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Learning Outcomes, Methodological Indications For Their Conception, Definition, And Implementation In Engineering Programs Based On The ABET/EUR-ACE® Principles And Criteria

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Abstract

This article proposes a theoretical and methodological alternative for the conception, definition, and implementation of learning outcomes (LOs) in engineering programs based on ABET/EUR-ACE® principles and criteria. From a socio-critical approach, the identification, definition, organization, and systematization of a set of theoretical categories associated with the incorporation of LOs in the teaching learning processes (TLPs) in professional engineering training programs is highlighted, based on the guidelines and principles of the different accreditation bodies worldwide. A theoretical and methodological approach is presented of the different conceptions, principles, and criteria valued as relevant in the process of defining LOs and their relation with engineering TLPs based on a didactic structure with a system character that streamlines the process of articulation of LOs with the educational objectives of said academic programs. A theoretical and methodological proposal shaped in practice is presented from an institutional experience based on ABET criteria.

Keywords: Learning outcomes, teaching learning process, international accreditation of academic vocational training programs, ABET, EUR-ACE®, quality management

(Assessment), comprehensive training in engineering programs.

Introduction

In the last few decades, the development of science, technology, and innovation processes has boomed in all sectors of the global economy. From this perspective, business and competitiveness processes in the world are being determined by various facts related to the incorporation of new and better tools for the management and administration of information, as well as new models for the administration of resources available to companies and organizations of all types and levels. This situation has promoted a new dynamic in the so-called knowledge society, which has generated transformations at social, political, cultural, and economic levels in the academic field, even amidst the COVID-19 pandemic.

These transformations within the organizations have fostered an articulating dynamic, where the higher education institutions (HEIs) (Colombian case) become critical elements of a system aimed at contributing to the improvement of processes and quality conditions in said organizations from the theoretical, methodological, and scientific contributions inherent to their curricular dynamics. In this sense, the academic work of these organizations presupposes promoting and assuming the commitment to train professionals with critical thinking who develop knowledge and skills to transform a world increasingly influenced by the effects of a globalized economy[1].

As a result of the transformations that have occurred worldwide in the professional training processes, learning outcomes (LOs) appear in the academic scene, which emerge from the interest shown by the European Union countries in trying to improve the mobility indices of students, professors, and administrators of the different universities.

[1] Chia-Ling Wang, "Mapping or Tracing? Rethinking Curriculum Mapping in Higher Education", *Studies in Higher Education*, 40 (2015), pp. 1550-1559. DOI: http://dx.doi.org/10.1080/03075079.2014.899343

Since the Bologna agreement in 1999, the LOs have been defined, structured, and applied in the academic systems of European countries and years before in Anglo-Saxon countries to favor the dynamics of the different training programs and their support structures, thereby agreeing to structure the contents and programs of higher education in terms of LOs since 2010.

The different exercises carried out internationally at the higher education level show a transition from the traditional professor-centered approach to another centered on the student and the development of their capabilities; in this sense, ANECA (National Agency for Quality Assessment and Accreditation) of Spain is considered as one of the benchmarks par excellence for this type of experience.

Similarly, since 2015, the United Nations Organization agrees with a development agenda regarding the sustainable development goals in perspective to 2030; further, UNESCO has established the Education 2030 Framework for Action, resulting in the publication of the "Learning Assessment at UNESCO" in 2016[2].

Concerning engineering training processes specifically, it is necessary to start from the basics of engineering, which could be understood as the discipline that, making use of universally defined scientific principles, energizes them in such a way that it favors the development of knowledge for the creation of technologies, techniques, tools, processes, and developments to meet needs and solve problems in different environments and contexts.

In relation to the above, engineering is assumed as a discipline that involves scientific knowledge applied to the development and improvement of organizational processes. It has applications in different technology areas, including the development of systematized processes and new products and

[2] MEN, "A Look at Learning Outcomes", < https://www.colombiaaprende.edu.co/sites/default/files/files_public/2022-07/Una%20mirada%20a%20los%20resultados%20de%20aprendizaje.pdf > (2021) [accessed March 2023].

services. This branch of knowledge creates a direct relation between scientific knowledge and the application of this knowledge to develop products or services that satisfy any social need.

The Accreditation Board for Engineering and Technology (ABET) and the European Network for Accreditation of Engineering Education (ENAEE) coincide in conceiving engineering as the application of scientific principles for the design and development of structures, machinery, or manufacturing processes or mechanisms, as well as for construction, operation, and forecast of behavior under specific operating conditions, all regarding a planned function, economy of operation, and safety to life and property[3][4].

The processes of measurement and scope of the results of teaching learning processes (TLP) in professional training programs in engineering are part of the criteria declared to be globally evaluated by the different accreditation agencies of engineering and technology programs.

MEN, in correspondence with what is declared in the National Development Plan 2018–2022 "Pact for Colombia, pact for equity," defines updating a set of processes that are part of the Quality Assurance System as one of its main activities. Among these actions, Decree 1330 of 2019 is issued, and concerning high quality accreditation processes together with the National Council of Higher Education, they promote agreement 02 of 2020; likewise, SACES is responsible for updating information systems associated with qualified registration procedures and others related to quality assurance processes in higher education in Colombia[2] [5].

[3] ABET, "Criteria for Accrediting Engineering Technology Programs 2022-2023", < https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-technology-programs-2022-2023/ > [accessed 2023].
[4] ENAEE, "EUR-ACE® Framework Standards and Guidelines", < https://www.enaee.eu/eur-ace-system/standards-and-guidelines/#general-introduction > [accessed 2023].
[5] MEN, Resolution 021795 (2020). <https://www.mineducacion.gov.co/1780/articles-402045_pdf.pdf> [accessed 2023].

One of the main innovations incorporated and described in Decree 1330 of 2019 refers to LOs, which are presented as a series of direct statements that describe the knowledge, capabilities, competencies, skills, and abilities that students must acquire, develop, and put into practice at the end of a learning experience, based on the context and the possible applications of that knowledge, favoring that the evaluation of this type of processes is carried out in an objective and fully contextualized manner. These statements allow both students and teachers to better understand how the acquired knowledge will be helpful for their future professional practice and development[6].

In Colombia, LOs are incorporated into the academic discourse based on the contributions and discussions of the National Council of Higher Education (CESU), an entity, which between 2013 and 2014, proposed the adoption of the Agreement for Higher Education 2034 as public policy, in which it is considered necessary to move toward a learning and student-centered approach, thereby establishing the need to design mechanisms to demonstrate and evaluate in terms of LOs [2].

For the particular case discussed in this article, the two most popular and representative agencies at a global level will be taken as reference, such as the ABET and EUR-ACE®, the first in the United States, a reference for the signatory countries of the Washington agreement and the second from the ENAEE, dedicated to the organization of different accreditation agencies in high quality engineering programs around the globe.

ABET is an accrediting entity for academic programs in applied sciences, computer science, engineering, and engineering technologies at different educational levels, such as associate, bachelor's, and master's degrees. Its reach extends beyond the United States, encompassing several countries in the Americas and Europe.

[6] Vladimir Ballesteros, "An Initial Approach to Learning Outcomes in Higher Education", *Revista Cientifica*, 39 (2020), pp. 259-261. <http://www.scielo.org.co/pdf/cient/n39/2344-8350-cient-39-259.pdf>

However, EUR-ACE® is conceived as a framework accreditation system that establishes criteria and standards for engineering programs in Europe and other countries that adhere to its international accreditation process. This system guides the evaluation and accreditation of different engineering degree programs.

Like EUR-ACE®, ABET defines, describes, and structures a series of nine criteria that assess the students' circumstances and experience, as well as what they learn throughout their educational process. This implies analyzing the LOs that students must achieve at the end of their professional training.

For both international accreditation processes, the HEIs (Colombia case) that apply must fully comply with each agency's requirements regarding their criteria and standards defined for each process.

In this sense, each of the agencies describes their dynamics for their accreditation processes; these dynamics presuppose compliance with their respective criteria and, in turn, complemented with the LOs defined for the professional training program in general as well as in each of the courses of the study plan.

These international accreditation models promote that each HEI should autonomously structure and define the dynamics with which each will assume and obey its process, firstly defining the initial conditions for each stage and phase required and, consequently, the other aspects to be fulfilled within the requirements of each one, especially concerning the operationalization of the LOs, which are understood as the articulating curricular axis of the entire accreditation process.

In the particular case of the international accreditation process with EUR-ACE®, there are six evaluation criteria, and they are oriented to the professional training process in terms of the student being partially able to appropriate the LOs of the course throughout their training process and the LOs of the program at the end of its process, framed in a profile or qualification or learning path.

These two major program quality assessment systems, although having differences in their focus, are complementary and can be addressed using the same quality management system if a program intends to obtain accreditation from both agencies[7].

Methodology

This article is presented as a result of the systematization of the theoretical and practical contributions of the doctoral theses of its authors, which coincide in having the TLP of problem solving and engineering as their object of study, defining the systemic approach of professional situations in correspondence with what is proposed as their field of action[8], focuses its analysis on a reflection on the TLP in engineering programs and the ABET and EUR-ACE ®; taking this into account, a set of four categories were established: two main ones (TLP and LOs) and two emerging ones (international accreditation processes of academic programs of professional training and the process of integral formation of students).

From the methodological perspective, this study is supported by the methods marked by the qualitative paradigm from a holistic perspective; the proposed contributions and/or results are based on the systematization of the previously described categories from a pilot proposal resulting from the applicability of the theoretical contributions of the afore mentioned doctoral research.

Likewise, this article is based on the elements that, by way of categories, are defined as methodological theoretical support, being assumed from the conception of the contributions of the general system theory, the structural systemic method, and the holistic research approach. Moreover, the dynamics of the proposal conceptually and methodologically assume the systematization of different contributions supporting the

[7] Henry Gómez Urquizo, "Proposal for Measurement and Assessment of Results", *16th LACCEI International Multi-Conference for Engineering, Education, and Technology*, (2018), pp. 1-7. DOI: http://dx.doi.org/10.18687/LACCEI2018.1.1.435

[8] Jose Rafael García-González and Paola Sánchez-Sánchez, "Theoretical Design of Research: Methodological Instructions for the Development of Scientific Research Proposals and Projects", *Información Tecnológica*, 31 (2020), pp. 159-170. DOI: http://dx.doi.org/10.4067/S0718-07642020000600159

conceptual theoretical structure of the proposal in its practical and applicative dimension at the technological level.

In the same way, the main perspectives and theoretical positions related to curricular dynamics, LOs, and the particularities of their incorporation into the study plans, academic programs, institutional dynamics, and international certification processes and/or accreditations are presented and discussed.

Findings

The establishment of LOs not only provides a facilitating model for the verification and measurement of student performance but is also conceived as one of the primary components for transparent higher education systems and qualifications[9].

Consequently, and as described in the introduction to this document, according to Decree 1330 of 2019, LOs are defined as explicit expressions of what a student is expected to know and be able to demonstrate at the end of their academic program. These statements must be consistent with the needs for comprehensive training and adapt to the dynamics of continuing education, which are essential for professional practice and responsible citizenship. Therefore, these results must be aligned with the student's graduation profile.

In this way, most institutions adopt the definition of LOs as the various knowledge, skills, abilities, aptitudes, and capabilities established as objectives in a specific training program, which are subsequently evaluated to verify their compliance, their appropriation by the students as a didactic transposition[10]. In

[9] Stephen Adam, "Using Learning Outcomes: A Consideration of the Nature, Role, Application and Implications for European Education of Employing 'Learning Outcomes' at the Local, National and International Levels", *United Kingdom Bologna Seminar*, (2004), pp. 1-30. <https://www.ehea.info/media.ehea.info/file/Learning_Outcomes_Edinburgh_2004/76/8/040620LEARNING_OUTCOMES-Adams_577768.pdf>

[10] Yves Chevallard, *The Didactic Transposition: Of Learned Knowledge to Knowledge Taught* (3rd ed.), AIQUE Publishing Group, 1998. <https://www.terras.edu.ar/biblioteca/11/11DID_Chevallard_Unidad_3.pdf>

most cases, the evidence of these outcomes is specified in the study plan (Curricular Mesh/Study Plan) where skills, knowledge, and abilities are correlated as a contribution to fulfilling the value proposition of the academic program.

This situation allows adopting a universal syntax for the conception and writing of LOs regarding the criteria defined by ABET and EUR-ACE®. Different ways of conceiving an LO are related in the literature; however, one of the easiest to understand in its application dynamics is the one proposed by Jerez[11], where he establishes a syntax for its writing based on three components to know: verb, content, and context.

Constituent elements of a Learning Outcome (LO):

- **Verb:** It directly describes the action the student should know how to perform at the end of their training process. It should be written in simple present tense, considering the characteristics of the discipline and the training objectives (skills) of each course. Likewise, it should involve higher order thinking skills, such as analysis and synthesis, induction and deduction, or analysis and critical reflection of sources and events.
- **Complement/content:** It can be understood as the knowledge associated with the discipline or area of science that the student should know how to apply in a given context.
- **Context:** This component refers to how and where the action will be carried out by the student. It is important to declare how learning is privileged, its application and evaluation clearly, and per the conditions of the environment[12].

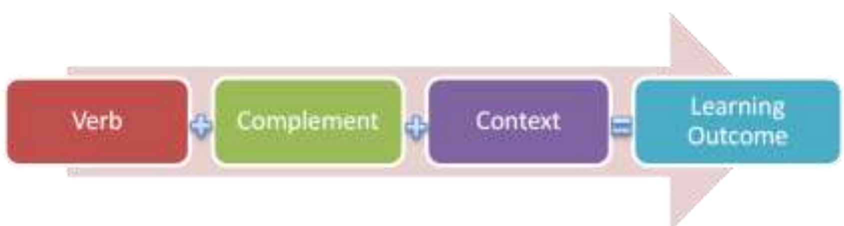
Syntax for writing LOs.

[11] Oscar Jerez, "Learning outcomes in higher education by competencies. PhD thesis. University of Nothing (2012).
[12] Teaching Development Center, "Guide to Writing Learning Outcomes", < https://cdd.udd.cl/files/2018/11/Guia_para_Redactar_Resultados_de_Aprendizaje.pdf > (2014) [accessed 2023].

For the conception and writing of an LO, the following criteria should be considered:

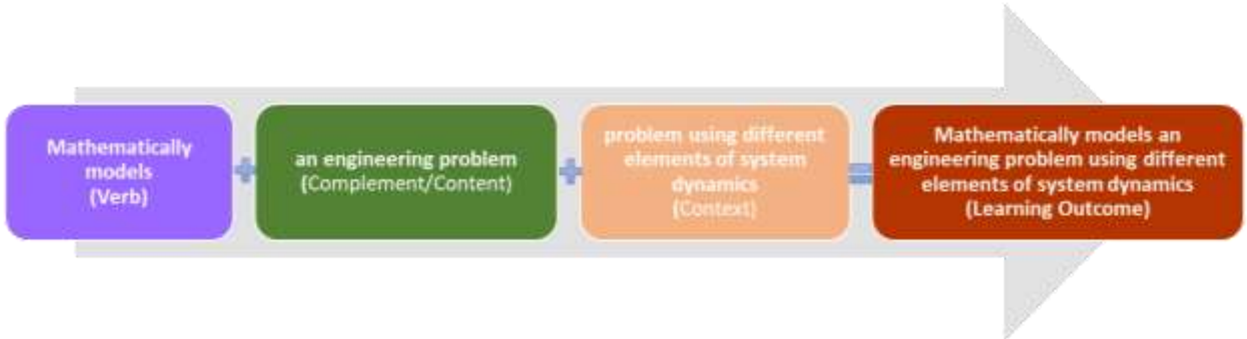
1. Initialize the writing of an LO with a verb that specifies an action.
2. When writing an LO, using more than one verb should be avoided.
3. Privilege a synthetic wording, avoiding the use of complex and difficult to understand sentences as much as possible.
4. Encourage the writing of the LOs of the course to correspond to the LOs of the program.
5. The writing of an LO should allow for its observation, analysis, measurement, and evaluation expeditiously.
6. When writing the LOs, temporality must be understood and assumed, i.e., the space of time required to favor their appropriation by the students.

Syntax:



Example 1:

Example 2:



Professional training processes are based on programs that prepare people to function independently in various areas that require more complex and extensive skills. These areas can cover scientific or technological disciplines as well as humanities, arts, or philosophy.

A university professional must be able to face new and challenging situations and propose original solutions to problems inherent to their field of work, even developing their own designs if necessary. Additionally, they must possess leadership skills, the ability to supervise and guide others, as well as an aptitude for analysis and evaluation.

Therefore, professional university training programs require a solid theoretical foundation and an adequate academic and administrative infrastructure, including a trained teaching staff, to offer broad coverage of specialized and research topics in the professional or disciplinary field.

Based on the principles of flexibility, sequentially, and complementarity, the main LOs that the student is expected to achieve during the training process and upon completion are identified based on the particularities of each level of training and in coherence with the dynamics of competences as an element that integrates aspects related to knowledge (knowing), skills (doing), attitudes (being), and behaving (knowing how to be).

As an example, and to promote understanding of the proposed LO identified and presented in this article, some of the concepts that emerge as a result of adapting the criteria of the accreditation bodies ABET and EUR-ACE® are initially highlighted, as well as of a set of expressions, also described as an example in Table 1. Among the emerging concepts, the following stand out:

- **Competence**: Set of **LO**
- **LO:** Written statement of what the student is expected to be able to do at the end of a module or program. The competence must be demonstrated in its entirety, globally or terminally, and not partially. However, LOs focus on a more specific development process.
- The competencies associated with a graduation profile provide meaning to the entire training, while the LOs are linked to curricular times and activities.

Table 1: LO model projected within the framework of an academic proposal

SPECIFIC TRAINING PURPOSES	KNOWING	DOING	BEING	KNOWINGHOW TO BE
1. Create, plan, build, and manage software solutions using established engineering principles and quality criteria.	X	X		
2. Use knowledge of computer science, information technology, and organizations to develop software solutions.	X	X		
3. Implement quality criteria in the process of developing and evaluating software solutions.		X		
4. Recognize possibilities to improve the performance of organizations through the optimal and effective use of software solutions.	X	X		
5. Assimilate emerging technological and social changes		X	X	X
6. Apply the systemic approach in the analysis and resolution of problems	X	X	X	
7. Acquire knowledge and put into practice along with ethical, legal, economic, and financial principles in decision-making and management of information technology projects.	X	X	X	X
8. Express orally, in writing, and visually and present arguments in a clear, coherent, and respectful manner, ideas and proposals related to the development of information systems and			X	X

the implications of their implementation in the organization and the environment.				
9. Assume various functions in information technology projects, in multidisciplinary and multicultural environments both locally and globally.	X	X	X	
10. Ability to create, build, choose, and value computer applications and systems, guaranteeing their reliability, safety, and quality, in compliance with ethical principles, current legislation, and regulations.	X	X	X	
11. Ability to organize, devise, implement, and supervise IT projects, services, and systems in various environments, leading their implementation and constant evolution, and evaluating their economic and social impact.	X	X		
12. Knowledge, administration, and maintenance of computer systems, services, and applications.	X	X		
13. Understand and use the essential algorithmic foundations of computer technologies to design solutions to problems, evaluating the adequacy and complexity of proposed algorithms.	X	X		
14. Acquire knowledge, design, and efficiently use the most appropriate data types and structures to solve a specific problem.	X	X		
15. Possess knowledge and apply the characteristics, functionalities, and structure of databases adequately, allowing their correct use, as well as the design, analysis, and implementation of applications based on them.	X	X		
16. Ability to choose, design, implement, integrate, evaluate, build, manage, use, and maintain hardware, software, and network technologies, meeting the appropriate cost and quality criteria.	X	X		
17. Ability to choose, implement, integrate, and manage information systems that meet organizational requirements, following established cost and quality criteria.	X	X		
18. Ability to understand, apply, and manage the	X	X		

security and guarantee of computer systems.				

Source: Prepared by the authors, origin of the data, compilation of main national and international training purposes for system engineers.

Discussion of results

The TLP is a process in which a relation is established between the teacher's activity, which implies teaching, and the students' activity, which implies learning, when interacting with a given study content. According to Álvarez de Zayas[13], the TLP is an effective and efficient training process.

The TLP is defined in terms of LOs as the set of actions and strategies used to achieve educational objectives and ensure that students acquire the desired knowledge, skills, and competencies. LOs are clear and specific statements that describe what students are expected to be able to do or demonstrate at the end of a course, program, or learning experience[14].

In this context, the TLP is oriented toward achieving these LOs. It involves a series of steps and activities designed to promote the acquisition of knowledge, the development of skills, and the transformation of students' attitudes and values. Some key aspects of the teaching learning process concerning learning outcomes are given below.

Teaching Design: LOs should guide teaching design. Educators should identify the essential knowledge and skills that students need to achieve and use those goals to inform the design of activities, materials, assessments, and teaching methods used in the classroom.

Teaching Strategies: Teaching strategies are selected and implemented based on the desired LOs. These strategies may include didactic methods such as lectures, group discussions,

[13] Carlos Alvarez de Zayas, *General Didactics the School in Life*. Cochabamba, Bolivia: Kipus Publishing Group, 2004.
[14] Megan Oakleaf, "Are They Learning? Are We? Learning Outcomes and the Academic Library", *The library Quarterly*, 81 (2011), pp. 61-82.

practical activities, case studies, simulations, or project-based learning. Strategies must be effective in promoting the achievement of LOs.

Learning assessment: Assessment is an integral component of the TLP in terms of LO. Different assessment methods and tools, such as exams, projects, practical work, or presentations, are used to measure the degree to which students have achieved the established LOs. The feedback provided to students through assessment allows them to identify strengths, weaknesses, and areas for improvement.

Adjustment and continuous improvement: The TLP in relation to the LOs is not static. Educators must monitor and analyze student outcomes against the established LOs and make instructional adjustments and improvements to maximize the achievement of those outcomes. This involves identifying the areas in which students are struggling and adapting teaching strategies accordingly.

In correspondence with the above, ABET and EUR-ACE® propose different ways to measure and evaluate LOs in engineering programs. It is important to note that each program and university can adopt, adapt, and use appropriate measurement and evaluation methods for their specific contexts. The main objective is to help students acquire the necessary knowledge, skills, and competencies required in their field of study.

Next, the articulation between each component and its context will be exemplified through a methodological design applied in a professional training program in systems engineering. The didactics for problem solving (as a central subject and/or reference course algorithm and basic programming) and the ABET accreditation process will be taken as references, leaving the methodological bases for the EUR-ACE® process indicated, which is conceived as similar to the one proposed for ABET in this article.

It is important to highlight that these forms of LO measurement and evaluation can be combined and adapted according to the program and the specific learning objectives defined for them. Assessment methods and tools should be carefully designed to ensure that they are valid, reliable, and aligned with the expected LOs.

Methodological indications and strategy design for monitoring, measuring, and evaluating learning outcomes (LOs)

In correspondence with the above, the teaching strategy is aligned with the monitoring and evaluation strategy where the pedagogical tools are built to record and evidence the achievements or advances of the students concerning the LOs that, for this particular case, refer to the Algorithm and Programming I course, wherein some indicators reveal the levels reached.

A rubric of the program for the evaluation of the competence Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics[3] is designed and particularized to a course rubric where it is articulated and compared with what the student is expected to know and know how to perform in a test or evaluative activity in which the progress indicators (PIs) that respond to the LO established for each course are recognized. For this case, the indicators were carried out considering the previously exposed method, the PI of the Algorithm and Programming I course are as follows:

- PI-1: Identify the input, output, and process variables and/or constants proposed in the problem statement; in the same way, determine the data type of each variable and its dimensions if necessary.
- PI-2: Mention the algorithmic structures that can help build the algorithm or solution.
- PI-3: Develop the algorithmic structure that solves the problem posed.
- PI-4: Argue why your algorithmic model solves the problem posed.

The indicators are assigned an importance value (weight) within the solution, which is assigned according to the teacher's criteria, similar to an achievement value associated with the student's performance during the test. Additionally, in the tool, the teacher writes down relevant aspects (observations) that describe what the student has prepared, highlighting positive aspects of the solution proposal delivered, aspects to be improved, and possible weaknesses or gaps in the theoretical foundations and skills related to the competency and its Los (See Figure 1).

Figure 1. Structure of the Evaluation and Monitoring Tool

PROGRAMA		INGENIERIA DE SISTEMAS												
ASIGNATURA		(5801)ALGORITMIA Y PROGRAMACION I												
PERIODO		2023-1												
SEMESTRE/GRUPO		1-A	4- Analizar		4- Analizar		6-Crear			5-Evaluar				
			PI-1 Identifique las variables y/o constantes de entrada, salida y proceso, propuestos en el enunciado problema, de igual forma determine el tipo de dato de cada variable y sus dimensiones de ser necesarias. (Valor 0.8)	Peso	PI-2 Mencione las estructuras algorítmicas que usted considera, pueden proporcionar ayuda a la construcción del algoritmo. (Valor 0.7)	Peso	PI-3 Desarrolle la estructura algorítmica que proporcione solución al problema planteado. (Valor 2.0) + (Java 1.0)		Peso	PI-4 Argumente porqué su modelo algorítmico proporciona la solución al problema planteado. (Valor 0.5)	Peso	Medición	$\sum_{i=1}^{n} Pesos$	
#	CODIGO	APELLIDOS Y NOMBRES	0.8	20	0.7	20	2.0	1.0	50	0.5	10	Nota	100	Observación

Source: Prepared by the authors.

This tool collects the detailed information of the test developed by each student and calculates the results for each student and the group in general, which guarantees not only an individual view but also group overview of students evaluated.

Implementation process of the tool and interpretation of results

It is essential to highlight that as a systemic process, there must be an alignment between the teaching method implemented, the evaluation or monitoring methods, and the LOs in such a way that the evaluation model reflects the development or progress of the LOs achieved by the student consolidating and evidencing the institutional pedagogical model and the autonomy and initiative of the teacher.

The didactic problem-solving model is a theoretical and methodological approach in which the way in which the program, teacher, and/or institution will carry out the strategy of applicability of the rubric is structured in a particular way. For this particular example, this model was implemented for the first time during the beginning of the 2021–22 academic period, corresponding to the second semester of the 2021 academic year with a population of 57 first-semester students in the subject of Algorithm and Programming I. For this purpose, a program rubric was designed to evaluate each of the PIs for the competence "Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics"[3]. The results obtained by the students were tabulated and graphed (Table 2).

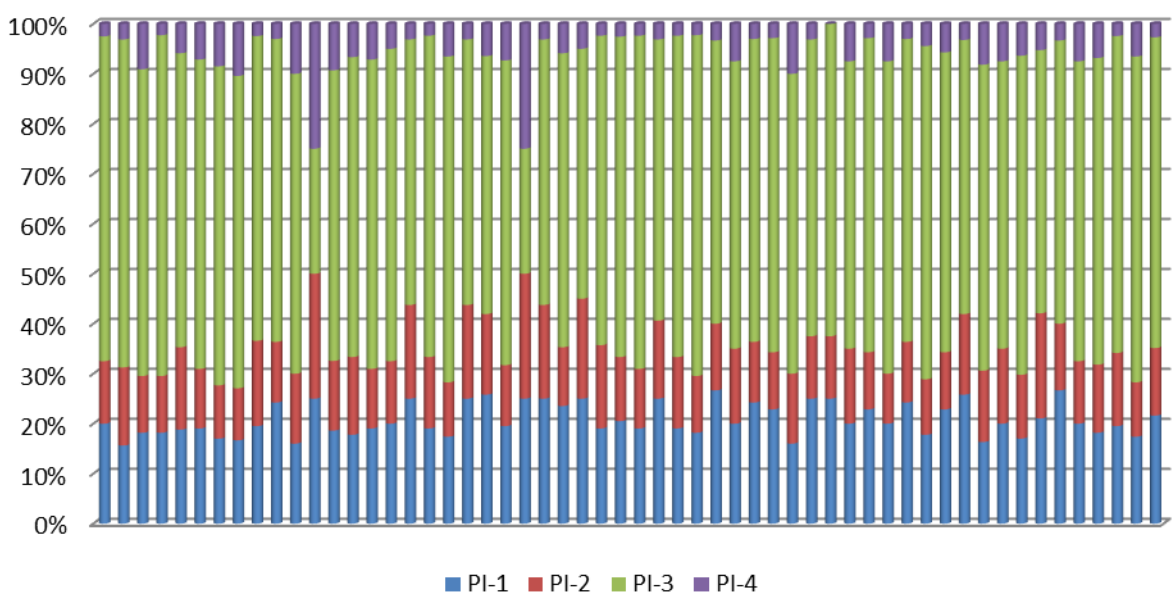
Table 2. Program Rubric, Ability to Identify, Formulate, and Solve Complex Engineering Problems by Applying Principles of Engineering, Science, and Mathematics.

SO (Student outcomes - ABET) (1): Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.				
Rubric SO (1)	**Unsatisfactory**	**In Development**	**Satisfactory**	**Outstanding**
PI-1(Performance indicator) – ABET)1: Identify the nature and components of the problem	Does not identify causes, effects, and variables associated with the problem	Identifies some causes, effects, and variables, but is unable to associate them with the problem	Fully identifies causes, effects, and variables associated with the problem	Fully identifies causes and effects and prioritizes variables according to the incidence of each one of them.
PI-2: Formulate the problem	Does not apply methodological tools to formulate the problem.	Applies methodological tools to formulate the problem, but not correctly	Applies the tools and techniques for the formulation of the problem.	Applies relevant tools and techniques to formulate the problem.
PI-3: Solve the problem by applying principles of engineering, science, and mathematics	Does not apply the principles of engineering, science, and mathematics to solve the problem.	Applies the principles of engineering, science, and mathematics to solve the problem, but not appropriately.	Appropriately applies the principles of engineering, science, and mathematics to solve the problem.	Appropriately and rigorously applies the principles of engineering, science, and mathematics to solve the problem.
PI-4: Draw conclusions from the proposed solution.	Does not interpret and relate the solution obtained with the context of the problem.	Interprets the obtained solution but does not relate it to the context	Issues pertinent conclusions for the solution of the problem	Issues pertinent conclusions for the solution of the problem and proposes new applications of the solution.

In Table 1, the program rubric was designed to be implemented in each study course that contributes to the promotion of the competence and its LOs.

However, each teacher in their course (subject) interpreted the indicators and landed them in a course rubric that is articulated with the topics and skills that are expected to be learned by students. In each academic period, an evaluation is implemented in which a problem statement is posed, and the student implements the method designed as a teaching strategy by the teacher for the solution of problems; the solution is aligned with each of the indicators in such a way that the teacher at the time of reviewing or grading gives a value corresponding to the level developed by the student. In the evaluation registration tool, each result provided by the student is recorded, and a series of graphs are obtained that allow the interpretation of results by student and by the group in general.

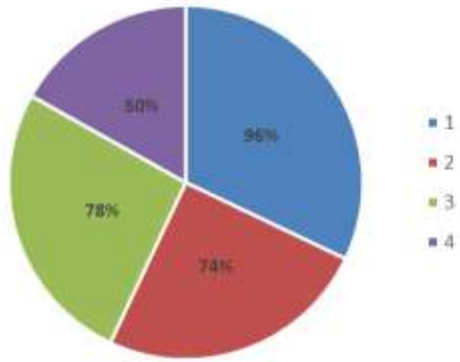
Figure 2. Measurement by Progress Indicator, Test 1.



Source: Prepared by the authors.

In Figure 2, the achievement levels of each student concerning each indicator can be interpreted, providing the individual status of those evaluated, an aspect that allows for analysis of the methodology and the search for improvement alternatives for each student.

Figure 3. Compliance with Progress Indicators 2021–22



Source: Prepared by the authors.

Figure 3 shows and describes the results obtained by the group as follows:

- PI-1, the first indicator, 96% of the students identify the elements of the problem and relate them to variables/constants, concerning the student's rubric. It fully identifies causes and effects and prioritizes the variables according to the incidence of each.

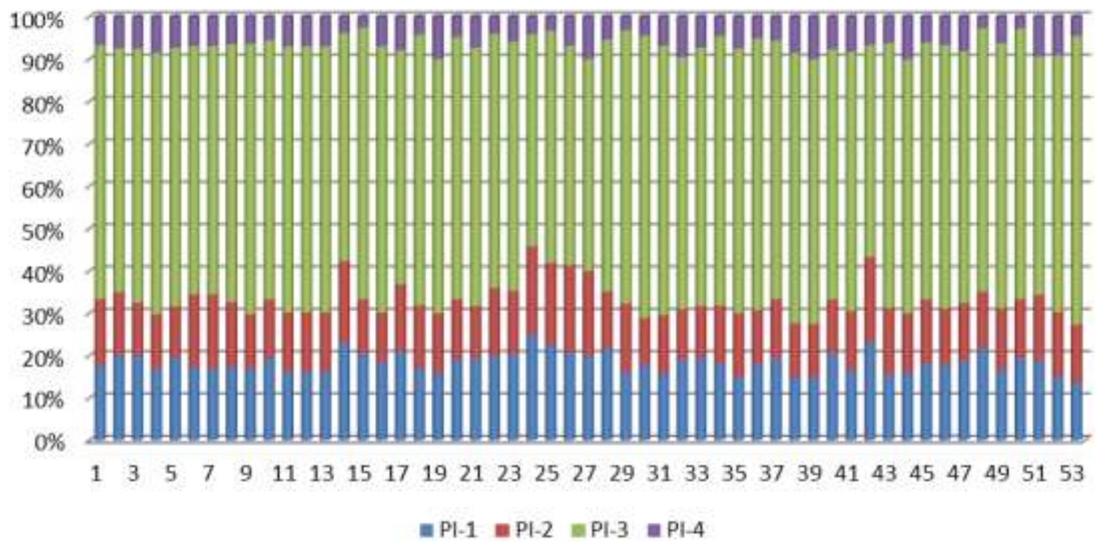
- PI-2, second indicator, 74% of the students establish the relation between variables/constants and identify the algorithmic and data structures to be used for the solution, concerning the rubric. The student applies the tools and techniques for the formulation of the problem.

- PI-3, third indicator, 78% of the students propose or outline a design or build an algorithm that responds to the solution to the problem posed, concerning the student's rubric. It appropriately applies the principles of engineering, science, and mathematics to solve the problem.

- PI-4, fourth indicator, 50% of the students argue about efficiency, effectiveness, and functionality of the solution proposal made and propose possible improvements. They verify if the solution is correct using logical tests, determine necessary changes if changes in the elements of the problem are proposed, and interpret the solution obtained but do not relate it to the context; concerning the rubric, the student cannot interpret and relate to the solution obtained with the context of the problem.

Continuing with the teaching and evaluation strategy by the professor in charge of the Algorithm and Programming I course, the evaluation of learning results continued to be applied in the first academic semester of the 2022-1 period, in which the following results were obtained.

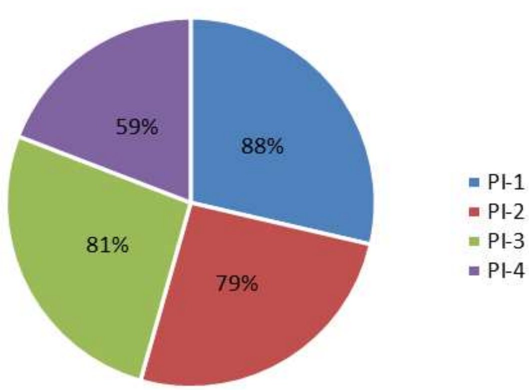
Figure 4. Measurement by Progress Indicator, Test 2



Source: Prepared by the authors.

The same teaching, evaluation, and rubric strategy was implemented for the first exam of the 53 new first-semester students, achieving the following results.

Figure 5. Compliance with Progress Indicators 2022-2



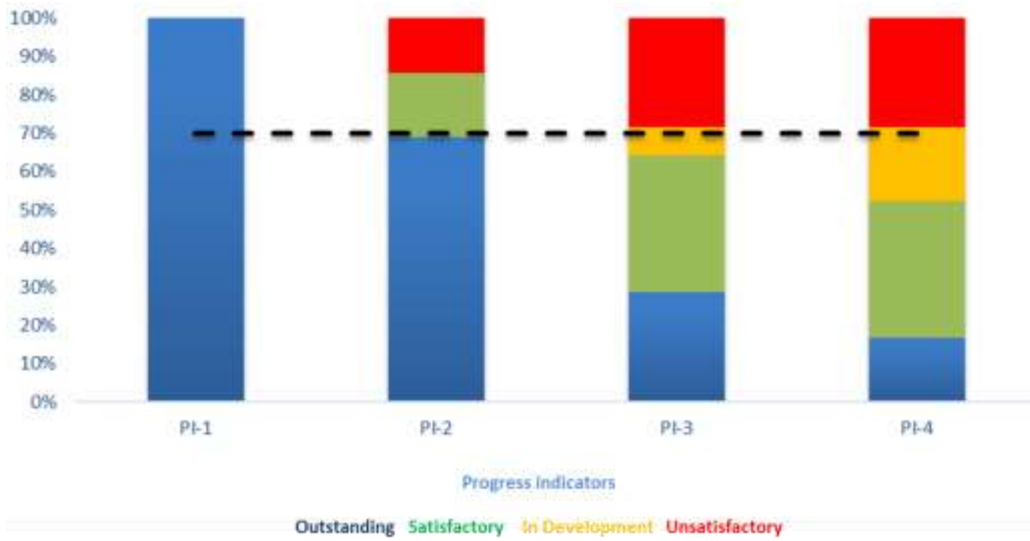
Source: Prepared by the authors.

Figure 5 shows that the results in each of the indicators were presented as follows:

- PI-1, the first indicator, 88% of the students identify the elements of the problem and adapt or relate them to variables/constants, comparing the student with the rubric. They fully identify causes, effects, and the variables associated with the problem, which is the first fundamental indicator for strengthening the aspects related to the LO.
- PI-2, second indicator, 79% of the students establish the relation between variables, identify the algorithmic and data structures to be used to structure or design a possible solution, concerning the rubric. Students apply the tools and techniques for formulating the problem, identifying the elements and structures that facilitate the solution.
- PI-3, third indicator, 81% of the students propose a design or build an algorithm or solution scheme applying logic to the requirements presented in the problem, concerning the rubric. The student applies the principles appropriately of engineering, science, and mathematics to solve the problem.
- PI-4, fourth indicator, 59% of the students issue pertinent conclusions for solving the problem, determines necessary changes if changes are proposed to the elements of the problem, interpret the solution obtained but do not relate it to the context of the proposed problem and designs repetitively, relating solutions or previous work.

Another type of graph that we can obtain from the tool is the one that allows us to reveal the level of achievement of the indicators by the group in general or consolidated, which reflects the level reached by the group in each of the indicators.

Figure 6. Distribution by Level of Performance (Percentage)



Source: Prepared by the authors.

The process carried out allowed teachers in each academic period to define strategies for implementing the LO and designing the tool that each one specifically used for this purpose. The process conducted enabled teachers in each academic period to define strategies for implementing the LOs and designing the tool that each one specifically used for this purpose.

Conclusions

The proposed methodology combines the best of two evaluation systems to accredit engineering and technology programs, evidencing that the ABET and EUR-ACE® accreditation approaches are complemented by what could be called the circle of continuous improvement, which is complete when improvement actions are adapted and adopted to the process.

Similarly, the same contextual applicability strategies in each program can be replicated in the different models that each HEI defines as ideal for its expectations.

In practice, the quality of professional training, both at the undergraduate and postgraduate levels, is supported by training processes backed by a series of academic and research structures updated according to the different standards with

which the curricula are constantly reviewed for professional training programs, especially engineering training programs, which makes it possible to permanently monitor the educational objectives and LOs proposed in each training program.
It is necessary to incorporate professors with a high degree of professional commitment into the academic dynamics of HEIs and therefore into their professional training programs. A professional preparation according to the different guidelines and criteria defined by each institution must be correlated in some way with those defined by the different accreditation bodies, which are limited to ABET and EUR-ACE® in this case.

This is due to the fact that both accreditation standards emphasize the reliability of the educational quality management system of the HEI.

It is essential to identify key activities in the process and measure, analyze, and evaluate student performance at each educational stage to identify improvement opportunities.

An important aspect concerning the quality assurance processes of higher education programs suggested by the MEN allow us to infer that the measurement and evaluation of ABET LOs and program outcomes for EUR-ACE® can gradually become evident to the extent that there are elements related to the identification of key activities of the training process, the application of rubrics for objective measurement, and the use of key indicators of student performance on the path toward the achievement of LOs and program outcomes.

Finally, it is important to document the entire process of measuring and evaluating the achievement of both LOs and program outcomes, in correspondence with the type of accreditation that the HEI has chosen to adopt for its international certification.