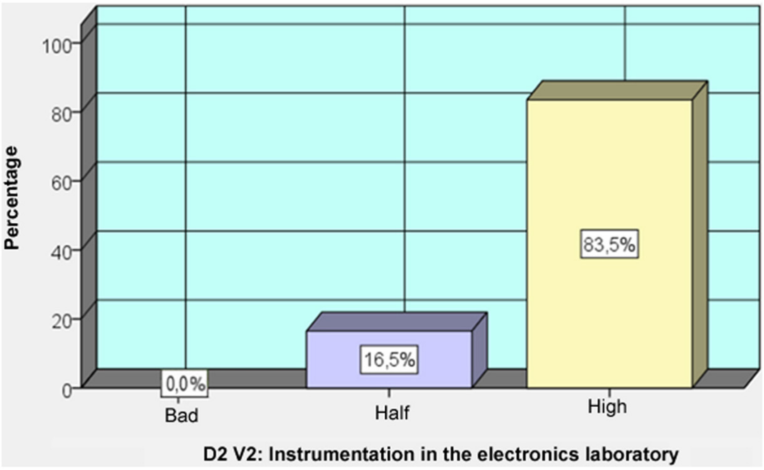

Fig. 12. Bar chart of the variable "instrumentation in the electronics laboratory"

Dimension D3V2: Dimension of the variable "introduction to digital electronics": In Table 15 and Figure 13, the percentage values and the bar chart displaying the percentages of the dimension "introduction to digital electronics" are presented. We observe that 0.0% have a bad level, 4.1% present a regular level, and 95.9% show a good level. In addition, no missing data is presented.

Table 15. Levels of the dimension "introduction to digital electronics"

Levels	Number of Students	Percentages
Bad	0	0.0
Regular	4	4.1
Well	93	95.9
Total	97	100.0

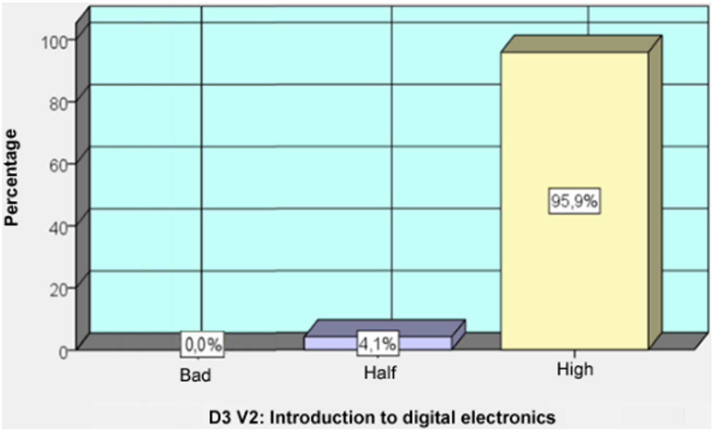

Fig. 13. Bar chart of the dimension "introduction to digital electronics"

Dimension D4V2: Dimension of the variable "micro-programmable circuits": Table 16 and Figure 14 display a bar chart along with its corresponding percentage values for the dimension. We conclude that 0.0% have a poor level, 11.3% have a regular level, and 88.7% have a good level. In addition, no missing data is presented.

Table 16. Levels of the dimension "micro-programmable circuits"

Levels	Number of Students	Percentages
Bad	0	0.0
Regular	11	11.3
Well	86	88.7
Total	97	100.0

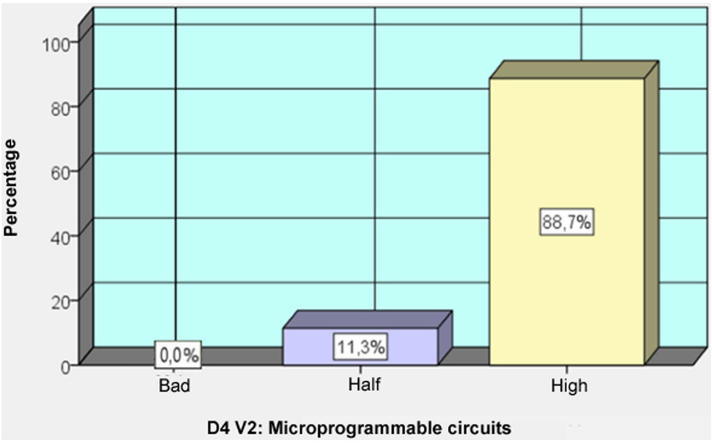

Fig. 14. Bar chart of the dimension "micro-programmable circuits"

4.2 Inferential statistics

Spearman correlation coefficient (Rho) analysis

Spearman's correlation coefficient (Rho) is used in statistics to conduct a non-parametric assessment for ordinal data. It assumes that values close to 1 1 indicate a positive correlation, values close to –1 represent a negative correlation, and values close to –1 0 are considered insignificant [27].

Hypothesis testing

Significance level: The authors of [20] indicate that a significance level is defined to determine the rejection or acceptance of the null hypothesis (Ho). By convention, 0.05 has been chosen as the margin of error below this value.

General hypothesis

Two hypotheses are defined below:

- The null hypothesis $H0$ assumes that there is no significant positive correlation between PBL and knowledge of the digital electronics course among engineering students in 2023.
- The alternative hypothesis $H1$ assumes that there is a significant positive correlation between PBL and knowledge of the digital electronics course among engineering students in 2023.

Table 17 displays the results of Spearman's *Rho* correlation between variable 1 and variable 2 to test the general hypothesis. The correlation coefficient is high *Rho* = 0.780**, with $p = 0.000$ ($p < 0.01$), demonstrating that only the alternative hypothesis is accepted, rejecting the null hypothesis. Therefore, we can conclude that there is a positive and significant relationship between PBL and knowledge of the digital electronics course among engineering students in 2023.

Table 17. Correlation between PBL and knowledge of digital electronics

Correlations				
			V1: Problem-Based Learning	V2: Knowledge of Digital Electronics
Spearman's *Rho*	V1: Problem-based learning	Correlation coefficient	1.000	**0.780****
		Next (bilateral)	.	0.000
		No.	97	97
	V2: Knowledge of digital electronics course	Correlation coefficient	0.780**	1.000
		Next (bilateral)	0.000	.
		No.	97	97

Specific hypotheses

In the same way, we test four specific hypotheses. The first involves the following two hypotheses:

- The null hypothesis $H0$ assumes that there is no significant positive correlation between PBL and the dimension "general concepts of electricity" among engineering students in 2023.
- The alternative hypothesis $H1$, which assumes that there is a significant positive correlation between PBL and the dimension of "general concepts of electricity" among engineering students in 2023.

Table 18 presents the results of Spearman's *Rho* correlation between PBL and the dimension "general concepts of electricity" to test the first specific hypothesis. The correlation coefficient is high *Rho* = 0.802**, with $p = 0.000$ ($p < 0.01$), demonstrating that only the alternative hypothesis is accepted, rejecting the null hypothesis. Therefore, we can conclude that there is a positive and significant relationship between PBL and the dimension "general concepts of electricity" among engineering students in 2023.

Table 18. Correlation between PBL and general electricity concepts

Correlations				
			V1: Problem-Based Learning	**SD1V2: General Concepts of Electricity**
Spearman's *Rho*	V1: Problem-based learning	Correlation coefficient	1.000	**0.802****
		Next (bilateral)	.	0.000
		No.	97	97
	D1V2: General concepts of electricity	Correlation coefficient	0.802**	1.000
		Next (bilateral)	0.000	.
		No.	97	97

The second specific hypothesis involves the following two hypotheses:

- The null hypothesis *H*0 assumes that there is no significant positive correlation between PBL and the dimension of "instrumentation in the electronics laboratory" among engineering students in 2023.
- The alternative hypothesis *H*2 assumes that there is a significant positive correlation between PBL and the dimension of "instrumentation in the electronics laboratory" among engineering students in 2023.

Table 19 presents the results of Spearman's *Rho* correlation between PBL and the dimension "instrumentation in the electronics laboratory" to test the second specific hypothesis. The correlation coefficient is high *Rho* = 0.741**, with $p = 0.000$ ($p < 0.01$), demonstrating that only the alternative hypothesis is accepted, rejecting the null hypothesis. Therefore, we can conclude that there is a positive and significant relationship between PBL and the dimension "instrumentation in the electronics laboratory" among engineering students in 2023.

Table 19. Correlation between PBL and instrumentation in the electronics laboratory

Correlations				
			V1: Problem-Based Learning	**D2V2: Instrumentation in the Electronics Laboratory**
Spearman's *Rho*	V1: Problem-based learning	Correlation coefficient	1.000	**0.741****
		Next (bilateral)	.	0.000
		No.	97	97
	D2V2: Instrumentation in the electronics laboratory	Correlation coefficient	0.741**	1.000
		Next (bilateral)	,000	.
		No.	97	97

The third specific hypothesis involves the following two hypotheses:

- The null hypothesis *H*0 assumes that there is no significant positive correlation between PBL and the dimension "introduction to digital electronics" among engineering students in 2023.
- The alternative hypothesis *H*3 assumes that there is a significant positive correlation between PBL and the dimension "introduction to digital electronics" among engineering students in 2023.

Table 20 presents the results of Spearman's *Rho* correlation between PBL and the dimension "introduction to digital electronics" to examine the third specific hypothesis. The correlation coefficient is high *Rho* = 0.791**, with $p = 0.000$ ($p < 0.01$), demonstrating that only the alternative hypothesis is accepted, rejecting the null hypothesis. Therefore, we can conclude that there is a positive and significant relationship between PBL and the dimension "introduction to digital electronics" among engineering students in 2023.

Table 20. Correlation between PBL and introduction to digital electronics

Correlations				
			V1: Problem-Based Learning	D3V2: Introduction to Digital Electronics
Spearman's *Rho*	V1: Problem-based learning	Correlation coefficient	1.000	**0.791****
		Next (bilateral)	.	0.000
		No.	97	97
	D3V2: Introduction to digital electronics	Correlation coefficient	0.791**	1.000
		Next (bilateral)	0.000	.
		No.	97	97

The fourth specific hypothesis involves the following two hypotheses:

- The null hypothesis *H*0 assumes that there is no significant positive correlation between PBL and the dimension of "micro-programmable circuits" among engineering students in 2023.
- The alternative hypothesis *H*4 assumes that there is a significant positive correlation between PBL and the dimension of "micro-programmable circuits" among engineering students in 2023.

Table 21 presents the results of Spearman's *Rho* correlation between PBL and the dimension of "micro-programmable circuits" to test the fourth specific hypothesis. The correlation coefficient is high *Rho* = 0.786**, with $p = 0.002$ ($p < 0.01$), demonstrating that only the alternative hypothesis and rejection of the null hypothesis. Therefore, we can conclude that there is a positive and significant relationship between PBL and the dimension of "introduction to digital electronics" among engineering students in 2023.

Table 21. Correlation between PBL and micro-programmable circuits

Correlations				
			V1: Problem-Based Learning	D4V2: Micro-Programmable Circuits
Spearman's *Rho*	V1: Problem-based learning	Correlation coefficient	1.000	**0.786****
		Next (bilateral)	.	0.002
		No.	97	97
	D4V2: micro programmable circuits	Correlation coefficient	0.786**	1.000
		Next (bilateral)	0.002	.
		No.	97	97

5 DISCUSSION

In the present study, using data from 2023, the results obtained verify the general hypothesis that the relationship between PBL and knowledge in the digital electronics engineering course has been validated (with a high correlation coefficient of approximately 0.78). The results show that engineering students enrolled in the digital electronics course have an average level of PBL (45.4%), achieving average levels in the following dimensions: student-centered (83.5%), active learning (14.4%), collaborative learning (3.1%), and critical reasoning (69.1%). Nuances need to be taken into account and developed in the curriculum with the support of teachers to enhance students' understanding of the course. As a result, it has been established that the system needs to be organized, and the program and teachers need to know how to use the method correctly.

With regard to specific hypothesis 1, the relationship between PBL and general electrical concepts in the knowledge of engineering students in the digital electronics course was verified in 2023. The statistical tests reveal a high correlation coefficient of approximately 0.802. In addition, it can be seen that no one has a low level, 38.1% of students have a regular level, and 61.9% have a good level. It has been suggested that the use of the PBL method is a beneficial alternative to the university's limited resources. This method allows for the adaptation of formats to various subjects and sessions, promoting teamwork and active participation among peers through the collaborative construction of new knowledge.

With regard to specific hypothesis 2, the relationship between PBL and instrumentation in the electronics laboratory was established in 2023. The results of statistical tests show a high correlation coefficient of approximately 0.741. What's more, no one has a mediocre level; 16.5% of students have a regular level; and 83.5% have a good level.

Similarly, the relationship between PBL and the introduction of digital electronics was verified in 2023, showing a high correlation coefficient of around 0.791. We observed that no one had a mediocre level, 4.1% of students had a regular level, and 95.9% had a good level.

Finally, the relationship between PBL and the introduction of microprogrammable circuits was verified in 2023, showing a high correlation coefficient of approximately 0.786. We observed that none of the students had a mediocre level, 11.3% had a regular level, and 88.7% had a good level.

6 CONCLUSIONS

The investigation conducted as part of this study demonstrates that it was possible to establish the relationship between PBL and knowledge of the digital electronics course among engineering students. In 2023, the results showed a high correlation coefficient of 00.780, confirming the alternative hypothesis. In other words, this result indicates that PBL contributes to enhancing students' understanding of the digital electronics course.

The work presented in this article has also established the relationship between PBL and fundamental electrical concepts in engineering students' understanding of the digital electronics course. Indeed, in 2023, the correlation coefficient of 0.802 is very high, enabling us to accept the alternative hypothesis. We can therefore affirm that there is a direct and significant correlation between PBL and general electrical concepts. In this sense, the principle of theoretical foundations supports the findings presented in this survey.

Similarly, the connection between PBL and instrumentation in the electrical engineering laboratory was also established. In 2023, a high correlation coefficient of 0.741 was obtained, according to the results. Accepting the alternative hypothesis, we enhance students' knowledge in the digital electronics course.

The relationship between PBL and the introduction to digital electronics was also demonstrated. According to the results, a high correlation coefficient of 0.791 was obtained, which allows for the acceptance of the alternative hypothesis. In this way, it was possible to enhance students' understanding of digital electronics.

Finally, the relationship between PBL and microprogrammable circuits was established. According to the results, a high correlation coefficient of 0.786 was obtained in 2023, confirming the alternative hypothesis.

All the results summarized above have significant practical importance in the field of education, especially in engineering training environments. The positive and significant relationship between PBL and professional knowledge of digital electronics underscores the effectiveness of this specific pedagogical methodology.

In the real world of education, these results can be applied to enhance the quality and effectiveness of teaching digital electronics in engineering programs. Here are some practical applications:

- Curriculum design: Research findings support the integration and reinforcement of PBL approaches in program design. Educators can adapt and develop lesson plans by incorporating more PBL activities and cases to enhance students' understanding of digital electronics concepts.
- Development of educational resources: Research suggests that creating problem-based teaching resources can be beneficial. Teachers can create case studies, practical problems, and activities that encourage critical thinking and problem-solving skills, thereby enhancing the understanding of digital electronics concepts.
- Teaching-learning methodologies: Educators can adapt their teaching methods to include more practical, problem-based approaches. Integrating problem-solving into the classroom can help students apply learned theories to real-world situations, reinforcing their understanding and practical skills.
- Learning assessment: Research supports the idea that problem-based assessment can be more effective in measuring knowledge of digital electronics. Assessment methods that mirror real-world situations can offer a more precise gauge of student comprehension and proficiency compared to conventional tests.

– Encouraging collaborative work: Since PBL often involves collaborative work, educators can promote and organize group activities that involve students in problem- solving. This enhances the comprehension of digital electronics and fosters crucial teamwork skills.

In summary, the results of this research provide a solid foundation for enhancing the teaching of digital electronics in educational institutions. They support the adoption of PBL strategies to facilitate more efficient and profound learning in the field.

Although significant conclusions were drawn from the research, possible directions for future research can be suggested to enhance the practical applications of the study and explore new research opportunities. The influence of specific variables could be further explored, such as the duration of PBL or the adaptability of this methodology to different levels of student proficiency. In addition, exploring how other engineering disciplines could benefit from similar strategies could offer a more comprehensive understanding of the pedagogical implications of PBL in engineering environments. These suggestions could help broaden understanding of the relationship between PBL and specific knowledge in the field of digital electronics, offering a more comprehensive framework for future research.

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