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FORMATIVE RESEARCH STRATEGY FOR THE MECHANICAL ENGINEERING PROGRAM OF THE UNIVERSIDAD FRANCISCO DE PAULA SANTANDER OCAÑA

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ABSTRACT:
Student-centered learning has been used as a teaching strategy. In addition, methodologies like project-based, active, problem-based, and experiential learning are available to improve the educational process. However, employing these strategies necessitates prior familiarity with the critical tenets of the applicable discipline. To facilitate communication between the demands of the workplace and the learning outcomes of the academy, this article examines the use of project-based integrated learning as an educational practice (formative research strategy) to integrate the institutional curriculum of the Mechanical Engineering program in the Virtual Instrumentation course and the requirements of skills that the industry today. Also, the course uses LabVIEW software, which enables the development of virtual instruments for monitoring, acquiring, and processing data. This study aims to connect to the program curse curriculum, considering that the students select a topic and then present the information to the class in an exposition. The outcomes demonstrate that all students employed different techniques to produce a workable prototype in just sixteen (16) weeks providing a viable solution related to mechanical engineering and that these projects improved their leadership, problem-solving, communication, and time management abilities.

INTRODUCTION

Nowadays, in a world where technological innovation occurs exponentially and changes are necessary for existence. In higher education institutions, teachers frequently seek to disseminate effective changes in teaching and learning techniques to help students acquire the skills necessary for work and life in the schools—real scenarios (Saputra et al., 2019)(Andriyani et al., 2019). Project-based integrated learning (PBL) is an innovative, student-driven, teacher-facilitated research-based learning approach (Ruslan et al., 2021). It differs from everyday learning because it encourages active learners by solving problems to complete a project (Hernáiz-Pérez et al., 2021).

Studies comparing the PBL with the conventional teaching approach show that the former produced significant positive effects on problem-solving skills (Tortorella & Cauchick-Miguel, 2018)(Vicente et al., 2011), conceptual understanding, attitudes towards learning, and comparing student performance or better on content knowledge tests. This behavior suggests that students become better researchers, problem solvers, and high-level thinkers through the PBL has also shown that students who participated in PBL achieved higher scores than their counterparts at the receiving end of traditional classroom instruction, according to different studies reported in the open literature.

Considering the above, formative research is essential in developing students' skills. Vicuña Ureta et al. (2022) developed a bibliometric analysis to observe the production and publications related to formative research (FR) in universities in Latin America. The results showed that Brazil is the most important Latin America country, with 35 articles related to the formative research topic. Also, FR improves the quality of the universities and institutions because a habit is generated among students and individuals. In the same way, Hernández et al. (2020) studied the research in universities founding that research is an essential skill for higher education. The main results reveal that the current specialized software for research activities facilitates the development of research projects and the incorporation of research methodology in different areas (Vieth & Lewis, 2022).

Mechanical engineers at the Francisco de Paula Santander Ocaña University are employed in various industries. Therefore, their education requires a multidisciplinary approach focused on the labor market and social challenges (Amiruddin et al., 2018). This fact increases the pressure on companies and higher education institutions to prepare their professionals (Haryudo et al., 2019). However, training now includes not only the acquisition of technical knowledge but also evaluating different innovative teaching methods to promote the acquisition of professional skills, such as project-based learning, active learning, peer assessment, active and collaborative learning, formative assessment, inquiry-based learning, flipped classrooms among others (Valencia et al., 2015)(Pan et al., 2021). In fact, many studies emphasize the importance of using a combination of different approaches to suit all student needs (Baccar et al., 2017).

The Virtual Instrumentation of Mechanical Engineering micro-curriculum at the Francisco de Paula Santander Ocaña University includes different training purposes to promote the integration of knowledge through the practical solution of engineering problems present in the community, favoring social projection and the intensification of the university and industry relations. Through application solution in LabVIEW software. Virtual instrumentation (VI) can be used to construct instruments for real problems. Still, it can also be helpful to build applications that simulate the operation of devices and instruments and for the animation and modeling of physical processes (Tiernan, 2010). The last represents a significant feature of LabVIEW, which can create helpful tools in the teaching process (Mogal, 2013).

LabVIEW software is a registered trademark of National Instrument (NI), whit specific instrumentation software and analysis software for operating PCs. Besides, it represents a programming environment that includes specific tools required for instrument control, data acquisition, storage, analysis, presentation, and integration of these functions into a single system. However, this software uses programming and a particular graphics language called G, considering that the main objective of LabVIEW is virtual instrument creation (Sivaranjani et al., 2021).

This study presents a project-based learning methodology based on a formative research strategy, intending to include different Virtual Instrumentation concepts in the mechanical engineering career at the Francisco de Paula Santander Ocaña University, with the primary objective that the students improve their skills and research methodologies. Also, this project allows the interaction and interrelation of students who work together on a typical project to give a solution to a real problem using LabVIEW software.

MATERIALS AND METHODS

Context of the Virtual Instrumentation Course

The Virtual Instrumentation Course is a professional elective offered to students in the ninth semester and is part of the applied mechanical engineering area. This area provides the identity of the Mechanical Engineer of the Francisco de Paula Santander Ocaña University and contributes to the development and performance of professional skills.

The course given around the LabVIEW software introduces the graphical programming environment to develop applications and provides a foundation to find solutions to any problem in real-time. This software allows a graphical programming approach that helps to analyze every aspect of the generated application based on a visual programming language, including hardware configuration, data, debugging, and integrates with different disciplines such as basic sciences, integration of LabVIEW and Matlab software, prototype validation during the product cycle integrating LabVIEW and SolidWorks, and instrumentation applications.

Stages of project-based integrated learning methodology

The main objective of the Virtual Instrumentation course is to generate the appropriation of knowledge related to virtual instrumentation, including continuous control and supervisory control for its application in Mechanical Engineering under the project-based learning methodology. Figure 1 shows the steps that were used in this project.

Figure 1. Stages of Project-based Learning**.**

Diagnosis to identify the problem in the Virtual Instrumentation course

In the Mechanical Engineering program of the Francisco de Paula Santander Ocaña University, project-based learning is based on classroom projects with the primary objective to solve a problem for the industry and the community. Initially, for the problem identification of the identified sectors, which are the service sector, energy mining sector, ceramic, and agroindustry, another way of looking for projects is through the national, sector, departmental, and local development plans.

In the second semester of 2020 in the Virtual Instrumentation subject, the following problems were defined, considering the evaluation developed in advance:

- The implementation of LabVIEW with SolidWorks for the movement of the hydraulic platform of the design of a mobile pneumatic lubrication equipment, workshop car.

- Temperature and humidity data acquisition system, which identifies the drying parameters of clay bricks.

- Acquisition of temperature data from a shell and tube exchanger.

- Construction of a milling machine prototype for wood controlled by LabVIEW software for the Francisco de Paula Santander Ocaña University machine and tools laboratory.

Planning and organization

During the first class, students are given a project list that was identified in stage one previously detailed and their corresponding specifications, which they can choose based on their interests and experience. Then, they meet in groups of five, based on common interests. Next, six lectures are given to give students the necessary knowledge to tackle projects. These lectures cover basic virtual instrumentation topologies such as visual programming and virtual sub-instruments, structured programming and data types, analysis, data visualization, strings and files, and data acquisition systems. Finally, the students received an overview of the project and the rules and regulations they must follow during the project briefing.

During the planning, a class was provided to the students of the different search engines and databases that they could consult to obtain preliminary information and the background of each problem and thus provided with the project format, which was a previous one was used. Which is established at the Francisco de Paula Santander Ocaña University, the section Research and Extension Unit (DIE), called a guide to present research projects that contain the project title, abstract, general objective, specific objectives, background, problems, justification, schedule, budget, and references. Table 1 shows the schedule that was proposed for the execution of the project of the course.

Table 1. Schedule by weeks for the execution of the project.

#	Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Team building	X															
2	Information search for the project background		X	X	X	X											
3	Project formulation			X	X	X											
4	Sustentation of the Preliminary Project						X										
5	Preparation of the prototype design								X	X							
6	Develop the graphical interface										X	X					
7	Sending the project report												X	X			
8	Presentation of the Project at the ENACIM event														X	X	

9	Sustentation of the project																X

Execution and evaluation of the project

In this stage, four prototypes were made by the groups of students with the advice of the teacher and experts on the subject, which included the knowledge seen in each lecture. Figure 2 describes the results section considering the project evaluation rubric, explained in detail in the following part.

The evaluation of the project course is due to the professor being in continuous contact with the students, and the project's progress is presented during the course. The project is evaluated with the evaluation rubric presented in Table 2. The Academic Meeting of the Mechanical Engineering Program - ENACIM is the academic board organized annually by the program and the Department of Mechanical Engineering of the Francisco de Paula Santander Ocaña University. The ENACIM event is a strategy for linking students in the formative research process and strengthens project-based learning of the subjects by courses.

Table 2. Project Evaluation Rubric.

Evaluation criteria	**Low (0.0 – 2.9)**	**Half (3.0 – 3.9)**	**High (4.0 – 5.0)**	**%**
Classroom project planning	The project planning according to the objectives set is not identified in the document	The document lacks some fundamental aspects of the project's planning against fulfilling the objectives.	The document shows the coherence of the activities compared to the objectives. Likewise, it shows the completeness of the basic aspects of planning, such as specific tasks, managers, times, and resources.	25
Development by stages of the project	The stages are not considered, or the tasks defined in the planning are not executed.	The activities are developing moderately, not complying with some of the aspects already planned.	The activities have fully complied with each of the planned stages.	35
Teamwork	Students cannot work as a team	Students develop some team activities	Students manage to complement each other and	20

			develop teamwork skills	
Presentation of the final classroom project	The project does not have defined guidelines for the presentation.	The project is presented with weaknesses in support and in the domain of the subject worked	The project is selected and presented at the ENACIM event	20

RESULTS AND DISCUSSIONS

Figure 2 shows the four projects developed in the second semester of 2020 in the Virtual Instrumentation subject and provides a solution to a real problem planted in the course.

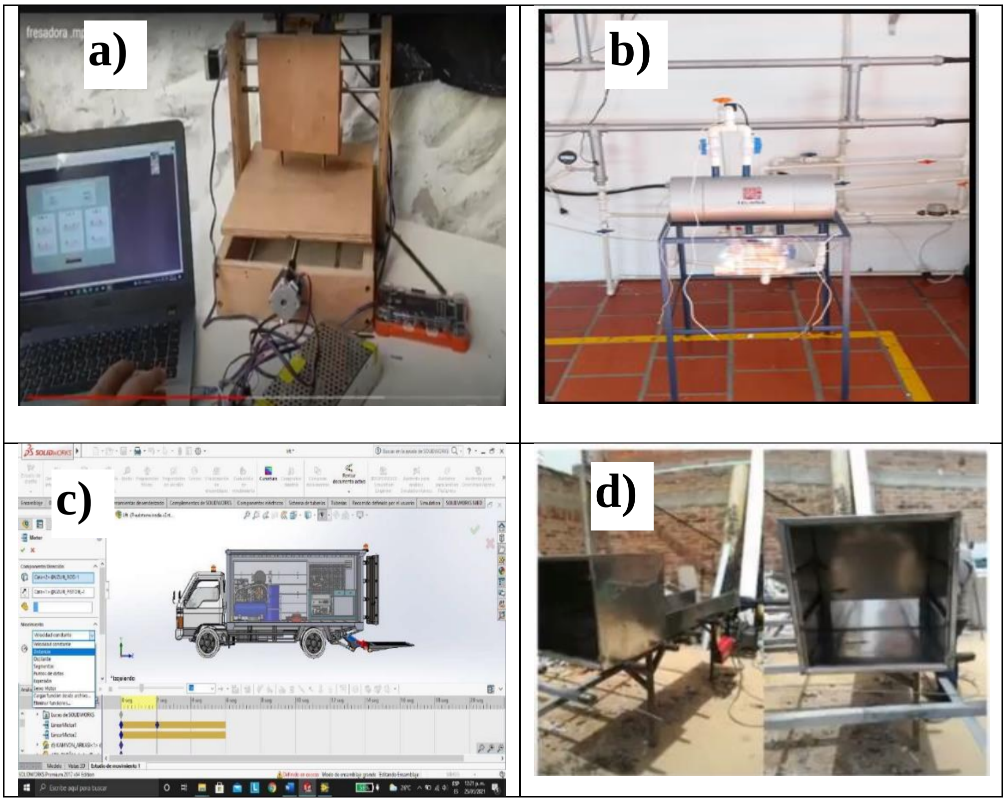

Figure 2. Projects developed using LabVIEW software. a) Construction of a prototype of a milling machine for wood, b) Virtual instrument for data acquisition and analysis of a shell and tube heat exchanger, c) Design of a hydraulic loading platform, and d) Temperature and humidity data acquisition system, which identifies the drying parameters of clay bricks.

In each of the figures, it is observed that a prototype was obtained, which provides a solution to the problem posed in the course. Figure 2 shows that 100% of the students used different strategies to create a functional prototype in sixteen weeks. The evaluation rubric presented in Table 2 was used to evaluate the project. The projects were supported in the Academic Meeting of the Mechanical Engineering Program-(ENACIM 2020 event) and were evaluated by two experts in areas related to the presented projects. Figure 3 shows the results of the evaluation of the projects by the jury of the event after applying the evaluation rubric (Pan et al., 2021).

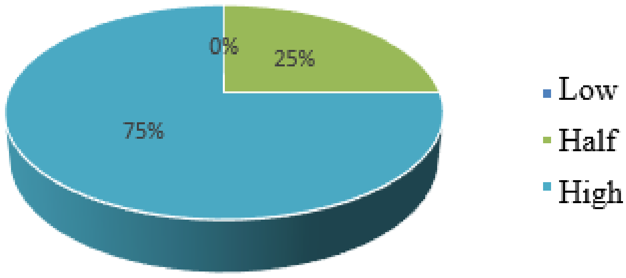

Figure 3. Project evaluation results.

Figure 3 shows that around 75% of the students obtained a high grade and 25% a medium grade, analyzing the evaluation rubric described in Table 2. In this way, it was concluded that more than 15 students developed teamwork skills, project planning, development by stages of the project, and final project presentation (Ramos et al., 2021).

CONCLUSIONS

This article shows an application of the paradigm of implementing Project-based Learning in the Virtual Instrumentation course of the Mechanical Engineering program of the Francisco de Paula Santander Ocaña University based on the analysis of student evaluations. This learning methodology enhances the skills that a ninth-semester student must demonstrate, allowing them to relate the different knowledge acquired in previous courses with the specific topics involved in this LabVIEW course, thus creating virtual instruments for the acquisition and control of data in real applications.

Applying the PBL to the subject "Virtual Instrumentation" has proven that this approach reports positive results related to student learning in content knowledge, teamwork skills, commitment and motivation, project planning skills, and presentation of projects at events.

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