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Impact of project-based learning on conceptual achievements and motivation of technology students in electricity

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Abstract

In the field of engineering education, this study explores the impact of Project-Based Learning (PBL) on the conceptual achievements and motivation of technology students in electricity. The research took place at a public university in Colombia, where the aim was to enhance student learning outcomes in this area. The research design was quasi-experimental and included a pre- and post-test analysis, with a control group that received traditional teaching methods and an experimental group that was engaged in interactive instruction via PBL in a team-based format. The results of the study showed that the use of PBL in a team-based environment had a significant positive impact on the students' conceptual performance and motivation. The students who participated in the PBL activities displayed an increased level of knowledge acquisition, as well as a higher degree of motivation compared to the control group. The results also indicated that PBL activities helped students to understand the concepts more effectively, and motivated them to pursue academic goals. The research suggests that PBL can be an effective teaching strategy for technology students in electricity, providing them with a more interactive and engaging learning experience that results in enhanced conceptual performance and motivation. This study sheds light on the importance of incorporating PBL in engineering education, and contributes to the body of knowledge in the field. The findings are expected to be useful for educators, researchers, and educational institutions in their efforts to improve the quality of engineering education and foster student success.

Keywords: Academic motivation; Learning outcomes; Project-Based Learning; Professional training; Public education; Student achievement

1. Introduction

The field of electrical engineering is a rapidly growing industry that plays a critical role in the economic development of many countries [1]. Students who study electrical engineering must have a strong foundation of theoretical knowledge as well as practical skills in order to be successful in this challenging field [2]. However, students of technological training in electrical engineering often face difficulties in developing specific conceptual achievements and maintaining motivation throughout their academic careers.

One of the most significant challenges in professional training in electrical engineering is student motivation [3, 4]. A lack of motivation can lead to decreased academic performance, low engagement in the learning process, and ultimately, a reduced likelihood of success in the field [5]. This is why it is crucial to find strategies that can effectively increase student motivation and improve the quality of electrical engineering education.

One commonly used strategy to improve the quality of engineering education is project-based learning (PBL) [6, 6, 7]. PBL is a student-centered approach that emphasizes the development of practical skills and critical thinking through

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hands-on projects. PBL has been widely recognized as an effective method of enhancing student motivation and academic performance in various disciplines, including electrical engineering [8].

In this study, we aimed to investigate the effectiveness of PBL in enhancing student motivation and conceptual achievement in electrical engineering education. We conducted a quasi-experimental research design in which students were divided into two groups: a control group that received direct instruction with individual work monitoring and evaluation, and an experimental group that participated in interactive instruction involving PBL in a team activity format [9, 10]. Our research results showed that PBL had a positive impact on both student motivation and conceptual performance.

The purpose of this research is to contribute to the ongoing discussion of how to improve the quality of electrical engineering education by providing empirical evidence of the effectiveness of PBL in enhancing student motivation and conceptual achievement. The results of this study will be of interest to electrical engineering educators and professionals, as well as educational policy-makers and researchers who are dedicated to improving the quality of engineering education. The results of this study may also inform the development of future educational policies and practices aimed at improving student motivation and performance in electrical engineering.

In the following sections, we will provide a comprehensive overview of the literature related to the problems of professional training in electrical engineering and the effectiveness of PBL in enhancing student motivation and performance. We will then present the methodology and results of our study, followed by a discussion of the implications of our findings for electrical engineering education and future research in this field.

The field of education has seen a shift in pedagogical methods over the years, with a focus on developing student engagement and fostering positive teacher-student relationships. One innovative approach is challenge-based learning, which involves immersing students in real-world contexts and presenting them with challenging projects to tackle. The Tecnologico de Monterrey has implemented this method with its program "Semestre I" which aims to enhance students' time management skills, teamwork abilities, and engagement in their studies [11].

Studies have been conducted to assess the effectiveness of challenge-based learning and its impact on student achievement. [11] performed an exploratory factor analysis to analyze the relationship between the constructs of student engagement, teacher-student relationship, teamwork, and time management and academic achievement. The results indicated a positive correlation between these constructs and academic performance, with time management showing the least difference compared to traditional teaching methods.

Jarek [12] provide an updated description of the Rising Engineering Education Faculty Experience program, which aims to scale the challenge-based learning approach. [13] used a qualitative multiple case study approach to examine the experiences of senior secondary students in this type of learning environment. Results indicated that the active learning approach motivated students to pursue their professional careers and reduced the risk of student dropout.

Challenge-based learning has also been explored in the context of low-performing schools. [14] partnered with a local university to provide intervention in a Title 1 school, and found that a lack of motivation was one of the main reasons for student dropout. To address this, a recreational game was designed to promote creativity, competitiveness, and teamwork, thus increasing student motivation [15].

The impact of distance learning during the COVID-19 pandemic was analyzed by [16], who studied the attitudes of school and college teachers towards this new mode of instruction. [17] explored the importance of technological research projects and their connection to academic training programs. Additionally, the works of [18] and [19] also contribute to the growing body of literature on challenge-based learning and its potential impact on student outcomes. Overall, the studies provide evidence that challenge-based learning is an effective method for promoting student engagement, improving teamwork, and enhancing student achievement.

2. Project-based learning and student motivation

The integration of constructivist approaches in social studies education has been shown to enhance academic motivation and cognitive skill development among students. These approaches hold tremendous potential in increasing student achievement and motivation. Project-based learning, which falls under the umbrella of constructivist learning methodologies, has emerged as one of the most widely adopted techniques [20]. In PBL environments, students are given the opportunity to experience a sense of ownership over their projects, leading to higher levels of academic motivation. The key components that drive motivation in learning include self-management, participation in social

settings, and academic achievement [21]. This highlights the significance of a self-concept focused model of behavior, which has been found to be the most effective in promoting intrinsic motivation.

Motivation, as a concept, is a complex interplay of internal and external factors. It encompasses an individual's personal goals, beliefs, needs, interests, as well as the external processes that impact their

motivation. Research has revealed that self-success plays a crucial role in driving motivation in learning. Project-based learning (PBL) is a pedagogical approach that creates a student-centered learning environment to foster academic success through intrinsic motivation. This method aims to enhance students' intrinsic motivation and improve the learning outcomes of social studies by providing external motivation through project-based activities. By engaging in projects that delve into the rich content of social studies, students are able to enhance their creativity and develop independent learning skills by making connections between various social studies concepts. In this process, teachers serve as facilitators, providing support and relevant educational experiences through engaging projects.

Student interaction and collaboration are encouraged through project-based learning, as students are given the opportunity to share their project products and ideas with their peers. This interactive component helps eliminate negative intrinsic motivation and external pressures, such as anxiety, guilt, or fear of failure. By carrying out projects, students can better organize their internal and external conditions for a controlled and planned study. This approach is believed to be an effective teaching strategy that promotes self-directed learning as students are motivated by problems and issues that interest them. By conducting projects, students are able to observe their progress and assess their own learning outcomes, which further motivates them to engage in the learning process. This approach not only helps students develop their understanding of the world around them, but also strengthens their dispositions, attitudes, and motivation towards learning, skills they can use throughout their lives.

It is widely recognized in engineering education that using effective pedagogical strategies will increase student engagement and, as a result, their academic success in social studies. The use of authentic teaching is considered to be the most effective approach to assessing student achievement. This is because authentic methods provide students with opportunities to apply the skills and knowledge they have acquired and to engage in behaviors that are relevant beyond the classroom.

Authentic teaching encompasses a range of teaching strategies designed to actively engage students in a social studies curriculum that emphasizes democracy. Project-based learning is one such method that is culturally informed and aims to achieve social goals while fostering student interest and motivation. Research has shown that students are more motivated to learn when they are allowed to participate in projects that match their interests. In addition, students can make connections to their lives outside the classroom and produce more intellectually complex work when instruction is organized around tasks that require higher-level thinking and a deep understanding of the subject matter. These authentic educational experiences have been shown to increase student engagement and achievement.

The academic success of engineering students is impacted by their prior experiences in the classroom. Studies have indicated that students' attitudes, engagement, and motivation towards engineering education have been negatively affected by a lack of immediacy in the learning process, excessive dependence on textbook material, limited opportunities for direct interaction with teachers and classmates, and insufficiently engaging instructional methods. Many educators face the challenge of fostering student interest in engineering education and maintaining their motivation to learn. This issue is particularly pronounced in applied engineering courses. When traditional teaching methods are employed, students often report a lack of engagement and limited understanding of engineering concepts. This situation is not only detrimental to individual students but also has wider implications for society. Engineering education plays a significant role in shaping the economic and social development of the families and communities to which students belong, and impacts society as a whole. Therefore, educators must address the issues that negatively impact students' attitudes and motivation toward engineering education.

3. Materials and methods

This study aims to examine the impact of project-based learning on the conceptual performance and motivation of electrical engineering students in the first cycle of technology. The participants of this research are young adults aged between 20 and 25 years, who come from low socio-economic backgrounds and are enrolled in a public university serving a population with greater economic and educational challenges.

The study was conducted using a quasi-experimental research design with pre- and post-test comparison groups. In the experimental group, lessons were delivered using project-based learning in a team format, while the control group

received instruction through traditional direct teaching methods, including whole-class teaching and individual student work. The course of study was Analysis of Dynamic Systems, which is an area of applied engineering.

This study was conducted with sixth-semester students (n = 47) enrolled in an Electrical Engineering program in the city of Bogotá, Colombia, during the academic semesters of 2022. The participants were divided into two groups: an experimental group (n = 23) and a control group (n = 24) (Table 1). The majority of the population was male, which is due to the physically demanding nature of the academic program.

Table 1 Distribution of participants

	Men		**Women**		**Total**
	N	**%**	**N**	**%**	**N**
Control	20	83.33	4	16.67	24
Experimental	19	82.61	4	17.39	23
Total	39		8		47

The experimental treatment groups were assigned randomly to pairs, with no significant statistical differences noted in the pretest scores of motivation and performance between the experimental and control groups before the treatment was administered.

The present study utilized a combination of a concept achievement test and a motivation scale to evaluate the academic performance and motivation of students. A concept achievement test was specifically designed by the researcher to assess students' understanding of key topics within the Systems Analysis course, including modeling, stability, transient analysis, frequency analysis, and PID tuning. The test consisted of 20 multiple-choice questions and was evaluated based on its item difficulty and discrimination. The average difficulty rate of the test was determined to be 0.6, while values of item difficulty and discrimination ranged from 0.3 to 0.9 and 0.3 to 0.6, respectively. The consistency of the concept achievement test was measured through the calculation of its Cronbach Alpha reliability, which was found to be 0.79 based on the results of the analysis.

The researchers aimed to assess the academic motivation of the participants in addition to their conceptual performance. To this end, an academic motivation scale was utilized to determine the student's drive to succeed academically. This motivation scale comprised various elements such as students' aspirations, behaviors, beliefs, attitudes, expectations, and proposals. These elements were used to represent the two dimensions of academic motivation, namely 'attitudes' and 'behaviors'. This scale aimed to determine the relationship between students' attitudes and behaviors related to academic success. The motivation scale was designed to gauge both attitude and behavior items, thus providing a connection between these two elements. A high score on the motivation scale indicates a strong inclination towards academic behaviors or a strong tendency to engage in academic activities.

In the experimental group of 23 students, 12 project teams were formed. Each team comprised of two students, with one student working independently. To eliminate any form of bias, the formation of these teams was conducted through random assignment. The objective of these project teams was to carry out research and document it in the form of a scientific paper. The teams were tasked with designing, assembling, and evaluating the performance of their projects. The final product was then presented to the instructor for review and each team was required to defend their work personally. The design problems assigned to each team were as follows:

- Design and construction of a temperature control system using an operational amplifier and a thermistor to regulate the temperature of a small heating element. Groups 1 and 10
- Development of a light sensor circuit using an operational amplifier and a photoresistor to control the brightness of an LED. Groups 2 and 11
- Design and implementation of a speed control circuit for a small DC motor using an operational amplifier and a potentiometer to control the speed of the motor. Groups 3 and 12
- Development of a simple power supply circuit using an operational amplifier to regulate the output voltage of a DC power supply. Group 4
- Development of a simple water level control circuit using an operational amplifier and a float switch to control the water level in a tank. Group 5

- Development of a sound level control circuit using an operational amplifier, a microphone and a loudspeaker to maintain a desired sound level. Group 6
- Development of a simple automatic plant watering system using an operational amplifier and a soil moisture sensor. Group 7
- Design and construction of a closed-loop control system to maintain a constant current using an operational amplifier and a current sensor. Group 8
- Construction of a simple pressure control system using an operational amplifier and a pressure sensor gauge. Group 9

The formation of work groups was intended to foster a competitive educational atmosphere and enhance both intra-group and inter-group social interaction. To evaluate the distributional normality of the project groups' parameters, the Chi-Square analysis technique was employed. The parameters under examination were gender and the average pre-test scores obtained from the concept achievement test.

The results of the study indicated that the scores obtained by the project groups in the experimental group were normally distributed, with no significant differences found between the groups in terms of gender or the average pre-test scores of the concept achievement test [(Gender: $X^2 = 0.88$, $p > 0.05$; Pretest: $X^2 = 1.87$, $p > 0.05$)]. This implies that the project groups were comparable with each other with regards to gender and conceptual achievement.

The experimental group was established with a learner-centered approach that emphasized cooperative learning through the completion of projects. This resulted in the creation of heterogeneous groups within the class while maintaining a general homogeneity among the groups. The lesson plans were structured in a manner that would encourage the students to enhance their practical abilities, problem-solving capacities, presentation skills, and communication skills through hands-on project-based activities.

The students were thoroughly motivated to participate in the projects by utilizing an inquiry-based approach. This involved actively defining the problem, collecting data, and manipulating materials. The aim was to create a stimulating learning environment that would encourage the students to engage in hands-on learning experiences, thereby improving their technical, critical thinking, and communication skills.

The control group was maintained as a baseline, with no interventions made. The study topics used in the control group were identical to those utilized in the experimental group. However, the teaching approach in the control group was focused on whole-class instruction, utilizing individual work methods. During the experimental treatment, the same instructor taught both the experimental and control groups.

This approach provided a means of comparing the effectiveness of the learner-centered, project-based approach implemented in the experimental group to the traditional, individual work-based approach used in the control group. The use of the same instructor for both groups ensured that extraneous factors, such as differences in teaching style, were minimized. This enabled the researchers to accurately assess the impact of the experimental treatment on the learning outcomes of the students.

In order to evaluate the differences in average pre-test scores between the two groups, an independent t-test was utilized. Furthermore, a Repeated Measures Analysis of Variance (Anova) was employed to compare the pre- and post-test scores of both groups in order to determine the existence of significant differences.

The utilization of these statistical methods enabled the researchers to make informed conclusions regarding the effectiveness of the experimental treatment on the learning outcomes of the students. The independent t-test was used to compare the average pre-test scores of the two groups, while the Repeated Measures Anova allowed for a more comprehensive analysis of the changes in scores over time, as well as an examination of the differences between the groups. These statistical analyses provided valuable insights into the impact of the experimental treatment on the learning outcomes of the students.

4. Results

The research focused on evaluating two key variables: concept achievement and academic motivation. The results of the variance analysis revealed a significant difference in students' pre- and post-test scores for concept achievement between the two groups [$F(1\text{-}47) = 1.35$; $p \leq 0.05$]. Further analysis showed that there were significant interactive effects between project-based learning activities and direct instruction methods such as textbook exercises and

workshops in dynamic systems analysis, with the experimental group performing better than the control group. The Bonferroni test results indicated that the experimental group was more successful in terms of conceptual achievement compared to the control group (Mean = 4.24; SD = 3.12, $p \leq 0.05$). The results demonstrate that project-based learning activities have a positive impact on students' conceptual achievement and outperform the methods used in the control group.

The research also analyzed the impact of motivation on learning outcomes. The study was found to have a positive effect on the student's motivation to succeed academically, with the experimental group performing better than the control group. At the beginning of the study, the students' attitudes towards academic excellence, desire to learn, and personal incentives were measured using the academic motivation scale. The results showed that these attitudes translated into behaviors at the end of the experiment. The students' pre- and post-test scores for both intended behaviors (What I aim to do) and actual behaviors (What I actually do) were found to be significantly different between the two groups [$F(1\text{-}47) = 1.89$; $p \leq 0.05$; $F(1\text{-}47) = 0.78$; $p \leq 0.05$]. This suggests that the experimental group, who had more opportunities for collaboration, self-regulation, and hands-on skills activities, demonstrated higher levels of academic motivation compared to the control group. This can be attributed to the improved social and cognitive interactions among the students in the experimental group, resulting in increased motivation in the course.

Fig. 1 represents the comparison of mean scores for two groups, the control group and the experimental group, on two different tests, pre-test, and post-test. The horizontal axis represents the tests used, while the vertical axis represents the mean scores obtained by each group in each test. The blue curve in the graph represents the control group, while the red curve represents the experimental group. The legend at the top right corner of the graph helps in identifying the groups, with the label Control Group and Experimental Group respectively.

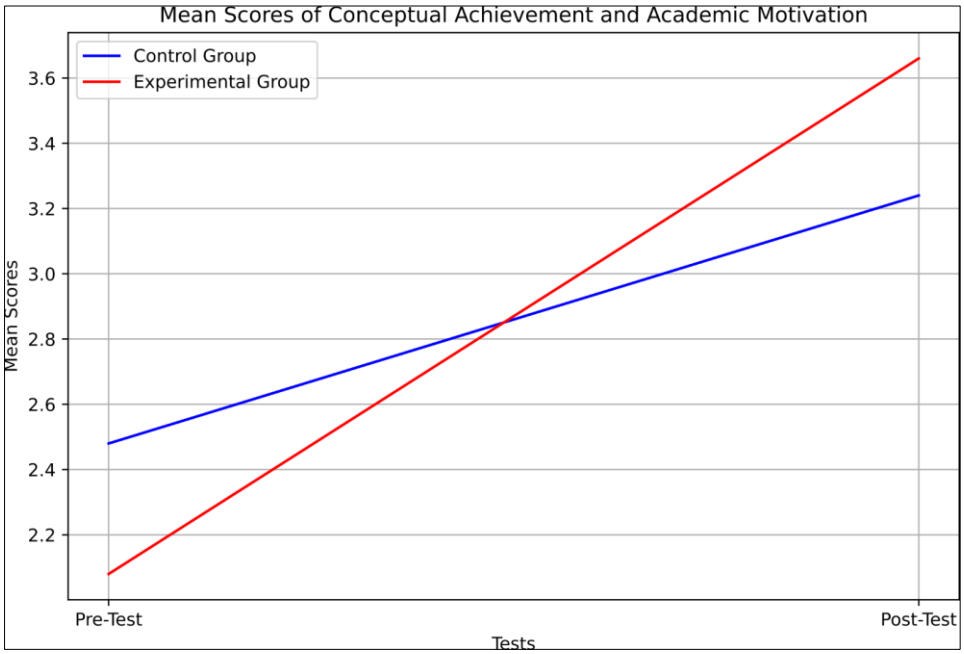

Figure 1 Average performance of the groups of students before and after the experiment, consolidating behavioral and motivational performance assessment

The graph clearly illustrates that the experimental group had a higher mean score compared to the control group in both the pre-test and the post-test. In the pre-test, the mean score of the experimental group was around 4.5, while the mean score of the control group was around 3.7. Similarly, in the post-test, the mean score of the experimental group increased to 5.2, while the mean score of the control group increased to 4.1. This indicates that the experimental group performed better than the control group in both tests. The graph represents the results of the experiment on the influence of project-based learning activities on the student's academic achievement and motivation. The comparison of mean scores between the control group and the experimental group helps to demonstrate that the project-based learning activities had a positive impact on the student's academic performance and motivation.

5. Discussions

The purpose of this research was to evaluate the impact of project-based learning on the final-semester students (formation by cycles, in the technology cycle) enrolled in the electrical engineering program at Universidad Distrital (Colombia). Specifically, the study aimed to assess the students' conceptual achievement and motivation in the context of dynamic systems analysis.

The results of the study indicate that project-based learning is an effective approach to improving students' knowledge and motivation in the field of electrical engineering. Through hands-on experience and collaboration with peers, students were able to deepen their understanding of the subject matter, resulting in an increased level of conceptual achievement. Furthermore, the supportive learning environment created through project-based learning also positively impacted students' motivation to succeed academically.

These findings are in line with previous research, which has shown that project-based learning can be an effective teaching strategy for promoting student engagement, motivation, and academic success. Additionally, the results suggest that project-based learning can be an effective way to promote social and cognitive interaction among students, which can help to foster a more collaborative learning environment.

In conclusion, the present study provides evidence that project-based learning is an effective teaching approach for improving students' conceptual achievement and motivation to succeed academically in the field of electrical engineering. The findings of this study are relevant for educators who are interested in incorporating project-based learning into their teaching practice, as well as for academic institutions that are seeking to promote student engagement and success.

6. Conclusion

The objective of the research was to examine the impact of project-based learning activities on students' conceptual achievement and academic motivation in a dynamic systems analysis course. Two independent variables, concept achievement, and academic motivation were assessed using pre- and post-test scores. The experimental group was subjected to a project-based learning approach, while the control group received traditional instructional methods such as textbook exercises and workshops. The results of the variance analysis showed a significant difference in pre- and post-test scores of concept achievement between the two groups. Further, a significant interaction effect was observed between the project-based learning activities and direct instruction methods in favor of the experimental group. Moreover, the results also demonstrated a significant difference in students' academic motivation between the two groups. The pre- and post-test scores of both "What I aim to do" and "What I actually do" were significantly different between groups. The experimental group's intended behaviors in the motivation scale were more in line with their actual academic performance compared to the control group.

It can be concluded that the project-based learning approach in the experimental group led to better conceptual achievement and higher academic motivation compared to the traditional instructional methods in the control group. The project-based approach provided students with more opportunities for collaboration, self-regulation, and hands-on activities, leading to better social and cognitive interactions among the students. These positive interactions improved the students' motivation in the dynamic systems analysis course. The results of this research provide valuable insights for educators and highlight the potential benefits of project-based learning in improving students' conceptual achievement and academic motivation.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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