Ingeniería Solidaria

Analysis of learning outcomes in engineering programs

Análisis de resultados de aprendizaje en programas de ingeniería

Análise dos resultados de aprendizagem em programas de engenharia

Karla Cecilia Puerto-López[1]
Félix Joaquín Lozano Cárdenas[2]
Byron Medina Delgado[3]
Carlos Vicente Niño Rondón[4]
Sergio Alexander Castro Casadiego[5]

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[1] Universidad Francisco de Paula Santander, Facultad de Ingeniería, Cúcuta, Colombia.
Email: karlaceciliapl@ufps.edu.co
ORCID: https://orcid.org/0000-0003-3749-676X
CvLAC: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0001172778

[2] Universidad Francisco de Paula Santander, Facultad de Educación, Cúcuta, Colombia.
Email: felixlozano@ufps.edu.co
ORCID: https://orcid.org/0000-0003-0832-6374
CvLAC: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0000885240

[3] Pontificia Universidad Javeriana, Facultad de Ingeniería y Ciencias, Cali, Colombia.
Email: carlosvicenteninor@javerianacali.edu.co
ORCID: https://orcid.org/0000-0002-3781-4564
CvLAC: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0001703664

[4] Universidad Francisco de Paula Santander, Facultad de Ingeniería, Cúcuta, Colombia.
Email: byronmedina@ufps.edu.co
ORCID: https://orcid.org/0000-0003-0754-8629
CvLAC: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0000290157

[5] Universidad Francisco de Paula Santander, Facultad de Ingeniería, Cúcuta, Colombia.
Email: sergio.castroc@ufps.edu.co
ORCID: https://orcid.org/0000-0003-0962-9916
CvLAC: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0001132598

Abstract

Introduction: The present review article is the product of the research "Teaching digital modulation techniques in engineering: experiential learning theory " developed at the Franciso de Paula Santander University and Pontificia Universidad Javeriana in 2022.

Problem: The learning outcomes correspond to the statements related to what the future engineer is expected to be able to do, learn, understand and demonstrate.

Objective: Analyze learning outcomes in engineering programs globally.

Methodology: A methodology based on analysis stages is used for information selection through search filters and inclusion and exclusion criteria, design for the classification of information by geographic location and area of knowledge, with qualitative results by location and trends by area of knowledge.

Results: Divergence was observed towards the way in which learning outcomes are evaluated, and convergence towards the need to involve agents external to the academy in the feedback for the learning outcomes evaluation processes.

Conclusion: This allows for the identification of individual and collective strengths and weaknesses, which helps to make informed decisions to improve the quality of education.

Originality: Originality is based on the way in which the information is analyzed, considering information by areas of knowledge as well as by continents.

Limitations: None given the nature of the literature review.

Keywords: Learning outcomes, engineering, trends, information selection.

Resumen

Introducción: El presente artículo de revisión es producto de la investigación "Enseñanza de las técnicas de modulación digital en ingeniería: una mirada desde la teoría del aprendizaje experiencial" desarrollada en la Universidad Francisco de Paula Santander y la Pontificia Universidad Javeriana en 2022.

Problema: Los resultados de aprendizaje corresponden a los enunciados relacionados con lo que se espera que el futuro ingeniero sea capaz de hacer, aprender, comprender y demostrar.

Objetivo: Analizar los resultados de aprendizaje en los programas de ingeniería a nivel mundial.

Metodología: Se utiliza una metodología basada en etapas de análisis para la selección de la información a través de filtros de búsqueda y criterios de inclusión y exclusión, diseño para la clasificación de la información por ubicación geográfica y área de conocimiento, con resultados cualitativos por ubicación y tendencias por área de conocimiento.

Resultados: Se observó divergencia hacia la forma de evaluar los resultados de aprendizaje y convergencia hacia la necesidad de involucrar a agentes externos a la academia en la retroalimentación de los procesos de evaluación de resultados de aprendizaje.

Conclusiones: Esto permite identificar las fortalezas y debilidades individuales y colectivas, lo que ayuda a tomar decisiones informadas para mejorar la calidad de la educación.

Originalidad: La originalidad se basa en la forma de analizar la información, considerando la información por áreas de conocimiento, así como por continentes.

Limitaciones: Ninguna dada la naturaleza de la revisión bibliográfica.

Palabras clave: Resultados de aprendizaje, ingeniería, tendencias, selección de información.

Resumo

Introdução: Este artigo de revisão é produto da pesquisa “Ensino de técnicas de modulação digital em engenharia: um olhar a partir da teoria da aprendizagem experiencial” desenvolvida na Universidade Francisco de Paula Santander e na Pontifícia Universidade Javeriana em 2022.

Problema: Os resultados de aprendizagem correspondem a afirmações relacionadas com o que se espera que o futuro engenheiro seja capaz de fazer, aprender, compreender e demonstrar.

Objetivo: Analisar os resultados de aprendizagem em programas de engenharia em todo o mundo.

Metodologia: Utiliza-se metodologia baseada em etapas de análise para seleção das informações por meio de filtros de busca e critérios de inclusão e exclusão, desenho para classificação das informações por localização geográfica e área de conhecimento, com resultados qualitativos por localização e tendências por área de conhecimento. conhecimento.

Resultados: Observou-se divergência na forma de avaliar os resultados da aprendizagem e convergência na necessidade de envolver agentes externos à academia no feedback dos processos de avaliação dos resultados da aprendizagem.

Conclusões: Isto permite identificar os pontos fortes e fracos individuais e coletivos, o que ajuda a tomar decisões informadas para melhorar a qualidade da educação.

Originalidade: A originalidade baseia-se na forma de analisar as informações, considerando as informações por áreas do conhecimento, bem como por continentes.

Limitações: Nenhuma dada a natureza da revisão bibliográfica.

Palavras-chave: Resultados de aprendizagem, engenharia, tendências, seleção de informação.

1. INTRODUCTION

The level of formation of engineers is an issue of international importance. Social responsibility, scientific and technological updating, and the professional commitment of engineers with the expectations of the society to which they belong, are born in the classrooms and, consequently, are the essence of the curricular design, as well as the raison d’être of the teaching commitment [1]. The relevance of the responsibility of engineering teachers demands the particular concern of higher education institutions for the training and monitoring of the commitments of their professors. The quality of the curricular offerings in engineering depends significantly on the quality of the teaching that is exercised in them, and consequently, the qualification of teachers and the recognition of their importance are key factors of curricular management and the fulfillment of a mission based on the social commitments granted to higher education [2], in favor of the development of various areas of humanity [3].

In addition, knowing that the psychological and material situation of teachers is diverse, it is essential to revalue their status if lifelong education is to fulfill the key mission assigned to it in favor of the progress of our societies and the strengthening of mutual understanding between peoples. Society must recognize the teacher as such and provide him/her with the necessary authority and adequate working resources [4].

Evaluation is one of the fundamental aspects of education and an infallible tool that teachers must use for the adequate supervision of their pedagogical work [5]. Many researchers agree on the need for research on the relationship between evaluative theory and practice. There are studies focused on the relationship between specific theoretical aspects and evaluative practice [6], and although it has shown great resistance to change, there is already a well-established international movement calling for more authentic assessment tasks, real and contextualized challenges that students will face in the world at the end of higher education. This is a trend that will accelerate and become the norm for assessment tasks to look and feel like activities undertaken in the real world. Likewise, assessment tasks will need to be brought closer to professional scenarios so that students learn what is meaningful to themselves and to the social and professional world they are entering [7].

The passage of time in higher education sees educators adapt to the needs of the changing university world, and indicates a precise orientation: to inquire about learning from the students' perspective. It is necessary to analyze and understand what happens within the learning processes of students and the processes of university teaching, revealing the practices that take place in these areas, and be able to derive institutional strategies that favor better training processes [8].

Learning outcomes are presented as an effective alternative to comprehensively supply the requirements of an adequate learning process. They are simply objectives, a written statement of what an academically successful student is expected to be able to do at the end of a module, or degree [9]. It is important that they are precisely stated, observable, measurable and achievable. Undoubtedly, it is possible that a subject may have other types of objectives or propose important results that are difficult to evaluate, but it is advisable that the results that define the subject and govern its planning, without being reductionist, are concrete and evaluable in some way. It is unreasonable that the effects that justify a subject cannot be verified in some way. The learning outcomes that define a subject must be consistent with the competencies that define the degree and, in turn, all subject planning must be consistent with the outcomes that define the subject [10].

Learning outcomes also provide greater clarity and transparency for higher education systems and their qualifications. They are tools for clarifying the fruits of learning for students, citizens, employers and educators themselves. For universities, they are a useful tool for the planning and organization of learning, since they make the expected learning outcomes clear and easily understandable for teachers, students, employers and other stakeholders in the university system. On the one hand, it helps the professor to orient his or her teaching towards the achievement of certain objectives that have been made explicit in terms of knowledge and competencies. On the other hand, it allows students to know in advance the challenges they will face throughout their training, i.e., what is expected of them at the end of their studies and how the learning achieved will be evaluated. Furthermore, the use of learning outcomes increases the coherence of the student-centered teaching-learning model, as it establishes a link between training activities, assessment methodologies and outcomes [11].

Learning outcomes function within the entire educational context, since they measure the quality of teaching [12], for example: they encourage research training [3], are a key tool in the implementation of internal evaluation systems [13], facilitate curriculum design [14], and even play an important role in identifying the competencies of university graduates [15]. They have shown excellent results in research in various areas of knowledge such as accounting [16], statistics and probability [17], podiatry[18] and engineering, as discussed below.

This paper presents an analysis of the current state of learning outcomes in engineering. Scientific papers from high-impact bibliographic databases were searched, with information filtering by means of search filters and inclusion and exclusion criteria. The information is classified by areas of engineering knowledge and the trend and applicability of learning outcomes by continent of origin of the authors is also analyzed. The search window for the information in the scientific papers is between 2010 and 2022. A guide of information sources is developed through the search, signaling, description and qualitative classification of the references according to the fundamental aspects of education, processes, methodologies, evaluative criteria and achievements reached through the application of learning outcomes in the university pedagogical practice in Engineering [19].

2. METHODOLOGY

A methodology based on three stages is proposed: Analysis, Design and Results, as shown in Figure 1.

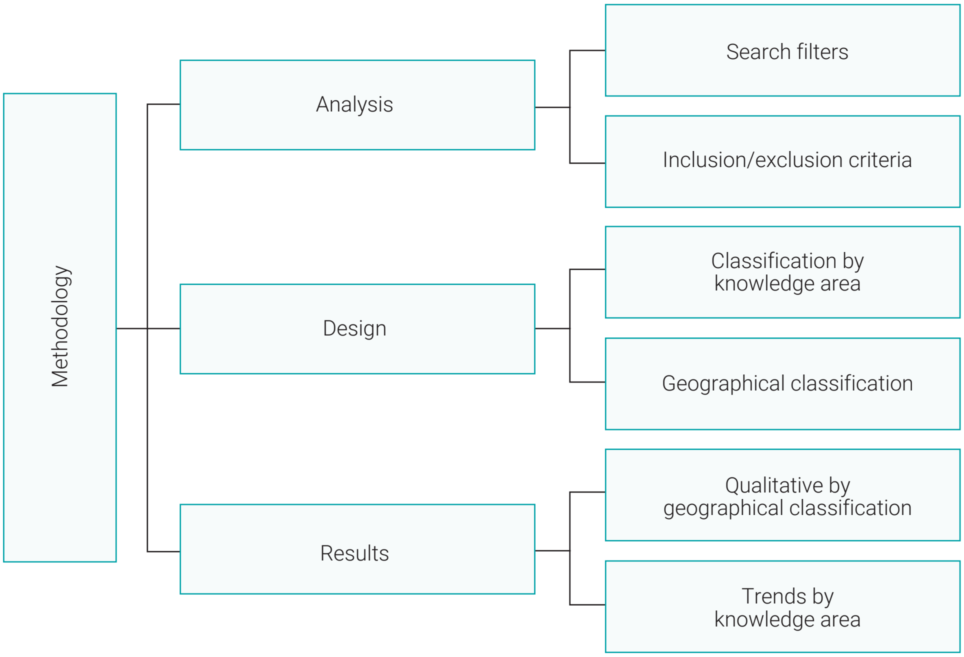

Figure 1. Methodology used.
Source: Own work

In the analysis stage, the information selection criteria are determined, based on search filters and inclusion and exclusion criteria. In the design stage, the selected information is classified by area of knowledge and geographic location. Likewise, in the results stage, the information is shown in depth and qualitatively according to geographic location, and the trends of application and use of the learning outcomes by area of engineering knowledge are determined.

A) Analysis

The selection of information is made first by successive keyword searches, complemented with criteria for inclusion/exclusion of information. The information is also filtered by year of publication.

Figure 2 shows the way in which the selection of information is made, using the keywords Evaluation, Learning outcomes, Engineering. Likewise, an inclusion/exclusion criterion is used, referring to whether or not the scientific document in question has the necessary information to replicate the research or study in engineering faculties of higher education institutions. For this purpose, high-impact bibliographic databases such as Google Scholar, IEEE Xplore, and ScienceDirect were used. The selected information is found in the window between 2010-2022.

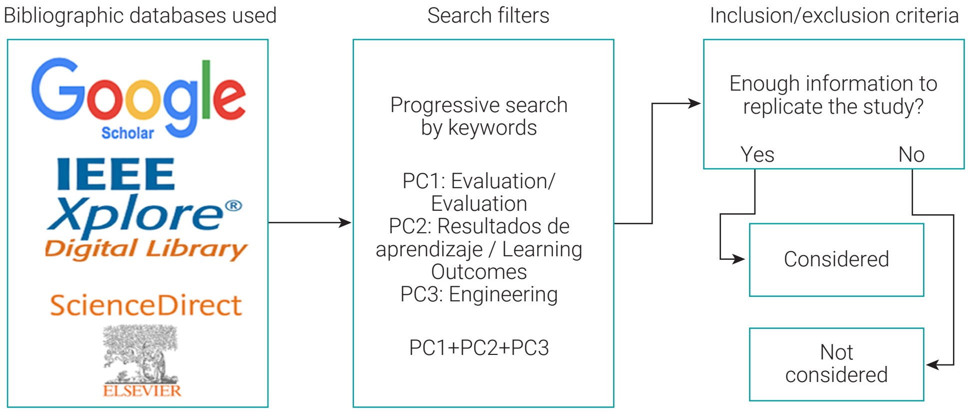

Figure 2. Methodology for information selection.
Source: Own work

B) Design

The scientific papers surveyed for the analysis of learning outcomes in engineering are presented below. Figure 3 shows the distribution of the learning outcomes according to the area of knowledge. As shown, 25 articles were selected for engineering in general, while for food, systems, industrial and civil engineering, the number of papers selected was 1, 3, 2, 2, and 3, respectively. Similarly, for electronic engineering the number of papers considered was 10, while for mechanical, biomedical, electrical and chemical engineering, the respective number of scientific articles considered was 5, 3, 1 and 3.

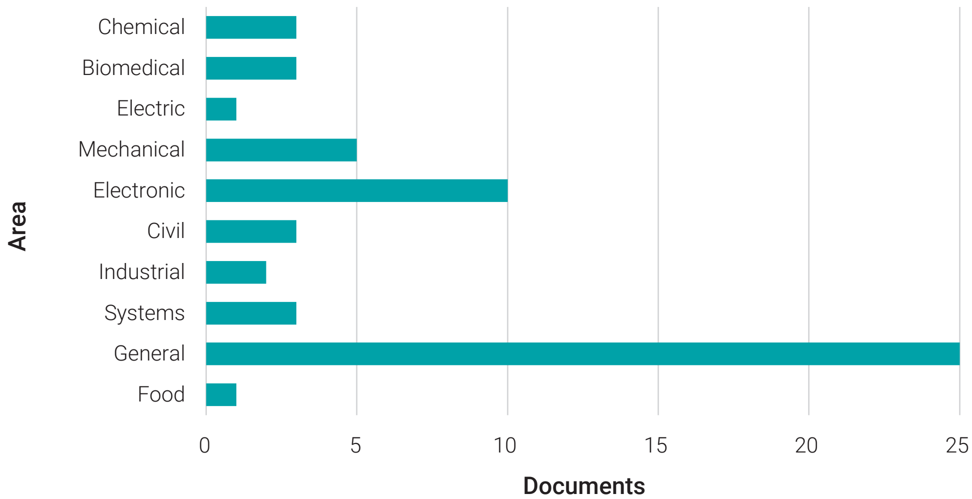

Figure 3. Classification of information by engineering area.
Source: Own work

The distribution of information that passed the search filters and inclusion and exclusion criteria by geographic area is also presented. A greater amount of information on learning outcomes in engineering is observed for the American continent with a total of 27 documents, while for Asia and Europe the number of documents was 13. On the other hand, the continents with the least information were Oceania and Africa with 2 and 1 document respectively.

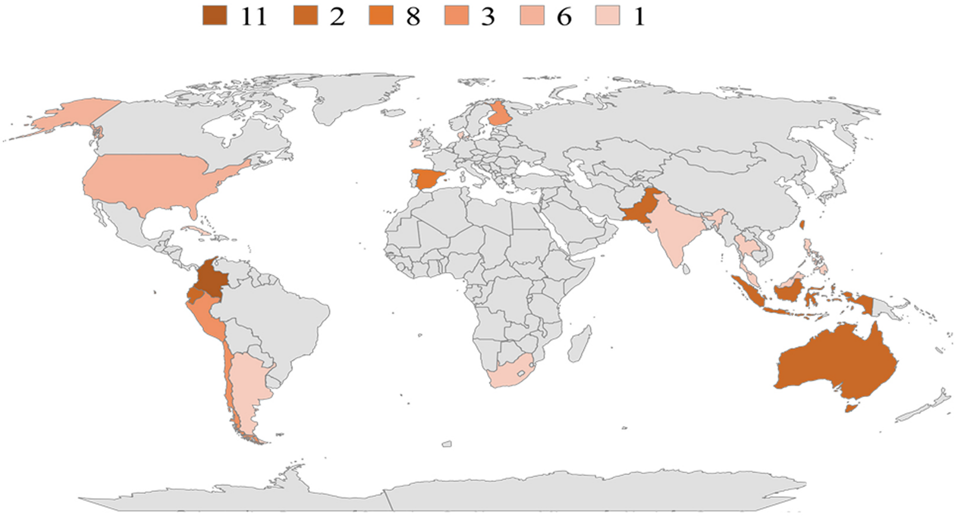

Figure 4. Classification of information by the authors' place of origin.
Source: Own work

3. RESULTS

The information analyzed for learning outcomes in Engineering is presented below. The information is broken down by continent.

A. America

The Chemical Engineering Department of the Universidad de Concepción has submitted its Chemical Civil Engineering degree to the accreditation process before the North American agency ABET. The focus of the accreditation is on a process of continuous improvement that requires adjusting the teaching process to new forms of measurement, control and evaluation. A model is presented that implies changes in the culture of measurement and evaluation in the subjects, towards one focused on the achievement of learning results by the students. As part of the strategy adopted by the Department, teacher improvement activities were carried out and work was carried out in stages to establish the continuous improvement process: first, creation of portfolios for each subject with their respective syllabus, evaluation instruments and guidelines; second, workshops to define the learning outcomes of all subjects in the course; third, spreadsheets for all subjects, with percentage of compliance with the learning outcomes; fourth, definition of key performance indexes and their relationship with each learning outcome; fifth, rubrics as a method of evaluation; and sixth, work of a Continuous Improvement Commission [20].

The disciplines of civil and environmental engineering have identified the levels of sustainability knowledge that it is desirable for students to attain upon graduation with a bachelor's degree, as well as the sustainability-related competencies that should be obtained during a master's degree, and on the job, prior to professional licensure [21]. There are different pedagogies that are best suited to help students achieve these levels of cognitive ability, while developing affective outcomes. Bielefeldt provides examples of different methods used at one institution to educate engineering students about sustainability, with data indicating whether the method has achieved the intended learning outcomes. Likewise, Rodriguez and San Andrés reflect on essential aspects related to competencies and learning outcomes, with the purpose of clarifying both concepts and showing in a practical way how learning achievements and their respective evaluative criteria can be formulated in the Programming II subject of the programming chair at UTM [22].

Lowe and Goldfinch inquired about the intended role of integrative courses that aim to connect technical and professional skills and, in particular, the appropriate stage within a program for different levels of integrative capability [23], taking into account the need for engineering graduates to balance technical competence with professional and cross-disciplinary skills. Multidisciplinary integrative projects have become a common approach to managing this balance and have been the subject of significant research. However, minimal consideration has been given to the level of integrative skills that might be considered appropriate at different stages of degree programs. The authors asked: Do the intended learning outcomes of integrative projects vary with their stage in degree programs? If so, then what does this variation reveal regarding expectations about the development of integrative capabilities? To address these unknowns, they collected examples of project units that claim to be addressing integrative objectives and for which learning outcomes are available. Guided by the existing literature on the purpose of integrative units, a thematic analysis of these units was conducted by coding the learning outcomes against the Structure of Observed Learning Outcomes (SOLO) taxonomy.

It is worth noting that the learning outcomes related to the engineering design process, teamwork, and design communication are set at a variety of performance levels [24]. Tables of performance descriptions define engineering design performance along a continuum of competencies from novice to practicing professional. Generally, learning outcomes are proposed for graduate engineers and for engineering students in the middle of their programs of study. Assessment instruments and scoring scales are developed around these learning outcomes [25]. On the other hand, there are aspects such as race [26] and gender [27] [28], which influence learning outcomes in engineering. Women and underrepresented minorities in traditionally white and male-dominated disciplines tend to report lower learning outcomes than their white peers. Adopting a feminist intersectionality framework, these studies analyzed the intersections of gender and race to investigate differences in self-assessed learning outcomes in undergraduate engineering education.

Díaz also focused on the analysis of learning outcomes applied to the microcontroller course in electronic Engineering [29]. Using project-based learning methodology, accompanied by theoretical foundations, he sought the convergence between microcontrollers and micro robotics, finding that students significantly improved their knowledge regarding microcontrollers, using micro robotics as a learning strategy. Clavijo et al focused their learning outcome analysis study on the evaluation of the potential of remote laboratories using electrical simulators in a metallurgy course. Using the Toulmin model for argumentation analysis, they found that this type of tool not only trains the future engineer in the acquisition of metallurgy skills, but also in transversal skills such as the use of ICTs and virtual interaction. With this, they infer the possibility of stimulating the development of cognitive-linguistic skills for the practice of engineering.

Patiño implemented learning outcomes models in undergraduate engineering programs [30]. Identifying goals, requirements, results, projection, alignment and measurements, and with the implementation of the Assessment model, he confirms the need for integrality in the teaching-learning processes for the improvement of processes through audited evidence and accredited documentation. Similarly, Chirikov et al. [31] and Ro et al. [32], focused their studies on the convergence and utilization of learning outcomes in engineering with educational approaches such as STEM. In addition, Avagliano and Vega [33] focused on micro-curricular design using learning outcomes to improve teaching and learning processes in mechanical engineering, complemented with digital classrooms. Although when implementing these strategies and evaluating them, improvements in the teaching-learning relationship were observed, it was also observed that these strategies are not sufficient to obtain considerable improvements in the practical engineering modules, thus inferring the need for continuous improvement of these types of strategies.

B. Asia

Alhefnawi determined the effectiveness of online lecture handouts versus active lectures as two modes of presentation at the undergraduate level [34]. A sample of thirty-eight fourth-year students from the architecture department of the Faculty of Architecture, Planning, and Civil Works the Imam Abdulrahman Bin Faisal University were selected to undergo a three-phase questionnaire on perceptions of the term sustainability and its related practices. The first phase was to measure prior knowledge about sustainability and the base case of the students was considered. After uploading the handouts to Blackboard, the second phase was a web-based e-learning interface. And the final phase was implemented after a common lecture presented to the students. On the other hand, learning outcomes have been accepted as criteria for accreditation of academic programs, according to Khampirat [35]. however, little is known about why students vary in their desired outcomes and how workplace experiences and learning strategies have different impacts. Based on social cognitive career theory SCCT, the relationships between WIL work-integrated learning, learning strategies, institutional and goal commitments, engineering skills self-efficacy, engineering career outcome expectations, lifelong learning skills, and achievement goal orientation are investigated.

In complement, Ghulam et al [36] inquired about learning outcomes in the context of basic mathematics courses for engineering professionals. They relied on the development of testing and coaching models for teachers for 4 continuous weeks. In agreement with other authors, they determined that there are several factors external to the course itself that directly influence academic scores. However, they find an improvement when implementing the PSA method with respect to the TMT method, due to the involvement and interest generated by the PSA method. Abdeljaber and Ahmad [37] developed a learning outcomes assessment method focused on multi-academic accreditation of systems engineering. They relied on mapping and systematization of academic program objectives. In addition, they propose to track low-scoring program outcomes, taking into account and considering possible errors in the mapping. Likewise, Tshai et al. [38] inquired about learning outcomes assessment in the mechanical engineering program. They focused on professionals in the program, and employed anonymous online surveys as a data collection instrument. However, this collective method does not allow for in-depth knowledge of individual experiences and professional development plans. Similarly, they propose to take into consideration the opinion of employers in the learning outcomes analysis process.

In addition, Naqvi et al. [39], investigated learning outcomes and assessment methods in the case of industrial and project engineering, taking into account the successful implementation of outcome-based education in higher education. Particular emphasis was placed on end-of-degree projects, so that they are aligned with those stipulated by the Washington Agreement. The evaluation is carried out according to self-assessment rubrics. The work developed is presented as an orientation strategy for students facing project design and evaluation problems. Epiphany reflects on global learning outcomes in engineering [40], emphasizing the fundamental levels of learning outcomes: “Programme”, “Principal”, “Enabling” and “Sub-enabling”. Taking Bloom’s taxonomy as a reference, it indicates that teachers are obliged to design lessons and tasks to support students in the achievement of established objectives, comprising cognitive, affective and psychomotor learning domains. This document is presented as a guide to the teaching-learning process with a view to learning outcomes and their importance.

Luk y Chan [41] sought to answer the research question “What learning outcomes do students perceive in the engineering practice experience” by relying on qualitative approaches to identify commonalities and differences between perceived learning outcomes. They relied on both content and constant comparative analyses to understand the information provided by engineering students in Hong Kong. The study found that the main categories of learning outcomes found were knowledge, generic academic skills, and technical skills. These results are opposite to those highlighted by the literature, which indicate that the main categories of learning outcomes in engineering students are information technology skills and non-technical generic competencies such as teamwork skills. These results allow creating future constructive alignment strategies for the design of engineering courses. Similarly, Nerona, through collaborative learning among engineering courses, evaluated learning outcomes and performance improvement of future engineers [42]. He employed the experimental research design pre-test and post-test, on a population of 287 students from courses in economics for engineers, differential equations, and engineering management. To identify the potential improvement in students’ scores, t-tests with 5% significance level were employed. In general terms, they express the need for collaborative learning for the improvement of students’ performance and achievement, and hence, the attainment of ideal learning outcomes.

On the other hand, Chou [43] evaluated learning outcomes to identify the effects of self-directed learning skills in electronic engineering students. He focused on two scenarios: Lab-based and Online courses. A positive relationship was found between the skills developed by self-directed learning and the learning outcomes of the online course. However, in a second study, it was noted that there were no significant differences for the learning outcomes of online courses, inferring that the effects of self-directed learning were not reflected in this type of learning. The author points to randomization, online learning environment, self-directed learning ability, and online instructional activity as possible causal factors for these effects. Finally, in Indonesia, Timor et al. determined the efficiency of the problem-based learning model on learning outcomes in basic electronics students [44]. The research is pseudo-experiment type based on pretest-posttest models. The instruments used to collect information on learning outcomes were tests and questionnaires. The obtained data infer a great influence of the PBL model on learning outcomes, with mean scores of the questionnaires at almost 80%. In addition, Silalahi [45] used the learning outcomes obtained in mechanical engineering courses for the development of electronic modules based on Exe-Learning, with information collection through questionnaires and, when applying the modules, an improvement in learning outcomes between 66% and 80% was achieved.

C. Europe

Hartikainen et al. [46] focus on learning outcomes towards shaping the concept of active learning. They developed a critical literature review with the aim of highlighting the variation and problems present in the search for coupled learning outcomes, so as to focus further studies on the recognition of conceptual and methodological features. In the context of electronic engineering, Daza et al. [47] focused on the influence of the achievement of learning outcomes to validate the teaching-learning relationship using coordinated practices. They developed proposals for integrated practices between the subjects of electronic systems and instrumentation and signal conditioning. In an unexpected way, in the first sections of integrated practices, the academic performance indexes were lower, this being generated by the novelty of the proposal and by errors in the approach of the instruments and strategies. The improvement of results one year after the implementation of these strategies was caused by the improvement of the instruments and the recurrence of the students, who had already been among the students who participated in the first section of tests of the coordinated practices strategy.

Guerra and Kolmos [48] evaluated the learning outcomes and reports, based on the Tuning-Ahelo framework. They selected 3 end-of-degree projects at random, and content analysis grids were built. Thus, the authors recommend this framework in order to establish relevance in content analysis, since, by applying these strategies, students achieve the learning outcomes initially proposed. Additionally, Kilmartin and McCarrick analyzed learning outcomes in electronic engineering students using service learning modules [49]. This is shown as an evaluation method to a strategy proposed since 2008, which has replaced traditional subject-based group project modules. With the new strategy, students in a period of 6 months carry out a project involving community organizations that work with people with various physical disabilities. The strategy had a great impact on the students, since for many of them it was the first project they had developed with a meaningful and structured design. In addition, there was a tendency for students to prefer this type of practical project instead of classroom projects where, in addition to enjoying the interaction with the community, they opened their minds to the implementation of engineering projects focused on business models.

On the other hand, Kybartaite studied the impact of educational technologies on learning outcomes in virtual environments [50]. It is a study with four approaches: theoretical, practical, evaluative and developmental. Through surveys, it was noted that students preferred traditional face-to-face lectures instead of continuing with videoconferences. However, they highlight as advantages of videoconferences the ease of reviewing the course material. Thus, the author suggests the need to reduce the use of virtual audiovisual tools for lectures in engineering courses, since this has a considerable influence on the weighting of learning results. Margallo et al [51] studied the assessment of competencies and learning outcomes for the incorporation of assessment tools in chemical engineering subjects. Considering that student-centered teaching methods contribute to improved teamwork and communication skills, they propose a micro (Assess-23 Analyze-Act) (M-3A) assessment model focused on closing the learning circle, thus demonstrating that these approaches have increased analytical capabilities to quantify a situation, as well as the adaptation of the academic load by students. Tuunila and Pulkkinen analyzed the effects of continuous assessment of learning outcomes in chemical engineering courses [52]. Improved learning outcomes were obtained by applying this methodology, and furthermore, the need to improve the quality of teaching was inferred, since, by implementing more activating methods, students are forced to study actively throughout the courses.

D. Africa and Oceanía

In Australia, Gutierrez et al. employ the review of learning outcomes to assess the sustainability of civil engineering education [53]. They rely on the exploration of curriculum, teaching and learning renewal approaches, finding evidence of the need to make sustainability a concept created from the integrality of diverse agents. Likewise, they suggest reevaluating the meanings and importance of being and becoming engineers, emphasizing social responsibility in engineering education. Likewise, Male and King focused on analyzing the influence of industry participation in improving learning outcomes [54]. With 12-week internships, they highlight industry engagement with end-of-career students so that doubts in the knowledge and skills acquired during their stay in the engineering faculty are minimized. This allows universities to develop guided plans for the development of professional practices, improving models and requirements for integrated learning, considering virtual and electronic strategies that reflect changes in industrial practices in engineering. Likewise, Stewart studies the relationship between self-directed learning and project-based learning outcomes [55]. Applying 26 questionnaires with 5 sections, which allowed for extracting information from the profile of the respondents, desires to learn, self-management and self-control. The instruments also provided information about the students' perspectives on the evaluative components during their study stay, as well as the levels of dedication to solving unknown problems in their area of knowledge and a rating of the learning outcomes of the courses seen. Migration towards student-centered teaching methodologies is proposed, even from the secondary education stages, so that programs are designed to enable the development of problem-solving skill levels in future engineers.

In South Africa, Meda and James analyzed learning outcomes in electronic engineering programs using illustrative verbs from Bloom's taxonomy [56]. Based on the idea that in many institutions the learning outcomes are structured in ways that do not promote student learning, they developed a qualitative study in which they reviewed the learning outcomes after using a series of illustrative verbs as a teaching methodology, emphasizing the ability to remember specific methods and processes, to understand information and ideas, expecting improvements in the evaluation of analysis and synthesis processes. In the case study, it was found that, with traditional methodologies, 9% of the learning outcomes are not clear, 10% are not observable and 23% cannot be measured. The authors express the need to constantly measure and evaluate learning outcomes to promote student learning.

E. Trends

Table 1 lists the trends found towards the application and improvement of learning outcomes in engineering. The trends are presented by areas of knowledge. At the level of engineering in general, for the improvement of learning outcomes, there is a tendency to use integrative courses, with improved training for the strengthening and balance between technical competences and transversal competences.

Table I. Trends by knowledge area for the improvement of learning outcomes in engineering

Engineering knowledge area	Tendency to improve learning outcomes
Chemical	Changes in evaluation models, with constant self-evaluation and migration to international accreditation models.
Civil	Adoption of methodologies to increase knowledge levels, with emphasis on the creation of sustainability concepts.
Food	Application of knowledge in real contexts, to converge with reflective and pragmatic student learning models.
Electrical and Electronics	Application of project-based learning, with a focus on the STEM model. In addition, self-directed learning complemented with online courses. In addition, there is a need for feedback with the industrial sector and follow-up with graduates.
Mechanical	Application of models for training in transversal competencies and development of cognitive-linguistic skills. Implementation of digital classrooms and feedback with employers
Systems	Mapping and systematization of objectives with continuous monitoring of the evolution of students' skills. In addition, need to include the business sector for feedback.
Industrial	Outcome-based learning and project-based learning.
Biomedical	Traditional approaches to the improvement of face-to-face teaching processes, using ICT tools.

Source: Own work

4. DISCUSSION

Overall, it has been identified that emphasis has been placed on improving the measurement and assessment of learning outcomes in their Civil Chemical Engineering program. They developed portfolios for each subject, defined learning outcomes, created spreadsheets to track compliance, and used rubrics for assessment. In addition, the Civil Engineering and Environmental Engineering disciplines identified desired levels of sustainability knowledge to be achieved upon graduation with a bachelor's degree, as well as sustainability-related competencies to be obtained during a master's degree and on the job prior to professional licensure. Different pedagogies and methods were used to educate engineering students about sustainability, and their effectiveness in achieving the desired learning outcomes was evaluated.

Also, the role of integrative courses and projects in engineering programs was explored, focusing on the appropriate stage within the program for different levels of integrative capability.

The learning outcomes of integrative projects were analyzed and the variation of these outcomes at different stages of degree programs was examined. Similarly, learning outcomes related to the engineering design process, teamwork, and design communication were established. Performance descriptions were defined to assess the performance of the students in the different stages of the degree programs.

5. CONCLUSIONS

The monitoring of the evolution of results in engineering contributes to the formation of competitive and integral professionals. The methodology used for the classification of information by geographic location, allowed us to identify that at a global level there is a divergence in the ways in which learning outcomes are evaluated, since in some cases the evaluation is done from the purely academic point of view, while in some other cases, the evaluation is done from the analysis of the incidence of factors external to the academy, such as education from high school levels, race, gender, and student profiles and their prospects for future employment. Additionally, the classification by areas of knowledge led to finding convergence between different areas, inferring, among others, the need that, in careers with a labor focus in companies, industries and services, the perspective of the employer and the employer should be taken into consideration in the processes of feedback and continuous improvement of the learning results. Likewise, at a global level, the importance of graduate follow-up and periodic evaluation of learning outcomes is highlighted.

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