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DEVELOPMENT OF COMPETENCIES FROM PROJECT-ORIENTED LEARNING

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ABSTRACT

The results achieved show improvements in skills related to solving problems in the real world, as well as in project management through the preparation and socialization of reports, which result in achieving the specific competencies that will allow the student to achieve efficiency, effectiveness, and competitiveness in the organization in question. The proposed methodology can be used to diagnose and correct weaknesses in the training process of future industrial engineers. In addition, content aims to understand the importance of skills training based on Project-Oriented Learning.

I. INTRODUCTION

Today, the training of engineers is a challenge due to the vast amount of available information, the increasing complexity of the problems they must face, and the globalization of markets. Additionally, the environment has become a crucial factor in the engineer's activities, requiring the development of sustainable products and processes that do not harm it. Likewise, the engineer must take on social responsibility concerning the products generated by recent technologies and their impact on all areas of human activity. Furthermore, corporate structures are becoming increasingly participatory, demanding more teamwork and decision-making responsibility from professionals [1- 2]. All the afore mentioned implies that a competent professional must possess great adaptability to change, along with proper information management skills and an ethical attitude that enables them to make appropriate decisions within their socio-cultural environment.

Universities and educators are constantly concerned with developing and adapting new pedagogical and didactic strategies that enable the training of engineering professionals with the necessary competencies for increasingly dynamic work and social environments. These new methodologies aim to enhance the development of generic competencies such as learning how to learn, organizing and planning, analyzing, and synthesizing, applying knowledge to practice, expressing oneself orally and in writing in one's language, critical and self-critical thinking, collaborative work, initiative and leadership skills, and knowledge of a second language [3-4]. Specific competencies are targeted according to the specific knowledge areas of the academic program under consideration. Indicators of these competencies have been included in the accreditation criteria for engineering programs by various institutions responsible for this process, such as ABET (Accreditation Board for Engineering and Technology) in the United States [5].

Among the various methodologies for developing competencies, we can mention cooperative learning, collaborative learning, competency-based learning, project-based learning (PBL), and problem-based learning, among others [6-11]. These methodologies have been enhanced through the use of Information and Communication Technologies (ICT), which, in the case of engineering, involve the use of online platforms for educational activities, virtual laboratories, and remote experimentation, web interfaces for content visualization, as well as simulation tools specifically designed to develop skills and abilities in future engineers [12-15].

PBL is a methodology that brings students closer to solving real-world problems and allows them to take greater responsibility for their learning. It enables them to apply the skills and knowledge acquired during their education to real projects. It intends to guide students toward situations that lead them to rescue, understand, and apply what they learn as a tool to solve problems and perform tasks.

This paper presents the experience of applying the PBL methodology, adapted for the development of professional competencies in industrial engineering students enrolled in the Distance Learning Program (CPE) at the "Marta Abreu" Central University of Las Villas.

II. DEVELOPMENT

II.1 PROFESSIONAL COMPETENCIES

The concept of competencies has evolved from its initial use in the business field with the task-centered approach, which gave rise to what is known as job competencies. These refer to the effective capacity to successfully conduct a fully identified work activity [16]. This definition emphasizes the knowledge, skills, and abilities that a person must possess to efficiently fulfill a specific task. The occupational profile-centered approach establishes professional competencies. These can be the result of a process of education of the personality for professional performance, efficiency, and responsibility, which does not end with the student's graduation from a professional training center but accompanies them throughout their professional development process and in the practice of the profession [17]. From this perspective, the important thing is not the possession of certain knowledge, but how the individual uses it, the motivation to do so, and the commitment to achieve a result.

Competencies are also defined as comprehensive performance to interpret, argue, and solve problems in the context with creativity, suitability, continuous improvement, and ethics, developing and putting into action the knowing how to be, the knowing how to coexist, the knowing how to do, and the knowing how to know [18]. It is precisely this concept that serves as the basis for this proposal.

The model of comprehensive professional competencies organizes them into three levels: basic, generic, and specific, ranging from the general level to the specific level. Basic competencies are the essential intellectual capacities for learning a profession. They encompass cognitive, technical, and methodological competencies, many of which are acquired at previous educational levels (such as the proper use of oral and written language and mathematical language). Generic competencies are the common foundation of the profession or refer to specific situations in professional practice that require complex responses. Finally, specific competencies are the foundation of professional practice and are therefore linked to specific performance conditions.

Given the current need and perspective of the job market, the development of a set of professional competencies in university graduates that enables them to successfully practice their profession and meet current demands is essential. To achieve this, the emphasis should be on the professional competencies the Industrial Engineering Project Discipline in the Industrial Engineering program in the Distance Learning Program (CPE) aims to develop. Among these competencies, we can mention operating a process or activity within it, describing production and service processes, their elements, and interrelationships, quantitatively and qualitatively characterizing industrial engineering problems, applying the working procedure of industrial engineering, and working in multidisciplinary teams to solve industrial engineering problems with a comprehensive approach and extensive use of ICT. To accomplish the above, the proposed competencies can be adapted to solve a range of professional problems common to the field, allowing future professionals to possess competencies that can be utilized by employing appropriate methods to identify needs, evaluate them, and provide suitable solutions to existing problems characterized by unforeseen circumstances, multiple solutions, or imprecise and incomplete information.

II.2 PROJECT-ORIENTED LEARNING

Project-Oriented Learning (POL)/Project-Based Learning (PBL) is defined as a teaching-learning method in which students conduct a project within a specified time limit to solve a problem or address a task through the planning, design, and implementation of a series of activities. It involves the application of acquired learning and the effective use of resources. It is a method based on experiential learning and reflection, where the inquiry process around the proposed project is important. It intends to guide students toward situations that lead them to rescue, understand, and apply what they learn as a tool to solve problems and perform tasks.

To undertake a project, it is necessary to integrate learning from various areas and subjects, overcoming fragmented learning. Through project work, students discover and learn concepts and principles specific to their specialization. It is action-oriented learning; it is not just about learning "about" something (as in problem-based learning), but about "doing" something. The teacher is not the primary source of information. The innovation brought by project work as a learning strategy lies not in the project itself, but in the possibilities, it offers to put into practice and develop different competencies.

The project-oriented teaching-learning method is a strategy in which the product of the learning process is a project or professional intervention program at the center of the organization of all training activities. It allows the development of professional competencies through its implementation. Among the main advantages offered by this method are:

- Improved motivation towards learning, as it is based on experience and promotes the establishment of task-related objectives.
- Application of acquired knowledge, skills, and attitudes to concrete situations, enhancing the corresponding competencies.
- Encouragement of integrated learning (knowledge, methodological, social, and affective aspects).
- Strengthening of students' self-confidence.
- Promotion of investigative learning approaches.

III. CASE STUDY APPROACH

Considering the requirements of the "E" Study Plan [19], the conducted study revealed that, as a result of profound and ongoing changes in the economy and social life, which are partially expressed in the dynamics of the curriculum, there have been deficiencies related to the performance of graduates in terms of the Model of the Professional and their professional competencies in the field of Industrial Engineering. These deficiencies relate to oral and written expression, the use of Scientific and Technical Information devices, the ability to make innovative decisions, the values of responsibility and social commitment, and economic thinking, among others. Therefore, it is necessary to emphasize the professional competencies the Industrial Engineering Project Discipline in the semi-presential pedagogical model aims to develop. However, the study plan does not include any pedagogical strategy to provide students with the necessary tools to develop these competencies. Hence, to achieve meaningful learning that allows students to apply the knowledge acquired during their education in an integrated manner, it is necessary to implement an active teaching method called Project-Oriented Learning (POL).

All of these situations have a negative impact on the quality of the graduate and, therefore, on the satisfaction of their expectations as a professional. Therefore, the problem presented here, to a large extent, justifies the need to systematize the improvement processes in a way that contributes to the development of professional competencies through the educational teaching process through the Main Integrating Discipline of the Industrial Engineering career in the pedagogical model. semi-presential, so that the deficiencies related to professional performance are mitigated, whose form of evaluation for the three subjects that comprise it, the study plan contemplates the implementation of applied projects, which will be executed in parallel with the subjects of the specific training field professional, but does not contemplate any pedagogical strategy that provides the student with the necessary tools to develop these competencies.

In order to seek meaningful learning that allows students to comprehensively apply the knowledge received during their training, it is necessary to implement a training strategy that addresses the weaknesses described above, through the application of an active teaching method called Project Oriented Learning., which constitutes the general objective of the present investigation. To complete the above, we set ourselves specific objectives:

- Develop in students a professional work methodology
- Generate knowledge from experience
- Achieve self-learning and creative thinking

The experience took place during the academic year 2019-2020 with students enrolled in the Industrial Engineering program in the Distance Learning Program (CPE) in their 3rd, 4th, and 5th years. They took the subjects Introduction to Industrial Engineering and Integrative Industrial Engineering Project I, II and III, which are part of the Industrial Engineering Project Discipline, as shown in the table 1.

Table 1: Discipline Industrial Engineering Project.

Subjects	Total class hours	Total work practice hours
Introduction to Industrial Engineering	42	0
Industrial Engineering Integrative Project I	28	192
Industrial Engineering Integrative Project II	24	196
Industrial Engineering Integrative Project III	18	202

Source: Authors, (2020).

The reports prepared must also reflect the technical, environmental, economic, social and computer and communications technology analyses, in correspondence with the impact of the engineering work derived from them. In the analysis of possible solutions, the laws, the current regulatory system and the impact on the country's defense will be taken into account. Through teamwork and research, students develop pedagogical skills and consultation of specialized and general bibliography.

The pedagogical training of our students is guaranteed from the humanistic training itself that is declared in the general objectives and in the values that guide the contents. The emphasis on the necessary training to develop competencies and raise performance in organizations indicates that only with the use of pedagogical methods based on objectives as a governing category is it possible to master technologies in both production and service processes.

For the CPE, periods of work practices must be integrated into the academic activities that must be paid through the work practice of those students who work or intentionally by the group of the discipline for students not linked to work. the race; with the purpose that they can develop the modes of action of the profession.

This discipline, due to its organizational structure, allows for the analysis of economic and social practice problems from an integrated, objective, and innovative perspective. It contributes to the development of students' modeling and systems analysis skills, their sense of responsibility within a work collective, interdisciplinary collaboration, and the application of technology in problem-solving.

The aim is to provide an answer to a challenging question: How can we ensure that our students truly develop competencies within an objective-based curriculum? The afore mentioned subjects aim to establish a link between academia and the world of work. They should help students acquire the foundations for successful performance in the job market and the ability to continue learning throughout their lives. Students should be capable of manipulating knowledge, updating it, selecting what is appropriate for specific contexts, constantly learning, understanding what they learn, and adapting it to rapidly changing situations.

Therefore, adopting an active methodology with significant student involvement is necessary, where the responsibility for learning depends directly on their activity, engagement, and commitment. Such methodologies are more formative than merely informative and generate deeper, more meaningful, and long-lasting learning outcomes, facilitating the transfer to diverse contexts. In this way, the chosen methodology becomes the means through which students acquire knowledge, values, skills, and attitudes, developing competencies. The table below (Table 2: Competencies by knowledge, skills, and attitudes-values) provides a breakdown of the project competencies, which served as the basis for evaluation.

Table 2: Competencies by knowledge, skills, and attitudes-values.

Competencies	Measurements	Criteria
1.- Knowledge	1.1. General for learning	▪ Analysis ▪ Synthesis ▪ Conceptualization
	1.2. Academic related to the subjects Integrated Project of Industrial Engineering I, II, and III	▪ Development and deepening of technical knowledge, skills, and abilities
	1.3. Related to the professional world	▪ Research and innovation of technical solutions ▪ Transfer of general and specific knowledge and procedures to practical situations
2.- Skills and abilities	2.1. Intellectual	▪ Systems thinking ▪ Critical thinking
	2.2. Communication	▪ Information management ▪ Oral and written expression
	2.3. Interpersonal	▪ Teamwork ▪ Respect for others ▪ Individual and group responsibility
	2.4. Personal organization/management	▪ Planning, organizing, and managing work. ▪ Research design ▪ Decision-making
3.- Attitudes and values	3.1. Professional development	▪ Initiative ▪ Perseverance ▪ Systematization
	3.2. Personal commitment	▪ Personal and group responsibility

Source: Authors, (2020).

IV. METHODOLOGY

The proposed methodology promotes the development of the following professional skills included in Study Plan "E":

- Operating a process or activity within it.
- Describing production and service processes, their elements, and interrelationships.
- Performing basic transactions of an entity in a Material Resource Planning (ERP) system.
- Quantitatively and qualitatively characterizing industrial engineering problems.
- Applying the work procedure of industrial engineering.
- Working in multidisciplinary teams to solve industrial engineering problems with a comprehensive approach and extensive use of ICT.
- Developing comprehensive solutions within the framework of current legislation and standards, verifying technical, economic, environmental, and social feasibility.
- Preparing and defending technical reports.
- Consulting technical literature in Spanish and other languages (English).

See the methodology for Project-Oriented Learning (POL) description below and in figure 1 (Phases of the POL Methodology).

The skills proposed in the methodology, also considered competencies to acquire by students at the end of the academic period, are as follows:

Skill 1 (S1): Proposing solutions to environmental problems through engineering projects.

Skill 2 (S2): Understanding the most appropriate methods and strategies for collecting, managing, and interpreting information, as well as developing engineering projects.

Skill 3 (S3): Preparing interim and final reports and sharing the results generated from the management of engineering projects.

In the research, students were required to develop a project throughout the second semester of the course, addressing a real problem related to the selected process (production or service).

They worked in coordination with the company's management, considering the level of complexity students could effectively manage based on the subjects they had studied. Project development in teams is a way to promote cooperative learning.

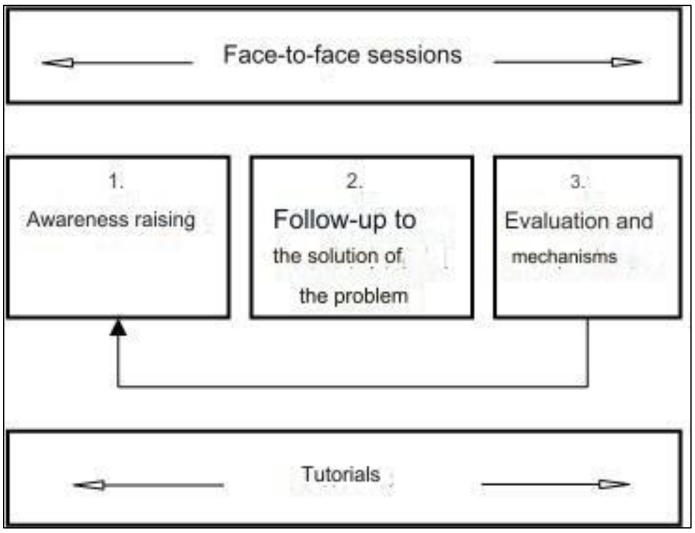

Figure 1: Phases of the Project-Oriented Learning (POL) Methodology.

Source: Authors, (2020).

First Phase: Sensitization

In this phase, the students approach the methodology and the problems, to select the problem in which solution they will work. Each person receives clear descriptions of the commitments and the roles of the actors involved in the experience.

Second Phase: Monitoring the Problem Solution

To monitor the progress of the project developed throughout the semester, the proposal includes four stages or checkpoints depending on the relevant subject: project outline, progress report, proposed solution, and final report.

- Project Outline: In this stage, students prepare a document that identifies the problem, outlines the working assumptions and the planned methodology, and specifies the necessary resources to solve it.
- Progress Report: Students submit a written report on the progress made in the project development. The report should highlight the completion percentage of activities, difficulties encountered, and partial achievements.
- Proposed Solution: Students submit a technical report that presents alternative solutions to the problem, justifying the decisions made from an engineering perspective.
- Final Report: At the end of the semester, students are expected to submit a final report based on the completed project. Depending on the subject and year level, the final report may take the form of a technical report, a case study, or an individual research project.

Third Phase: Evaluation and Mechanisms

Evaluation will be based on written reports and oral presentations. Four reports will be prepared throughout the course, corresponding to each stage of the project development: project outline, progress report, proposed solution, and final report (as described in the previous section). Evaluation criteria for written reports can be divided into two categories: content and format. Content criteria include illustrating methods or procedures, demonstrating the work performed, and the degree of problem solution. Format criteria include presentation and application of document-specific standards, coherence and clarity in writing, and the use of relevant vocabulary.

During each phase, students are required to deliver an oral presentation to support the information contained in the written report. Evaluation criteria for oral presentations include clarity of exposition, presenter's confidence, alignment of the presentation with the written document, appropriate use of technical vocabulary, use of audiovisual aids, and personal presentation. A rating scale of one (1.0) to five (5.0) is suggested for each of the above criteria. Furthermore, students will have the opportunity to self-assess their performance during the oral presentation (self-evaluation) and evaluate their peers' performance during the oral presentation (peer evaluation). The written report and oral presentation serve as evaluation mechanisms available to the teacher (hetero evaluation). The following weighting is suggested for evaluation: self-evaluation 25%, peer evaluation 25%, and hetero-evaluation 50%. During hetero evaluation, the teacher has access to the written document while the students do not. It is mandatory to submit the written report in digital format in all cases. Spelling errors will have an impact on the student's final evaluation.

A schedule of tutorials and face-to-face sessions will accompany and guide the students throughout the semester at each stage of their learning process.

IV.1 WORKS OF THE TEACHER AND THE STUDENTS

During the various face-to-face sessions conducted, the teacher provided guidance, reinforced achievements, corrected errors, etc., to facilitate meaningful and practical learning for the student's personal and professional development. In this case, the teacher played the roles of an expert, tutor, resource, and evaluator. The sequential tasks conducted by the teacher were as follows:

- Presentation and definition of the project
- Providing basic instructions on the methodological procedure
- Reviewing the work plan of each student team
- Conduct meetings with each team to discuss and guide the project's progress.
- Conducting specific classes to address common student needs.
- Reviewing individual and group progress of the project and learning outcomes
- Performing the final evaluation based on the presented results and acquired learning.

On the other hand, the students played the roles of protagonists, designers, and managers of their learning, and of their time. They were responsible for:

- Conducting self-evaluations
- Interacting with the teacher to clarify doubts and define the project.
- Defining the work plan including individual activities and team meetings.
- Individually searching and collecting information, proposing designs and solutions
- Reviewing the information and planning the work
- Developing the project and participating in meetings with the teacher and the tutor
- Submitting initial reports or proposals of results
- Presenting the achieved results and acquired learning.

V. RESULTS AND DISCUSSION

V.1. DEMONSTRATION OF STUDENTS' COMPETENCY DEVELOPMENT

The development of competencies evaluation took into consideration the surveys applied to teachers and students, and the project presentations. Based on the collected data, the performance in developing the proposed competencies became evident in the answers to the following questions (P):

P1: What is the purpose of a preliminary project?

P2: What aspects should be considered when formulating a problem?

P3: What elements in a preliminary project contribute to establishing coherence?

P4: What are the evaluation criteria for a preliminary project?

P5: Throughout your engineering education, have you solved real problems in the social or industrial environment, applying your engineering knowledge?

Table 2 presents the detected changes in the student's development of competencies, considering their performance in each of the analyzed situations.

Table 2: Detected changes in the development of competencies.

Skills (competencies)	Skills Related Questions Results (competencies)	Results			
		Survey 1		Survey 2	
		Incorrect	Correct	Incorrect	Correct
H1	P1	10	52	7	55
	P2	42	20	55	7
H2	P3	50	12	12	50
	P4	62	0	58	4
H3	P5	10	52	4	58

Source: Authors, (2020).

The columns in table 2 represent the skills (competencies) proposed in the methodology, the related evaluation questions, and the results obtained in Survey 1 (initial) and Survey 2 (final), rated as correct or incorrect. H1 was evaluated with questions P1 and P2, H2 was evaluated with questions P3 and P4, while H3 was assessed with question P5.

Figure 2 shows the final results of the survey that demonstrate the benefits of using the proposed PBL methodology in the development of the skills that Industrial Engineering students need to acquire in the blended pedagogical model. The results show a significant improvement in H1 and H2, which are related to proposing solutions to real-world problems through engineering projects, meeting the learning objective of creating a blueprint. In this case, H3, which focuses on project management through the preparation and sharing of reports, benefited the most from the application of the proposed methodology. However, it is considered that one semester and one course are not enough, since the ideal scenario would be for all students to reach a high level of mastery in these skills, which would contribute to their competence to achieve efficiency and quality in the research they carry out.

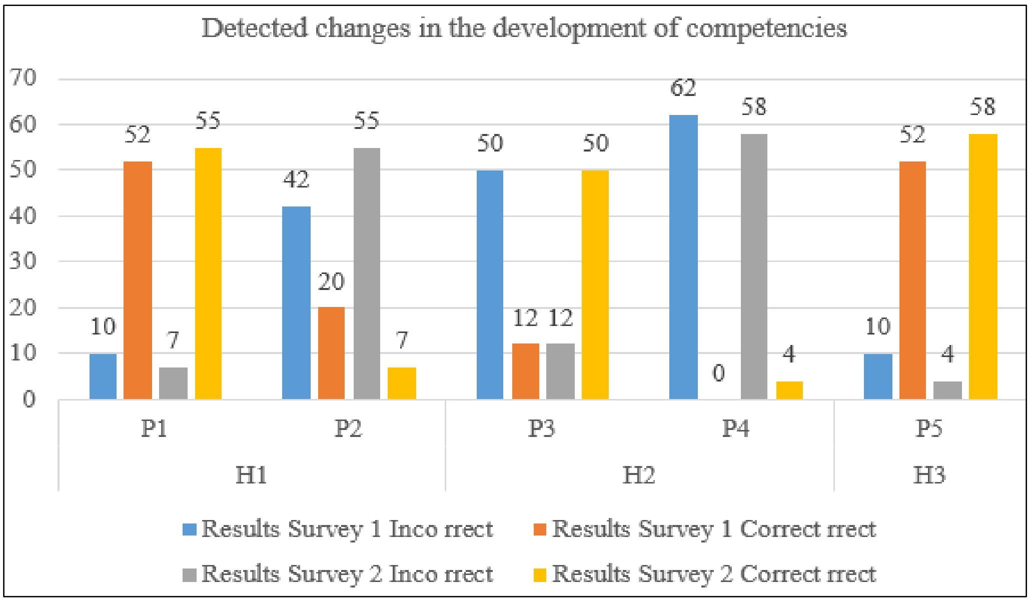

Figure 2: Detected changes in the development of competencies.
Source: Authors, (2020).

V.2 STUDENTS' OPINIONS

Among the students who took the course in the mentioned years, only six considered the AOP methodology inappropriate because they felt that there was a lack of guidance from the tutor in finding a complete solution to the chosen problem. Most students believed that this methodology is suitable because it allows them to apply the knowledge acquired in their education to the project development and learn to learn, making them active participants in their learning process, which is essential in a time of rapid knowledge obsolescence.

Regarding the difficulties encountered in solving the chosen problem, 10 students mentioned a lack of time due to their commitment to other courses, while others indicated a lack of knowledge in certain topics and a lack of bibliographic information. This indicates that for the implementation of the AOP methodology, sufficient technical resources should be available together with timely access to ensure students efficiently address problem-solving. It is also suggested that the proposed problem be connected to related subjects taught during the specific academic year, allowing for parallel work, and reducing time constraints caused by commitments to other courses.

V.3 TEACHERS' OPINIONS

The teachers involved in teaching each of the courses express that all stages of the proposed methodology are important, but the most critical one is the preliminary project, as it defines the problem and establishes the project scope. Making an excellent choice at this stage is crucial for successful outcomes. Motivation is essential, especially at the beginning, to clarify the methodology, roles, and expected outcomes at each stage.

Regarding the question, "In your opinion, what were the problems affecting the implementation of the methodology?" it was evident that despite considering students' educational level when formulating topics, there was a lack of knowledge in subjects related to the project. Regarding resources, access to them was not a limitation. Another issue is the extra time students must dedicate to the project outside of class, which is limited by their work commitments.

Regarding the advantages and disadvantages of the methodology as a strategy for developing skills through the courses of the Principal Integrative Discipline, Industrial Engineering Integrative Project, the teachers highlight the following advantages: it allows students to apply their previous knowledge, improving their skills in using appropriate techniques and technologies in current conditions to achieve efficiency, effectiveness, and competitiveness in the relevant organization; it enhances teamwork, as the final result depends on the contribution of all team members; and it fosters the development of comprehensive solutions in compliance with relevant laws and regulations, verifying technical, economic, environmental, and social feasibility. Due to the multitude of tasks, students must share information and take on responsibilities, these are competencies difficult to achieve with other methodologies, and that will enable them to solve industrial engineering problems with a comprehensive approach and dedicated support from ICT.

Among the disadvantages, it is challenging for a single teacher to provide technical assistance on different topics. It is recommended to improve the methodology by implementing it transversally in different courses throughout the program, forming a team of teachers who select topics, provide guidance, and assess the projects. Additionally, it would be beneficial to have an academic space, such as a workshop or event, to promote the students' achievements. This would serve as an additional motivating factor, allowing them to present their projects to the academic community. Some institutions have transitioned from objective-based to competency-based curriculum plans, acknowledging the challenges involved: constructing a theoretical framework to support the new model, adjusting administrative processes, redefining the roles of teachers and students, and modifying the graduate profile to align it with the demands of the context.

VI. CONCLUSIONS

As a result of the conducted research, students learned to make their own decisions and acted independently, which motivated them throughout the entire process, making the experience positive.

The experience has contributed to strengthening students' confidence in their roles or positions within different production or service organizations, approaching them with considerable expectations.

To achieve better results, this methodology should be applied in the Industrial Engineering Project Discipline, considering the advantages offered by the new Plan of Study E. This plan represents a new step in the improvement of the Industrial Engineering program considering the current times and the challenges they pose for professionals called upon to transform the country's economic and productive reality in pursuit of prosperous and sustainable socialism.

Although isolated efforts can identify weaknesses and strengths in the training of future engineers, these cannot be corrected or enhanced in a single course but require the joint effort of the teaching collective.

Emphasizing the necessary training to develop competencies and improve performance in organizations indicates that only by using pedagogical methods aligned with objectives as the guiding principle can technology be mastered in both production and service processes.

VII. AUTHOR'S CONTRIBUTION

Conceptualization: Lamay Rosa Montero Rojas, Melva García Martínez and Gilberto Juan Machado Burguera.
Methodology: Lamay Rosa Montero Rojas and Melva García Martínez.
Investigation: Lamay Rosa Montero Rojas and Melva García Martínez.
Discussion of results: Lamay Rosa Montero Rojas, Melva García Martínez and Gilberto Juan Machado Burguera.
Writing – Original Draft: Lamay Rosa Montero Rojas.
Writing – Review and Editing: Lamay Rosa Montero Rojas and Melva García Martínez.
Resources: Melva García Martínez.
Supervision: Melva García Martínez and Gilberto Juan Machado Burguera.
Approval of the final text: Lamay Rosa Montero Rojas, Melva García Martínez and Gilberto Juan Machado Burguera.

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