Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín*

Desarrollo de competencias en ingeniería industrial y programas afines en torno a la optimización de procesos productivos y logísticos: el caso de Medellín

iD Yenny Alejandra Aguirre-Álvarez**

iD Mauricio Montoya-Peláez***

iD Raúl Trujillo-Cabezas****

iD Camilo Esteban Solano Hurtado*****

* The project is the result of independent research and has no external source of funding.
** Universidad de Antioquia, Medellín, Colombia, yennya.aguirre@udea.edu.co
*** Politécnico Colombiano Jaime Isaza Cadavid, Medellín, Colombia, mmontoya@elpoli.edu.co
**** Universidad Externado de Colombia, Bogotá, Colombia, raul.trujillo@uexternado.edu.co
***** Universidad Nacional Abierta y a Distancia, Bogotá, Colombia, camilo.solano@unad.edu.co

Abstract: This study examines the correlation between the skills and competencies developed in engineering programs and those required by the most representative economic sectors in Medellín for optimizing their production and logistics processes. In general terms, this paper aims to contribute to the research on higher education institutions and the alignment of their programs with the expectations of businesses in emerging countries. Thus, the proposed research question is as follows: What is the systemic relationship between academia and businesses in Colombia regarding the development of skills and competencies related to the optimization of production and logistics processes? To address this question, the study methodology starts by defining the target population (Industrial Engineering and related academic programs) and the dialogue methods adopted. Subsequently, a morphological space is created to establish systemic interconnections among the study variables and factors. Finally, patterns and qualitative/quantitative relationships are identified and grouped into two drivers that support the optimization of production and logistics processes. These drivers, in turn, consist of five key driving variables: quality defects, work environment, information and communication technology usage, operation traceability, and logistics and planning. The results indicate a correlation of 60% between courses and job competencies, 85.71% between academic skills and job competencies, and 71.88% between courses and academic skills. These findings provide insights to enhance cooperation between the academic and business sectors and foster the development of new local competitive capacities.

Keywords: Academic skills, business sectors, engineering education-Colombia, production and logistics processes, university–industry relationship.

Resumen: el presente estudio examina la correlación entre las habilidades y competencias desarrolladas en los programas de ingeniería y las requeridas por los sectores económicos más representativos de Medellín para optimizar sus procesos productivos y logísticos. Desde una perspectiva más amplia, este artículo pretende contribuir a la literatura sobre las instituciones de educación superior y la alineación de sus programas con las expectativas de las empresas en los países emergentes. En este sentido, la pregunta de investigación propuesta es: ¿Cuál es la relación sistémica entre la academia y la industria en Colombia en torno al desarrollo de habilidades y competencias relacionadas con la optimización de procesos productivos y logísticos? Para abordar esta pregunta, la metodología empleada parte de la definición de la población objetivo (programas de Ingeniería Industrial y afines) y de los métodos de diálogo empleados. Posteriormente, se crea un espacio morfológico para establecer interconexiones sistémicas entre las diferentes variables y factores del estudio. Por último, se identifican patrones y relaciones cualitativas/cuantitativas y se agrupan en dos impulsores que contribuyen a optimizar los procesos productivos y logísticos. Estos impulsores, a su vez, constan de cinco variables impulsoras clave: defectos de calidad, clima laboral, uso de tecnologías de la información y la comunicación, trazabilidad de las operaciones, y logística y planeación. Los resultados indican una correlación del 60 % entre los cursos y las competencias laborales, del 85,71 % entre las competencias académicas y las competencias laborales y del 71,88 % entre los cursos y las competencias académicas. Estos resultados podrían ayudar a mejorar la cooperación entre los sectores académico y empresarial y favorecer el desarrollo de nuevas capacidades competitivas locales.

Palabras clave: competencias académicas, sectores empresariales, formación de ingenieros-Colombia, procesos productivos y logísticos, relación universidad-empresa.

INTRODUCTION

This article provides an overview of the acquisition of engineering competencies related to the optimization of production and logistics processes in the Colombian context. In addition, it adopts a comparative approach to identify and analyze the generic skills of engineering students. In this regard, Castrillón et al. (2015) highlight the need to reduce the gap between theoretical and practical competencies in higher education programs in Colombia. For his part, Rodríguez-Zambrano (2007) defines competencies as the skills and behaviors necessary for successful job performance and suggests considering the impact of competencies on the education–work–life relationship. Thus, the research question proposed in this study is as follows: What is the systemic relationship between academia and businesses in Colombia regarding the development of skills and competencies related to the optimization of production and logistics processes?

THEORETICAL BACKGROUND

The study described in this paper builds upon three theoretical frameworks: a) optimization of production processes, b) optimization of logistics processes, and c) skills as a necessary component of training.

Optimization of production processes

The First Industrial Revolution (1760–1840) and the Second Industrial Revolution (1870–1914) marked the beginning of practices aimed at increasing production capacity, automating processes, developing innovative machinery, implementing large-scale production, using new technologies, and globalizing industry. These changes led to improvements in quality of life and the optimization of manufacturing processes (McNeil, 2002). Following that, approximately in 1947, linear programing was introduced and, in 1963, Dantzing—considered the father of linear programming—proposed the simplex method, thus making an important mathematical contribution to optimization (Dantzing, 1963).

Subsequently, between 1946 and 1975, the Toyota production system was created by Toyota's founder Sakichi Toyoda, his son Kiichiro Toyoda, and the engineer Taiichi Ohno (Toyota Industries Corporation, 2024). This development, together with the emergence of international quality standards, promoted the adoption of process management systems.

Process management did not stop there. Business Process Reengineering (BPR) appeared in 1990 (Zairi & Sinclair, 1995) and gave rise to Business Process Management (BPM) in the 2000s—which is widely applied in industry. Although BPR is a radical concept and BPM is incremental, both emphasize the importance of quality and optimization. In European countries such as Germany, Ireland, the United Kingdom, and the Netherlands, where BPM is a growing field of study, it has made significant contributions to process optimization (Rozwell & Olding, 2009).

4

In the Colombian context, Alejandro López Restrepo is considered the father of management (Mayor Mora, 1988). In 1912, while leading the Escuela de Minas de Medellín, he introduced the Chair of Industrial Economics, after translating Taylor's work. His purpose was to study and promote scientific management, which later evolved into research on the principles of organization and management of industrial firms, locally called 'Industrial Engineering' (López Gallego, 2001). In 1928, López published *El Trabajo*, where he documented his experience and proposed training engineers with management competencies. This proposal was a key factor in the growth of some industrial firms in Colombia (Martínez Fajardo, 1999), hence its relevance to the study of the development of the country's productive sectors.

Optimization of logistics processes

Logistics in prehistory arose from the need to store, manage, and control resources. Later, between 500 and 430 BC, the Greeks, Athenians, and Romans began to define logistic profiles for certain people to perform tasks related to management and calculation. The term 'logistics' was first used in 1838, when Antoine-Henri Jomini spoke of 'military logistics' in Europe (Jomini, 1840).

Identifying optimal systems enabled humanity to discover potential in existing developments. Thus, the World War I (1914–1918) marked the beginning of logistics optimization, as optimization models were applied by the parties in conflict to facilitate transportation, establish routines, manage inventories, and distribute resources. After the World War II (1939–1945), firms became interested in logistics and started to integrate military logistics concepts into industrial logistics, which increased efficiency and productivity. This was later called 'process optimization'.

In 1956, Malcolm McLean, often referred to as the father of containerization, used the concept of 'supply chain' to create an efficient system that reduced both time and costs. By 1960, the concept evolved into 'supply chain management'.

Authors such as Bonilla and Borroto, Magee, Lalonde, Bowersox, Sahid, Gómez Acosta and Acevedo Suárez, and Lamb et al. (as cited in Betancour, 2012), despite defining logistics differently, agree that it is a systemic approach that encompasses the entire process from purchase to delivery to the final customer.

The Colombian War of Independence (1810–1824) marked the country's incursion into logistics. According to Olano García (2011), general officers were the first to implement logistics chains and models for the transportation of food, goods, and armament during war. Logistics chains have experienced a progressive growth in Colombia due to globalization, land transportation is now preferred over rail transportation, and industry is segmented in the central region of the country (Ferrer et al., 2019). Moreover, current focus of optimization is on time, cost, and resource investment.

Skills as a necessary component of training

Speaking of competencies is to take up again the thoughts and writings of Western philosophers such as Plato, Aristotle, Parmenides, and Protagoras, who referred to human beings and knowledge, but without a clear definition of their cultural importance. Since then, many authors have proposed definitions and practical notions of competencies. McClelland, Mertens, Boyatzis, Vargas, the Pan American Health Organization (PAHO), the International Labor Organization (ILO), the Spanish National Employment Institute (abbreviated INEM in Spanish), the Colombian National Training Service (abbreviated SENA in Spanish), the Colombian Institute of Technical Standards and Certification (abbreviated ICONTEC in Spanish), and the Colombian Institute for the Promotion of Higher Education (as cited in Rodríguez Zambrano, 2007, pp. 149–150) coincide in denominations related to knowledge, know-how, skills, aptitudes, attitudes, and values.

According to Bunk, competencies can be classified as technical, methodological, social, or participatory. UNESCO divides them into cognitive, technical, or formative. For his part, Mertens classifies them as behavioral (personal and technical), functional, or constructivist, with a subdivision into basic, generic, or specific. Similarly, the ILO and SENA categorize them as basic, generic or transversal, and specific (Rodríguez Zambrano, 2007, p. 159).

The skills-based approach was first introduced in the United Kingdom in 1986. It was later adopted by Australia in 1990 and Mexico in 1996, seeking to increase the competitiveness of their productive sectors. Likewise, countries such as Germany, France, Spain, Colombia, and Argentina have implemented this concept through different governmental entities. The United States, Canada, Japan, and Brazil have also identified its potential for boosting their economic sectors (Ruiz de Vargas et al., 2005). In Colombia, the methodology for the acquisition of job competencies began to be developed in 2002 with SENA, following the recommendations of the ILO and with input from professionals and expert entities in the field (Cárdenas & Navas, 2012, p. 113).

The Colombian Ministry of National Education, through the sectoral plan for Education (2002–2006), promotes the development of competencies in higher education programs. However, it is important for Higher Education Institutions (HEIs) to speed up the transition from the teaching model to competency-based learning, change the organization from structured to flexible systems based on academic credits and the evaluation models to competency-based assessments with a view towards accreditation (Rodríguez Zambrano, 2007, p. 163).

According to Contreras-Germán et al. (2019), the term 'competency' has an ancient origin and connotation. However, it can also refer to the skills and abilities required to use technology in the era of Information and Communication Technologies (ICTs). In addition, it can be applied to various academic, economic, and social scenarios.

In this sense, as mentioned by Ochoa-Duarte and Reina-Rozo (2022), organizations such as Engineers Without Borders have been created around the world since the 1990s, seeking to

integrate engineering and social competencies from different perspectives to meet national and international requirements.

In this way, some background information—which is part of the evolving body of knowledge on competencies—has been gathered regarding their study and applications in various contexts to facilitate the design of an experimental methodology.

METHODOLOGY DESIGN: METHODS AND TOOLS

This paper followed a descriptive method to narrate qualitative and quantitative experimental data. Simple correlational studies were employed to determine the courses offered and the academic skills and job competencies developed in industrial engineering, logistics, productivity, and quality programs in Colombia. They also served to identify the competencies required by the business sector for the optimization of production and logistics processes. The methodology was divided into three stages that are described below.

Stage 1. Target population and dialogue methods

The target population of this study was divided into two groups: HEIs and the business sector. Various methods and techniques were used to collect, classify, and analyze information or findings, following the proposals of Sautu et al. (2005) and Abarca Rodríguez et al. (2013).

Stage 2. State of the art

To synthesize the findings of the state of the art, a morphological space was elaborated to identify the systemic relationship between (i) the courses offered in HEIs; (ii) the academic skills developed in industrial engineering, logistics, productivity, and quality programs; and (iii) the job competencies required by the business sector in Colombia.

The content analysis started with the collection of information on 257 academic programs from the HEIs' websites (Sistema Nacional de Información de Educación Superior [Colombian National System of Higher Education Information], 2020). The collected information was organized by institution, program, municipality or locality, occupational profile, specific component course, and learning variable.

As for the second component of the state of the art, a survey was conducted with 34 firms in four study sectors. This sample was drawn from a universe of 7,661 medium-sized firms located in the metropolitan area of Medellín. The probability of occurrence was 0.1 for this finite population, the confidence level was 95%, and the error on the estimate was 10%.

The purpose of the survey was to characterize the sample and measure the optimization of production and logistics processes. To this end, business owners had to select the variables

Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín

7

trilogía
Ciencia Tecnología Sociedad

applicable to their business models and rate their degree of dependence and influence on other variables on a strong–moderate–weak scale.

Subsequently, the collected information was validated through an exercise involving experts from the commercial, food, plastics, and textile sectors. A total of 29 experts were invited to participate, but only 19 (66%) accepted the invitation.

Stage 3. Analysis of key or strategic variables

To identify the key or strategic variables, the study employed the Cross-Impact Multiplication Matrix Applied to a Classification (MicMac) technique (Godet et al., 2000). This method makes it possible to establish the relationship between the 16 variables of the morphological space.

Qualitative analysis

Using the morphological space as a reference, a structural analysis was conducted, which offered the possibility of describing a system with the help of a matrix that interconnected all its elements. This analysis aimed to highlight the main influential and dependent variables and, therefore, the essential variables in the system's evolution. The relationships between the variables were described using the MicMac technique (Godet, 1993). In a table of change factors, each expert rated the relationship among the variables using the following values: P: Potential, 3: Strong, 2: Moderate, 1: Weak, 0: Non-existent.

Quantitative analysis

Based on the results of the structural analysis, three quantitative techniques were employed to develop a methodological adjustment framework using analytical tools. This framework focused on the courses, academic skills, and job competencies resulting from the morphological analysis and related to the optimization of production and logistics processes.

This analytical construction was based on a series of relationships that mediated between courses, academic skills, and job competencies. It employed a rating scale from 0 to 1 to indicate the degree to which courses developed the academic skills or job competencies, and the degree to which academic skills met the job competencies. Thus, having built a morphological space, the analysis of key or strategic variables (patterns and relationships) was described using both qualitative and quantitative approaches. The findings and main results are explained in the next section.

ANALYSIS AND RESULTS

The interpretative interview or workshop lasted two hours. During this time, experts randomly rotated every seven minutes through four working tables that grouped the 16 study variables

identified from the survey and related to the optimization of production and logistics processes. Based on these variables, 138 academic skills, 64 job competencies required by the business sector, and 154 courses that contribute to the acquisition of these competencies were collected. The competencies' descriptions were written using the notions of learning objectives, drawing from Bloom's taxonomy of thinking skills (1956), which evolved into Bloom's revised taxonomy (Anderson & Krathwohl, 2001), followed by Bloom's taxonomy for the digital age (2008), and ultimately reaching Bloom's taxonomy associated with the SAMR model (2013). According to Tobón-Tobón et al. (2010), competencies to be developed or assessed from the analysis of contextual problems should include in their structure a performance verb, a conceptual object, a purpose, and a reference condition (p. 13).

Qualitative analysis

The identification of key variables provided a framework for organizing courses, academic skills, and job competencies related to the optimization of production and logistics processes. The dimensions that make up this construction are detailed below. Table 1 contains the 16 study variables.

Table 1. Comparative results by category

Variable	Resulting survey category	Focus group result category	Comparison
V 1. Work absenteeism	Regulatory	Regulatory	Same
V 2. Percentage of reprocessing	Unbiased	Regulatory	Change
V 3. Extra hours	Environment	Result	Change
V 4. Quality defects	Regulatory	Result	Change
V 5. ICT usage	Regulatory	Determinant	Change
V 6. Inventory levels	Secondary handle	Regulatory	Change
V 7. Refunds	Environment	Regulatory	Change
V 8. Logistics and planning	—	Unbiased	New
V 9. Inventory turnover	Environment	Regulatory	Change
V 10. Operation traceability	Regulatory	Regulatory	Same
V 11. Merchandise transportation	Secondary handle	Password	Change
V 12. Staff turnover	Secondary handle	Determinant	Change
V 13. R+D+i	Unbiased	—	Rethink
V 14. Non-quality costs	Regulatory	Result	Change
V 15. Risks and operational uncertainty	Secondary handle	Secondary handle	Same
V 16. Work environment	—	Environment	New

Source: Own work.

The findings from all three stages of the methodology revealed patterns and relationships that help to determine the current state of the system. The MicMac[1] analysis displayed the key

---

[1] MicMac is an open-source photogrammetry software developed by the French National Geographic Institute.

Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín

9

variables and their relational matrix (see Table 2), showing motricity and dependence relationships.

Table 2. Rating of the system variables

	1 : Wo_Abs	2 : Per_Repr	3 : Ext_Hou	4 : Qua_Def	5 : ICT	6 : Inv_Lev	7 : Ref	8 : Log_Plan	9 : Inv_Tur	10 : Oper_Tra	11 : Mer_Trans	12 : Staff_Tur	13 : R+D+i	14 : N_Qua_Cos	15 : Ris_Oper_U	16 : Wo_Envi
1 : Wo_Abs	0	1	2	2	0	1	0	2	1	1	1	3	1	1	2	2
2 : Per_Repr	0	0	2	1	0	2	0	3	2	1	3	2	0	3	2	2
3 : Ext_Hou	0	1	0	1	1	0	1	1	1	1	1	2	0	2	1	2
4 : Qua_Def	1	3	3	0	0	3	3	3	1	0	1	2	0	3	2	2
5 : ICT	2	3	2	3	0	3	2	3	2	3	3	2	1	3	3	P
6 : Inv_Lev	0	1	1	1	1	0	1	3	3	2	2	0	1	1	2	0
7 : Ref	0	2	2	2	1	2	0	2	2	0	2	1	0	3	1	2
8 : Log_Plan	2	1	2	1	3	3	1	0	2	3	2	2	0	2	P	2
9 : Inv_Tur	0	1	1	1	0	3	1	1	0	1	1	0	0	1	1	1
10 : Oper_Tra	1	2	2	2	3	2	1	2	1	0	1	1	1	1	2	1
11 : Mer_Trans	0	0	1	0	0	1	1	1	1	0	0	1	0	0	1	1
12 : Staff_Tur	2	1	2	2	2	0	1	1	0	1	1	0	0	1	1	2
13 : R+D+i	1	2	2	3	3	2	2	P	2	2	2	2	0	3	2	2
14 : N_Qua_Cos	1	0	0	0	0	1	0	1	0	0	0	2	0	0	2	1
15 : Ris_Oper_U	1	2	1	1	2	1	2	1	1	2	2	2	0	1	0	1
16 : Wo_Envi	3	1	1	2	2	0	1	3	0	1	1	2	0	2	3	0

© LIPSOR-EPITA-MICMAC

Source: Own work using MicMac.

To classify the 16 study variables in the different quadrants of the Cartesian plane, four zones were identified. Zone 1 encompasses input variables (input zone), such as variable 13 (R+D+i). Zone 2 contains link variables (conflict zone), such as variables 4 (Quality defects), 5 (ICT usage), 10 (Operation traceability), 9 (Logistics and planning), and 16 (Work environment). Zone 3 includes variables of low motricity and dependence (zone of autonomous variables), such as variable 1 (Work absenteeism). Zone 4 represents output variables (output zone), such as variables 2 (Percentage of reprocessing), 3 (Extra hours), 6 (Inventory levels), 7 (Refund), 9 (Inventory turnover), 11 (Merchandise transportation), 12 (Staff turnover), 14 (Non-quality costs), and 15 (Risks and operational uncertainty) (see Figure 1).

Figure 1. Influence/dependence map for the 16 study variables
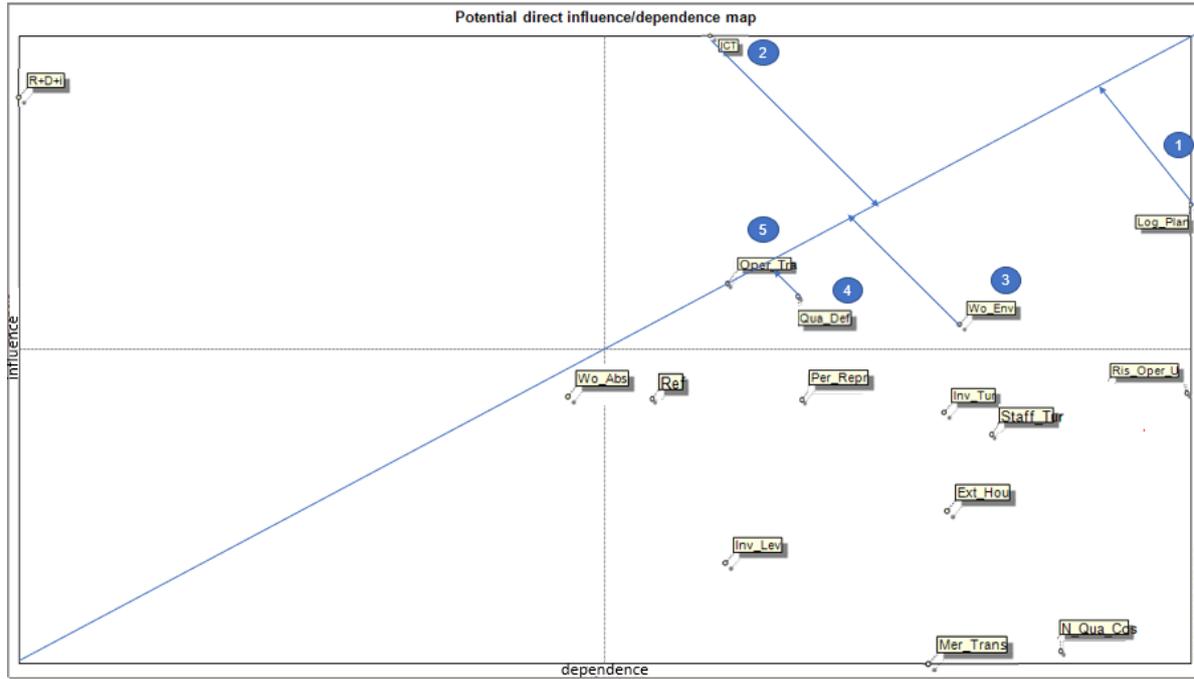
Source: Own work using MicMac.

The variables in the upper-right quadrant are the most relevant and those that pose strategic challenges for organizations. Table 3 lists these five key variables, which were used to group the 35 academic skills, the 32 courses that contribute to the achievement of these skills, and the 20 job competencies required by the business sector.

Table 3. Key driving variables

| Variable	Full name	Short name	Description
V4	Quality defects	Qua_Def	Number of non-conformities affecting product release
V5	ICT usage	ICT	Application of technologies in production processes
V8	Logistics and planning	Log_Plan	Processes and procedures that the organization uses to optimize the supply chain in order to help fulfil its promise of value
V10	Operation traceability	Oper_Tra	The process of tracking a service or product (location, path, history) using the firm's tools
V16	Work environment	Wor_Envi	Adequate physical and psychological conditions that the firm must provide for the proper execution of employees' tasks

Source: Own work.

Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín

11

trilogía
Ciencia Tecnología Sociedad

Quantitative analysis

Using analytical tools such as box plot, Principal Component Analysis (PCA), and clustering, this section describes the findings regarding the relationships between the courses, academic skills, and job competencies considered in this study.

To assess the level of correlation between the courses, academic skills, and job competencies under analysis, the box plot graph tool was used. This tool allows for the identification of outliers and enables comparison of data distributions. The findings revealed a correlation of 71.88% between courses and academic skills. In short, courses such as design of experiments, industrial safety, project formulation and evaluation, planning, programming, and production control were found to greatly contribute to the achievement of academic skills (see Figure 2).

Figure 2. Box plot - courses vs. academic skills
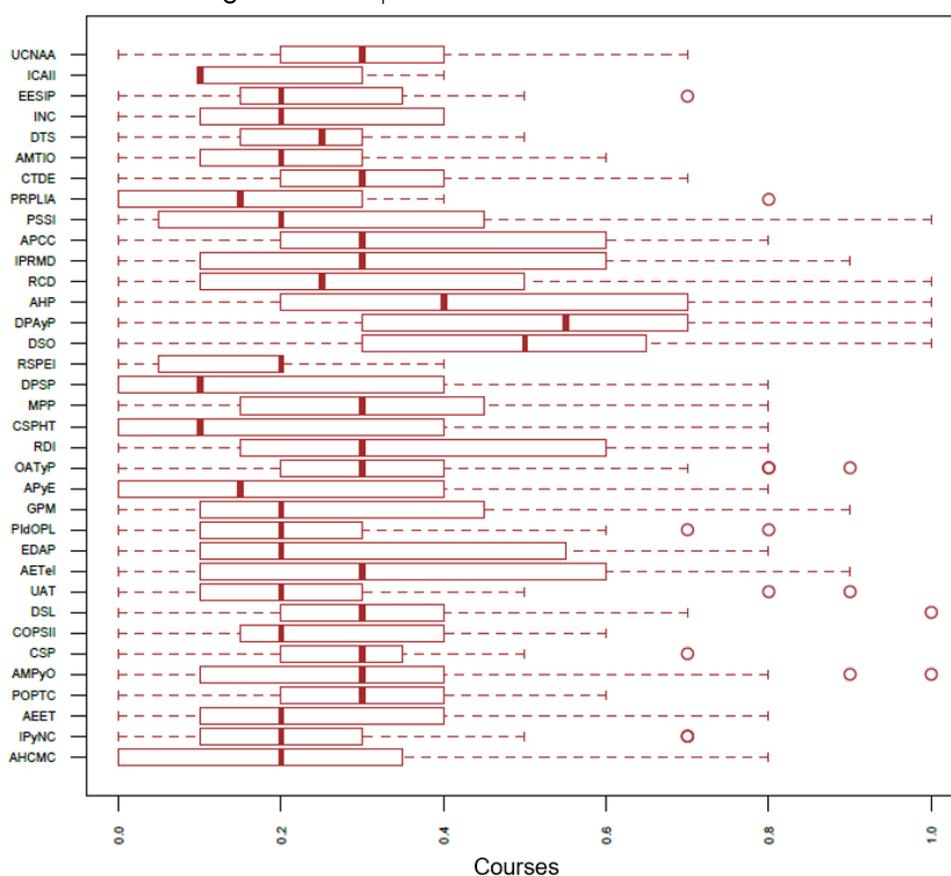
Source: Own work using RStudio[2].

Moreover, the results indicated a correlation of 60% between courses and job competencies. Notably, job competencies related to the control of standardized operational processes, the development of good work practices, and the traceability of operations were here identified as business requirements that still need closer integration with academic content (see Figure 3).

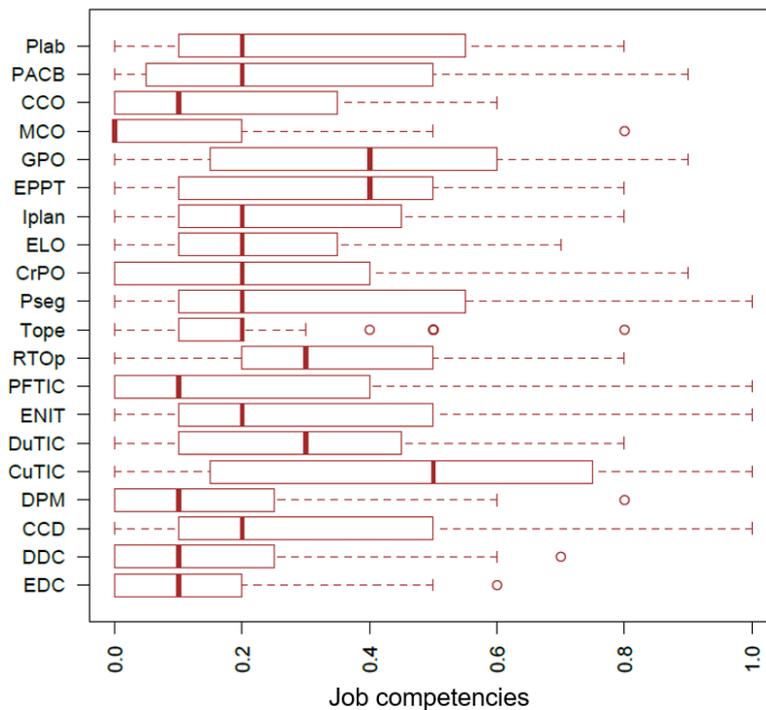[2] RStudio is a free, open-source integrated development environment.

Figure 3. Box plot - courses vs. job competencies
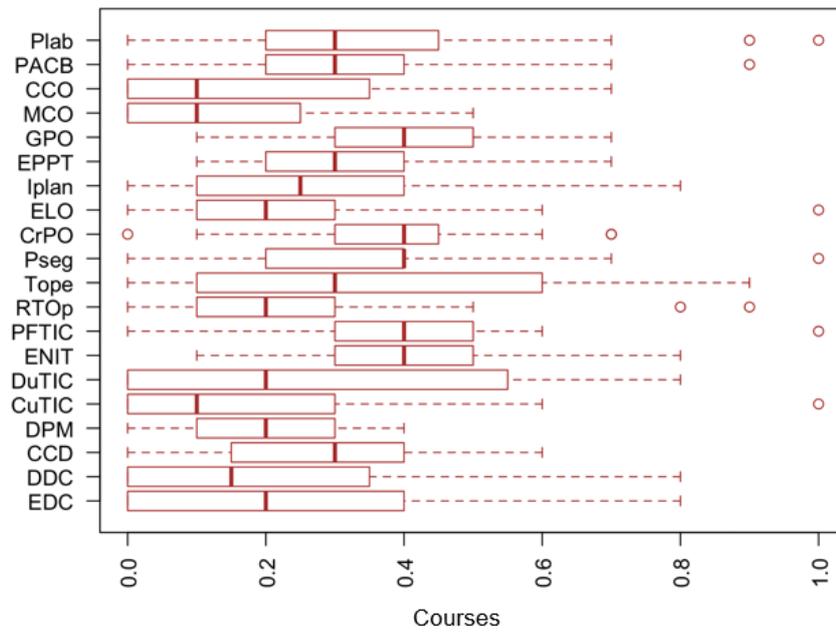
Source: Own work using RStudio.

Furthermore, a 85.71% correlation was observed between academic skills and job competencies. The findings demonstrate the importance placed by academia on the application of planning tools for optimizing and controlling production systems, as evidenced by its significant impact on three of the five study variables. To a great extent, this will help to create models that facilitate the management of quality defects, ICT usage, and operation traceability (see Figure 4).

Figure 4. Box plot - academic skills vs. job competencies

Source: Own work using RStudio.

Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín

13

trilogía
Ciencia Tecnología Sociedad

Concerning the data structure described by the quantitative variables, PCA was used to express the key drivers and their components through a set of uncorrelated linear combinations of factors. The findings revealed a high correlation between academic skills and courses (particularly courses that contribute to skill development), albeit in a less proportion with normative courses in the environmental and social areas. Therefore, it can be concluded that the courses are relevant for the development of the academic skills. According to the findings, the competences related to productive operations in integral logistic systems, productive systems – project management and the operation of technological and scientific processes, have a lot of similarity and subjects that strengthen the fulfilment of their objectives (see Figure 5).

Figure 5. Principal component analysis - courses vs. academic skills
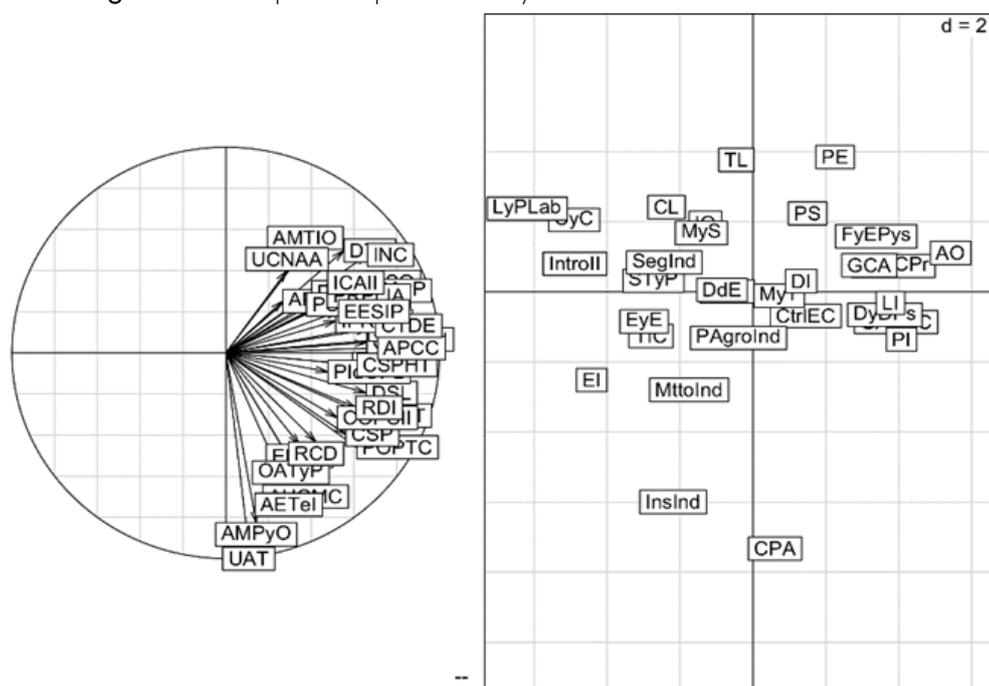
Source: Own work using RStudio.

Regarding the relationship between job competencies and courses, organizational process management and tactical planning and scheduling were found to include a wide range of topics for competency development. According to the findings, the necessary follow-up in the different representative areas of the logistics chain and training programs for ICT usage contribute a significant number of courses for competency development. Notably, the thematic content related to the necessary follow-up in the different areas of the logistic chain was found to have a great impact on job performance. Moreover, the findings showed that operation traceability and standardized operational processes encompass courses with very similar thematic intensity (see Figure 6).
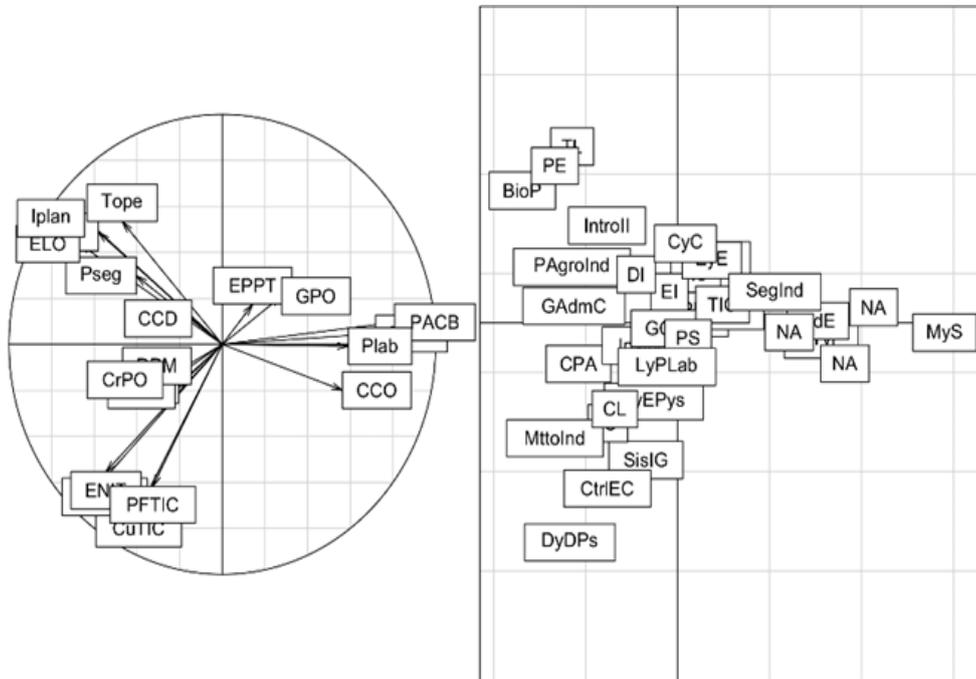
Figure 6. Principal component analysis - courses vs. job competencies
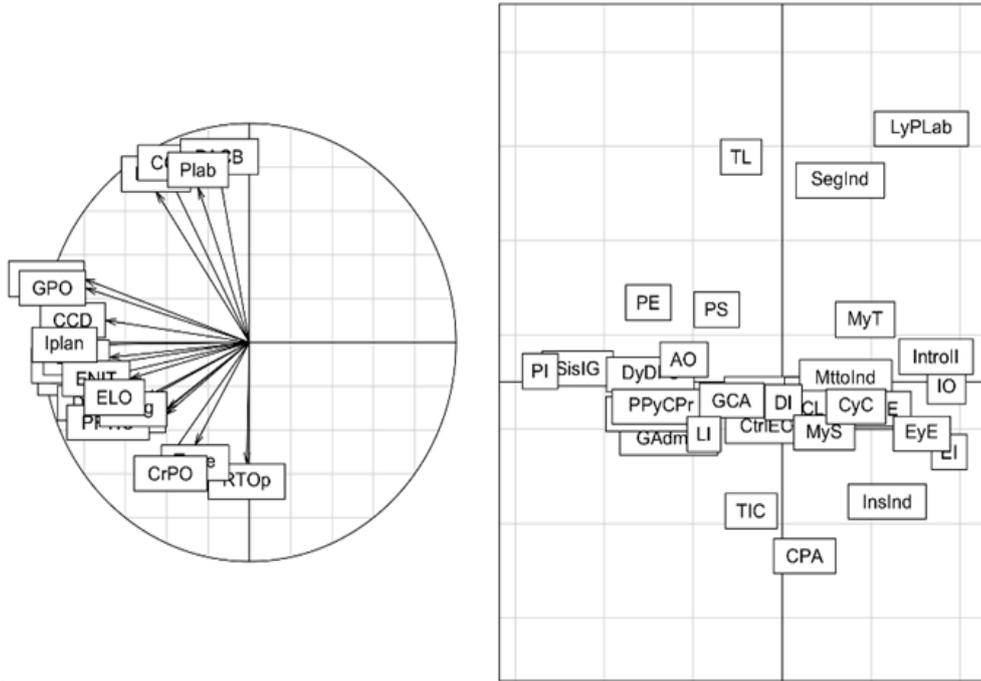
Source: Own work using RStudio.

Additionally, a high correlation between academic skills and job competencies was observed. Particularly, the competency related to good work practices was found to have a great impact on academic skills (see Figure 7).

**Figure 7.** Principal component analysis - academic skills vs. job competencies

Source: Own work using RStudio.

Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín

15

In this study, a clustering technique (dendrograms) was used to classify outcomes into clusters or groups that allowed the hierarchical identification of trends between the study variables and their components.

As for the clusters formed between courses and academic skills, five clusters were identified for the 32 courses under study. As observed in Figure 8, clusters 1 and 4 are very far from the academic skills, which means that the courses within these clusters do not contribute to the development of academic skills. Conversely, clusters 2 and 3 are the closest to meeting the requirements for academic skills.
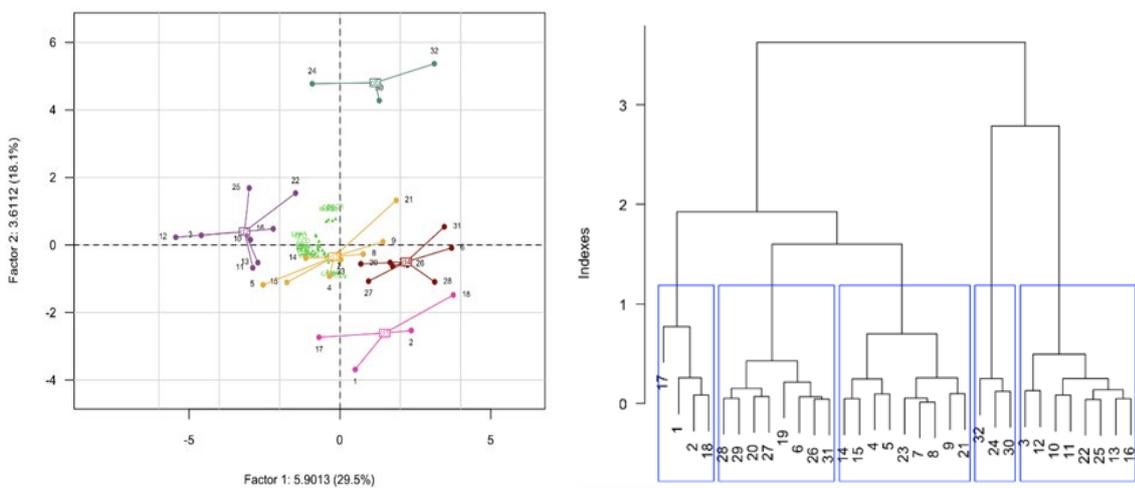
Figure 8. Clustering (dendrograms) - courses vs. academic skills
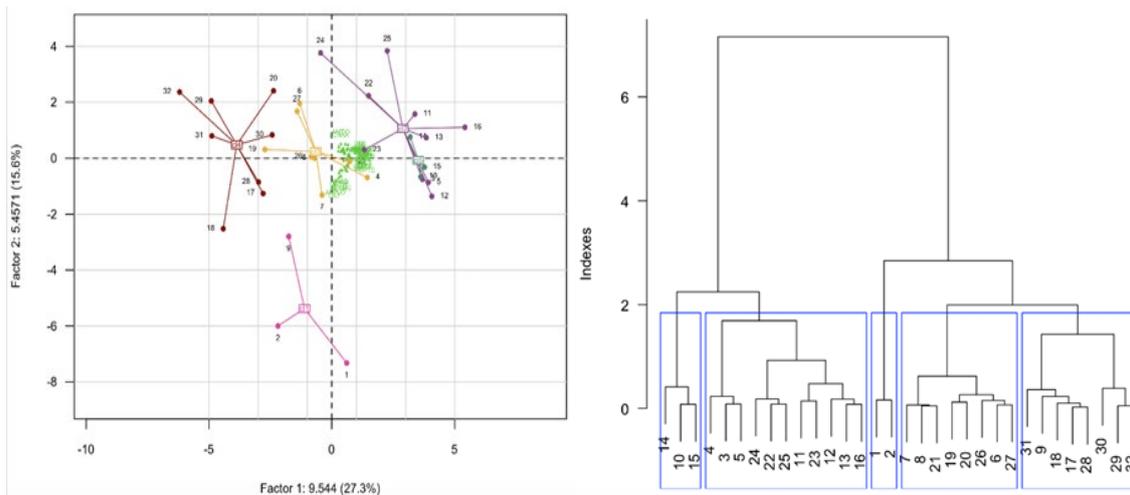
Source: Own work using RStudio.

Moving on to the clusters formed between courses and job competencies, five clusters were identified in grouping the 32 courses under analysis. As can be seen in Figure 9, clusters 3 and 2 are close to the job competencies, whereas clusters 4 and 5 are far apart from them. This suggests a mismatch between the courses that are taught and the real needs for job competencies.

Figure 9. Clustering (dendrograms) - courses vs. job competencies

Source: Own work using RStudio.

Regarding the clusters formed between academic skills and job competencies, five clusters were identified for the 35 academic skills under study. As shown in Figure 10, clusters 1, 2, and 3 are close to the job competencies, while clusters 4 and 5 are considerably far from them. This indicates potential issues in the alignment between the job competencies, academic skills, and courses considered in this study.

Figure 10. Clustering (dendrograms) - academic skills vs. job competencies
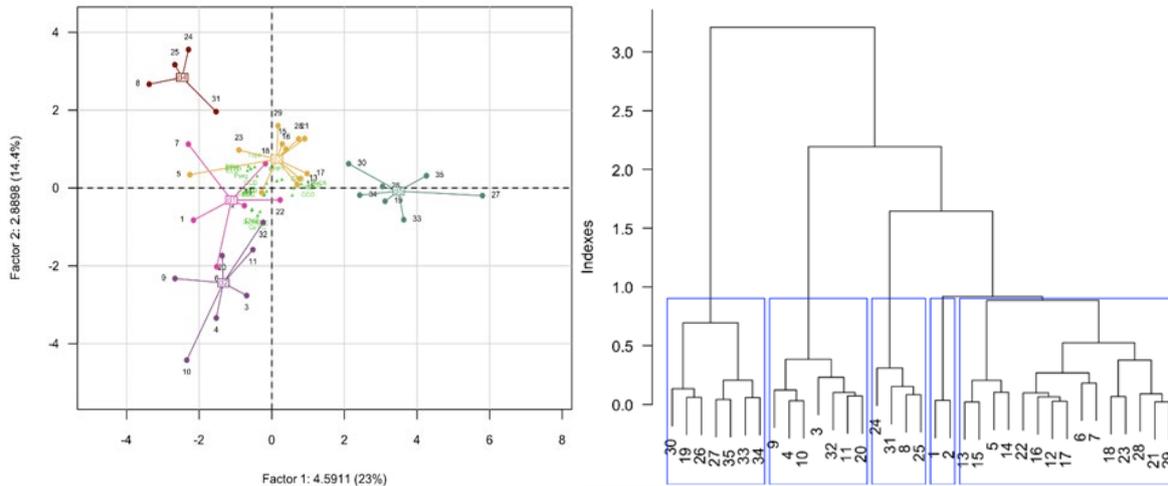
Source: Own work using RStudio software.

Finally, the methodological design employed in this study made it possible to construct a matrix describing the relationship between the 35 academic skills, the 20 job competencies required by the business sector, and the resulting five driving variables. By defining and grouping the driving variables, it was possible to propose two prospective drivers that, according to the findings, give insights into the current scenario and alternative scenarios regarding affinity between the topics under study. Table 4 shows how the five driving variables were grouped into the two proposed prospective drivers.

Table 4. Prospective drivers

Drivers	Name	Associated variables
1	Strategic operational and logistics model: It entails integrating soft skills and the ability to perform activities that are broadly applicable to the optimization process.	V 4 (quality defects)
		V 16 (work environment)
2	Traceability platform for quality assurance: It entails applying highly technical skills focused on the operation and implementation of new technologies to cultivate job competencies demanded by the productive sector.	V 5 (ICT usage)
		V 10 (operation traceability)
		V 8 (logistics and planning)

Source: Own work.

Connection to engineering education

Despite the changes in business environments and the rapidly advancing society, there is still a reciprocal relationship between soft and technical skills, both essential for future professionals. This study demonstrates how the identified drivers may improve the interaction between the academic and business sectors to support the development of new local competitive capabilities. Disciplines such as engineering, for example, significantly contribute to production dynamics and to the optimization of critical factors that influence an organization's competitiveness.

Gutiérrez Ossa (2015) highlights the importance of each stakeholder in the university–industry–government relationship, where each must define the necessary internal transformations to align with the needs of research processes as competence of graduates and professionals for companies and the government. In order to improve processes and close the gap between the university and the industry, HEIs play a crucial role in identifying variables that potentiate professional profiles, such as those in engineering, and strengthen the social fabric connecting science and technology. As mentioned by Cote (2018), one of the great paradigm shifts in education involves looking for ways to show skills and demonstrate how future professionals can develop them. According to the author, HEIs need to do more than just impart knowledge; they also need to culturally reframe education.

Study limitations

One limitation encountered in this study was the difficulty in establishing connections with companies in the productive sectors under analysis. Additionally, difficulties arose during the extraction of the academic skills from the programs that were examined. This introduced content ambiguities, as some HEIs did not record competencies, and others lacked the appropriate structure for their wording.

DISCUSSION

According to research by Stocklmayer et al. (2010), students in developing countries are more optimistic about the role of science in society and their aspirations for employment in this field. The results of this study, for instance, which used Colombia as a case study, confirm, through an academic and business analysis, a keen interest in potentializing the relationship between key variables that drive the optimization of production and logistic processes, ultimately contributing to science and technology.

Together with an understanding of students' potential abilities, academic skills should serve as a guide for structuring the micro-curriculum of courses in professional programs, thus leading the teaching process to the desired learning outcomes. Davis et al. (2016), however, state that there is limited interaction between teachers and course materials, which may be a contributing factor to the lack of a systemic relationship between academia and firms' requirements.

For their part, Millunchick et al. (2021) mention that there are five important types of student participation in curricular activities: design and competition teams, professional societies, identity-based engineering organizations, college-run engineering organizations, and research with a faculty member. By doing this, the authors explicitly demonstrate that cultivating competencies within the academic community can result in a greater value proposition by considering not only demographic factors but also university knowledge and proactive behavior at the curriculum level.

Educational proficiency, as described by Levander et al. (2020), encompasses the idea that teachers, as agents of the learning process, must have experience in both research and pragmatic areas. The aim is for them to contribute to the services provided by university programs in any area of knowledge and to instill in students the skills necessary to form knowledge for their academic and professional lives.

As mentioned by Adams and Felder (2008), given the rapid changes and expansive scope of the engineering profession, curricula should be modified to promote thinking skills and professional judgment. They must so adapt to different work environments and technological advancements. Learning, according to the authors, must be oriented towards understanding impact, working across different perspectives, and constantly evaluating the essence of being an engineer.

CONCLUSIONS AND FUTURE WORK

Concerning the question motivating this research—What is the systemic relationship between academia and businesses in Colombia regarding the development of skills and competencies related to the optimization of production and logistics processes?—it is concluded that the key drivers in terms of optimization of production and logistics processes are quality defects, work environment, ICT usage, operation traceability, and logistics and planning.

When grouped, these driving variables give rise to two prospective drivers (see Table 4) that allow for the creation of a baseline scenario. This scenario aims to describe the systemic relationship between courses, academic skills, and job competencies, as demonstrated by this study's findings.

Regarding the first driver—strategic operational and logistics model—the variables are centered on human relations and improvement plans within production processes. The courses that were found to greatly contribute to strengthening academic skills, primarily focused on improving production processes and planning tools, included project formulation, industrial design, bioprocesses, planning, programming and production control, and design of experiments.

Concerning the academic skills oriented toward industrial safety systems and employee skill development, the key courses included operations management and industrial safety, which greatly contribute to competitiveness. Other courses, although related, were found to have a very low impact compared to the previous ones; hence, it is recommended to strengthen or

redesign their contents. These courses included quality management and administration, operations research, supply chain management, industrial logistics, system thinking, industrial design, human talent, and strategic planning.

For their part, the academic skills that were found to substantially contribute to the development of the variables within this axis focused primarily on enhancing production processes, planning tools, industrial safety systems, and employee skill development. Their aim is to provide better customer service and strengthen the organization's promise of value.

Lastly, the job competencies that were found to contribute the most to the associated variables were those related to documenting quality defects, handling non-conformities, managing organizational processes, measuring the work environment, providing technical training for employees, and implementing good practices.

Based on the above, it is clear that job competencies motivate the development of an academic proposal, leading to the belief that there is a proper alignment with employers' demands. However, the evidence shows that many of these demands for job competencies are met without deepening much in the academic skills mentioned here. To put it in other words, "much is done with very little."

As for the second driver—traceability platform for quality assurance—the variables are centered on technical skills and technological components. The courses that were found to have a greater influence on the development of ICT-related skills included automated process control, industrial design, bioprocesses, project formulation and evaluation, planning, programming and production control, and design of experiments. Those that were found to have the greatest influence on the development of skills related to planning and logistics were statistical quality control, quality management and administration, supply chain management, plant design and distribution, project formulation and evaluation, simulation models, logistics costs, and packaging. Finally, those that were found to have a major influence on the development of skills related to operation traceability were plant design and distribution, production planning, programming and control, design of experiments, operations research, systems thinking, industrial design, strategic planning, and simulation models.

Furthermore, the academic skills that were found to contribute to the alignment between supply and demand were mainly focused on employability, including technology and production systems, integrated logistics systems and planning, as well as simulation and process optimization techniques. Currently, there is great awareness of the need to better align academic skills with the adoption of new technologies. Nonetheless, in most fields, this is done superficially, with the primary goal of covering a broad spectrum of training.

In terms of job competencies, these were found to be oriented toward understanding planning within the logistic chain—a key aspect of the planning and logistics variable. According to the results, there was an average alignment with the academic skills, being robust with those related to operations, inventories, and integral management systems and poor with those oriented towards the inclusion of technologies. The job competencies within this axis are clearly supported by ICTs in terms of operational logistics, management systems, operations,

and follow-up in the logistics chain. The operation traceability variable, for its part, was found to be the one requiring the greatest amount of effort when compared to the other variables on this axis. It primarily focuses on establishing the most important academic skills for the advancement of the profession. It is evident that these can be the areas with more emphasis on the development of improvement actions. Yet, it is important to assess whether the content used in the courses is actually the most updated, given the predominant and fundamental nature of this competency in academic programs. In this context, the motricity of the environment and the availability of partnerships with productive sectors are deemed vital.

In light of the above, and regarding the relationship between job competencies and the most relevant academic skills within the ICT usage variable, a low correlation was observed between firms' demands and their alignment with academia. This could be considered too optimistic when compared to the reality, as it could lead to the belief that these skills are significantly developed and deepened. However, this can be contested given the wide range of possibilities and tools available in the environment.

In conducting a prospective analysis, it becomes imperative to advance the construction of future scenarios regarding the optimization of production and logistics processes, starting from a base scenario and the system's driving variables. This could help propose strategies (from both academic and production perspectives) that contribute to the strengthening of the university–industry relationship and the development of educational models closely aligned with the business context.

This Colombian case study aims to assist in identifying the factors that can guide training programs in HEIs, specifically in the field of optimizing production and logistics processes in emerging countries. The responsibility of HEIs will be to develop curriculum proposals for Industrial Engineering and related programs that are in line with industry demands. To achieve this, they ought to promote strategies such as classroom projects, business challenges, targeted internships, and collaborative consultancies. These strategies, in addition to involving all stakeholders in the educational model, should create relevant roadmaps, from graduate profiles and academic skills to relevant job competencies.

ACKNOWLEDGMENTS

CONFLICTS OF INTEREST

The authors declare that they have no financial, professional, or personal conflicts of interest that could inappropriately influence the obtained results or the interpretations proposed in the manuscript.

AUTHORS' CONTRIBUTIONS

Yenny Alejandra Aguirre-Álvarez participated in the conceptualization, design, and development of the research (including baseline data collection, analysis, and interpretation), as well as in the drafting and final revision of the manuscript.

Mauricio Montoya-Peláez participated in the conceptualization, design, and development of the research (including baseline data collection, analysis, and interpretation), as well as in the drafting and final revision of the manuscript.

Raúl Trujillo-Cabezas participated in the development of the research (including prospective studies, principal component analysis, descriptive analysis, statistical analysis, and interpretation), as well as in the drafting and final revision of the manuscript.

Camilo Esteban Solano Hurtado participated in the development of the research (including prospective studies, principal component analysis, descriptive analysis, statistical analysis, and interpretation), as well as in the drafting and final revision of the manuscript.

REFERENCES

Abarca Rodríguez, A., Alpízar Rodríguez, F., Sibaja Quesada, G., & Rojas Benavides, C. (2013). *Técnicas cualitativas de investigación.* Editorial UCR.

Adams, R. S., & Felder, R. M. (2008). Reframing Professional Development: A Systems Approach to Preparing Engineering Educators to Educate Tomorrow's Engineers. *Journal of Engineering Education, 97*(3), 239–240. https://doi.org/10.1002/j.2168-9830.2008.tb00975.x

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* Longman.

Betancour, O. A. (2012). *Logística. Conceptualización y tendencias actuales.* https://www.eumed.net/cursecon/ecolat/cu/2012/oab.html

22

trilogía
Ciencia Tecnología Sociedad

Cárdenas, A., & Navas, A. (2012). Normalización de competencias laborales en Colombia. *Revista Vanguardia Psicológica*, *3*(1), 103–121. https://dialnet.unirioja.es/servlet/articulo?codigo=4815144

Castrillón, J., Cabeza, L., & Lombana, J. (2015). Competencias más importantes para la disciplina administrativa en Colombia. *Contaduría y Administración, 60*(4), 776–795. https://doi.org/10.1016/j.cya.2015.07.009

Contreras-Germán, J., Piedrahita-Ospina, A., & Ramírez-Velásquez, I. (2019). Competencias digitales, desarrollo y validación de un instrumento para su valoración en el contexto colombiano. *Trilogía Ciencia Tecnología Sociedad, 11*(20), 205–232. https://doi.org/10.22430/21457778.1083

Cote, D. A. (2018). Ciudad y educación: persistencias, transformaciones y correspondencias de un vínculo inmanente. *Praxis & Saber*, *9*(20), 119–141. https://doi.org/10.19053/22160159.v9.n20.2018.8300

Dantzing, G. (1963). *Linear Programming and Extensions.* Princeton University Press.

Davis, E. A., Jannsen, F. J. J. M., & Van Driel, J. H. (2016). Teachers and science curriculum materials: where we are and where we need to go. *Studies in Science Education, 52*(2), 127–160. https://doi.org/10.1080/03057267.2016.1161701

Ferrer, M., Ariza, Y., Martínez, J., Garizao, J., & Pulido-Rojano, A. (2019). Modelo de optimización colaborativo para la minimización de los costos variables de transporte de carga por carretera en Colombia. *Investigación y Desarrollo en TIC, 10*(1), 26–36. http://revistas.unisimon.edu.co/index.php/identic/article/view/3487

Godet, M. (1993). *De la anticipación a la acción. Manual de prospectiva estratégica.* Marcombo.

Godet, M., Monti, R., Meunier, F., & Roubelat, F. (2000). *La caja de herramientas de la prospectiva estratégica* (4th Ed.). Cuadernos de LIPS.

Gutiérrez Ossa, J. A. (2015). Modelo de competencias investigativas empresariales desde la universidad, empresa y estado en Colombia. *Praxis & Saber*, *6*(12), 241–267. https://revistas.uptc.edu.co/index.php/praxis_saber/article/view/3771

Jomini, A. H. (1840). *Compendio del arte de la guerra ó Nuevo cuadro analítico de las principales combinaciones de la estrategia, de la táctica sublime, y de la política militar.* Imp. de D. M. de Burgos, y Librería de D. A. Perez.

Levander, S., Forsberg, E., & Elmgren, M. (2020). The meaning-making of educational proficiency in academic hiring: a blind spot in the black box. *Teaching in Higher Education, 25*(5), 541–559. https://doi.org/10.1080/13562517.2019.1576605

López Gallego, F. (2001). El surgimiento de EAFIT en el contexto del desarrollo de la Educación en administración y la práctica administrativa en Colombia. A propósito de la celebración de los 40 años. *Revista Universidad EAFIT*, 37(121), 9–18. https://publicaciones.eafit.edu.co/index.php/revista-universidad-eafit/article/view/1013

Martínez Fajardo, C. E. (1999). *Administración de organizaciones. Productividad y eficacia* (2nd Ed.). Universidad Nacional de Colombia.

Mayor Mora, A. (1988). Alejandro López, padre de la Administración. *Revista Escuela de Administración de Negocios*, (4), 64-65. https://journal.universidadean.edu.co/index.php/Revista/article/view/958

McNeil, I. (2002). *An Encyclopedia of the History of Technology.* Routledge.

Millunchick, J. M., Brennan-Wydra, E., Henderson, T., Johnson, A., & Finelli, C. J. (2021). The role of college knowledge and proactive behavior on participation in cocurricular activities. *Journal of Engineering Education, 110*(1), 114–142. https://doi.org/10.1002/jee.20380

Ochoa-Duarte, A., & Reina-Rozo, J. D. (2022). Engaged Engineering: A Preliminary Review of University Practices on Engineering and Society in Colombia. *Trilogía Ciencia Tecnología Sociedad, 14*(27), e2247. https://doi.org/10.22430/21457778.2247

Olano García, H. A. (2011). Breve revisión de la logística militar en Colombia: el caso del General Santander. *Revista Prolegómenos, 14*(28), 203–215. https://doi.org/10.18359/prole.2387

Rodríguez Zambrano, H. (2007). El paradigma de las competencias hacia la educación superior. *Revista Facultad de Ciencias Económicas, 15*(1), 145–165. https://revistas.unimilitar.edu.co/index.php/rfce/article/view/4554

Rozwell, C., & Olding, E. (2009). Social BPM: Techniques to Uncover Process Patterns. *Gartner.*

Ruiz de Vargas, M., Jaraba Barrios, B., & Romero Santiago, L. (2005). Competencias laborales y la formación universitaria. *Psicología desde el Caribe*, (16), 64–91. https://rcientificas.uninorte.edu.co/index.php/psicologia/article/view/1996

Sautu, R., Boniolo, P., Dalle, P., & Elbert, R. (2005). *Manual de metodología: construcción del marco teórico, formulación de los objetivos y elección de la metodología.* Consejo Latinoamericano de Ciencias Sociales.

Sistema Nacional de Información de Educación Superior. (2020). *Consulta de Programas.* https://hecaa.mineducacion.gov.co/consultaspublicas/programas

Stocklmayer, S. M., Rennie, L. J., & Gilbert, J. K. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education, 46*(1), 1–44. https://doi.org/10.1080/03057260903562284

Tobón Tobón, S., Pimienta Prieto, J. H., & García Fraile, J. A. (2010). *Secuencias didácticas: Aprendizaje y evaluación de competencias.* Pearson Educación.

Toyota Industries Corporation. (2024). *History.* https://www.toyota-industries.com/company/history/

Zairi, M., & Sinclair, D. (1995). Business process re-engineering and process management: a survey of current practice and future trends in integrated management. *Management Decision, 33*(3), 3–16. https://doi.org/10.1108/00251749510085021

trilogía
Ciencia Tecnología Sociedad