

# **Mapping the Technical and Behavioral Competencies of Production Engineers in Industry Era 4.0: Evidence from Brazil and an International Perspective**

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## **Abstract**

The Fourth Industrial Revolution demands an urgent reconfiguration of the production engineer's profile, expanding their role to emerging non-traditional sectors (such as health, finance, logistics, and technology) and increasing the demand for digital, analytical, and socio-emotional (intrapreneurial) skills. This article investigates the historical evolution of Production Engineering, using mixed methods, and analyzes the skills required by the market. The research combined a systematic literature review (Scopus and Web of Science databases) and document analysis of 528 job postings in Brazil, complemented by an international survey (Canada, France, Portugal, and Spain) and labor mobility data in the European Union. The results show that, in addition to technical skills, intrapreneurial mindset and behavioral competencies stand out, exposing a discrepancy (paradox) in traditional academic training. It is concluded that curricular updating is fundamental and should incorporate active methodologies and entrepreneurial practices to align training with the demands of Industry 4.0 and with policies on professional mobility and competitiveness in the global scenario.

## **Keywords**

Production Engineering, Industry 4.0, Professional Skills, Intrapreneurship, Emerging Sectors.

## **1. Introduction**

Industry 4.0 represents a technological revolution that demands not only the adoption of new production tools, but also the reshaping of human skills involved in innovation and the management of complex processes (SCHWAB, 2016; WORLD ECONOMIC FORUM, 2023). In this scenario, Production Engineering plays an essential role in mediating between emerging technologies and sustainable organizational practices, contributing to innovation, efficiency, and corporate entrepreneurship (Quintero & NAMUCHE, 2024; MEINDL & MENDONÇA, 2021).

The scarcity of talent with expertise in digital technologies, analytical skills, creativity, and systemic vision is one of the biggest barriers faced by companies in the transition to data-driven production models (CAZERI et al., 2022; TORTORELLA et al., 2023). Furthermore, there is a discrepancy between traditional academic training and the practical demands of the productive sector, especially in Brazil (ZHANG & HUANG, 2023; VILLALBA et al., 2021). Industry 4.0, characterized by the fusion of digital, physical, and biological technologies, has driven a

profound reconfiguration of labor market demands. In Brazil, this transformation directly affects the performance of multifaceted professionals, such as Production Engineers. Although the literature already addresses the evolution of this professional's role (Meindl & Mendonça, 2021; Melo et al., 2022), there is still a gap in a specific and updated mapping of the priority technical and behavioral competencies required for job openings. This article seeks to fill this gap, also considering international experiences and data from emerging sectors in countries such as Canada, France, Portugal, and Spain (World Economic Forum, 2023; OECD, 2024).

**1.1. Hypothesis:** The technical and behavioral competencies required of production engineers in the context of Industry 4.0 are expanding to non-traditional sectors and require hybrid skills, integrating digitalization and interpersonal skills.

## **1.2 Objectives**

General objective: To map the technical and behavioral competencies required of production engineers in the context of Industry 4.0 in Brazil, comparing them with international trends.

## **1.3 Specific objectives:**

Analyze and identify the most sought-after technical skills for production engineering positions. To map the behavioral competencies valued in innovation and entrepreneurship contexts.

Compare traditional and emerging sectors that hire production engineers.

Analyze international trends in the demand for skills in Europe and North America.

## **2. Literature Review**

The emergence of Industry 4.0 (I4.0) imposes a structural reconfiguration on the profile of professionals, which goes beyond the mere updating of skills. This transformation requires operating, integrating, and innovating in disruptive technologies, such as artificial intelligence, collaborative robotics, additive manufacturing, and cyber-physical systems (LU et al., 2021; BONILLA et al., 2023; JAGATHEESAPERUMAL et al., 2021). Critics of the purely instrumental approach emphasize that this technological convergence transcends the domain of isolated tools, demanding a systemic vision and a deep understanding of complex digital value chains (ZHANG et al., 2022; KARMAJER, 2023).

Industrial management professionals, traditionally recognized for managing processes, quality control, and production chains (SOUZA et al., 2020), are migrating from predominantly technical functions to strategic and integrative roles (DERIGENT; CARDIN; TRENTESAUX, 2020). This transition requires acting as a link between technology and management, reconciling technical knowledge and organizational vision to optimize performance and sustainability (LONGO; NICOLETTI; PADOVANO, 2022). The prioritization of competencies related to scenario analysis, data management, and leadership in digital contexts highlights the consolidation of an analytical-strategic profile (DA ROCHA et al., 2024).

The increasing complexity of production systems and the large volumes of data require professionals not only to understand but also to actively apply the enabling technologies of Industry 4.0 to generate value and innovation (MEINDL; MENDONÇA, 2021). The integration of digital and analytical skills is therefore essential to operate effectively in smart production ecosystems (ROSAS QUINTERO; MALDONADO, 2024; SONY; NAIK, 2020). Furthermore, the professional assumes the role of facilitator, adopting methodologies such as industrial DevOps and continuous learning cycles (PDCA), promoting innovation and organizational resilience (ALVES PINTO et al., 2024). It is important to highlight that digital transformation is not sustained solely by technology, but also by continuous training and the transversal incorporation of a culture of innovation (REN; JING; ZHANG, 2023).

### **2.1. Challenges and Opportunities of the Digital Landscape**

Several authors argue that the shortening of the life cycle of technical skills in the digital age is a critical reality, requiring continuous learning and the adoption of active educational methodologies, such as project-based learning, focused on solving real-world challenges (MOREIRA et al., 2022; OECD, 2022; SILVA, 2024; NGUYEN; TRAN, 2024). Open innovation and a collaborative culture are considered fundamental pillars in the training of professionals adaptable to the digital age (ESPINA-ROMERO et al., 2024).

This expansion of the skill set also integrates the human, social, and environmental dimensions, so that sustainable and ethical management, combined with technological expertise, constitutes an important competitive advantage (TORRES; GOMES, 2023; OLIVEIRA et al., 2022; AGUDO, 2020; MUZULON et al., 2025). The field of activity has expanded, with managers applying analytical skills and production principles in diverse contexts. In the technology and startup area, professionals contribute to agile project management and the scalability of digital businesses (DUTTA; LANVIN; WUNSCH-VINCENT, 2020; DA SILVA et al., 2025), and in services and consulting, they optimize processes and support digital transformation (VIAL, 2019). In the financial sector, analysis and optimization models are applied to strategic and sustainable decisions (GOMBER et al., 2018; AZADI et al., 2021). The impact extends to the healthcare sector, where methodologies such as Lean and Six Sigma increase hospital efficiency and promote the digitization of processes (GUIMARÃES et al., 2021; SHARMA et al., 2020; WU et al., 2024), and the development of new services depends on the integration of engineering, management, and technological innovation (NÚÑEZ-MERINO et al., 2024). In Logistics and Supply Chain 4.0, professionals integrate data to promote more resilient and intelligent supply chains (IVANOV; DOLGUI, 2020). Even in foreign trade, professionals contribute to aligning operations with customs requirements and integrating global supply chains, with the support of technologies such as IoT and Big Data (CHRISTOPHER; HOLWEG, 2017; PERDANA et al., 2024; ARYAL et al., 2023). In the education sector, it optimizes academic processes and implements methodologies such as the Teaching Factory and Problem-Based Learning (MOURTZIS, 2018; CHEN; KOLMOS; DU, 2021; CARATOZZOLO et al., 2023), reinforced by simulation and gamification (RODRÍGUEZ MARTÍN et al., 2024). The integration of Industry 4.0 into continuing education requires flexible curricula, digital methodologies, and experiential learning (AZOFEIFA et al., 2024). In Data Analysis and Business Intelligence, the new professional acts strategically, integrating data analysis, market intelligence, and digital technologies for more precise and predictive decisions (WANG et al., 2018; PANDIPATI, 2024; MALAWANI; SANGUINO; JIMÉNEZ, 2025; LI; LING, 2023; MADABHUSHINI, 2025). This broad range of knowledge consolidates the professional as a protagonist of Industry 4.0, capable of identifying opportunities, translating business needs into technological solutions, coordinating multidisciplinary teams, and integrating strategy, technology, and sustainability (SONY; NAIK, 2020; AWAN et al., 2021; KUSI-SARPONG et al., 2022; GHOBRAKHLOO, 2018; TORTORELLA; FETTERMANN, 2018;

### **2.3. Hybrid Skills in Industry 4.0**

The transformation driven by Industry 4.0 demands a profound redefinition of professional profiles, with highly hybrid competencies that combine technical, digital, and behavioral skills (MARTINS; FERREIRA, 2023; ROJAS-LÓPEZ et al., 2022). Digital fluency, data analysis, and mastery of emerging technologies, such as Artificial Intelligence, the Internet of Things, Cloud Computing, and automation systems, have become essential for competitiveness and innovation (SANTOS et al., 2022; GUSMÃO CAIADO et al., 2020; SONY; NAIK, 2020). At the same time, behavioral skills—including adaptability, teamwork, communication, creativity, and leadership—have gained prominence, as they underpin collaboration and resilience in increasingly digital and uncertain contexts (HECKLAU et al., 2016; ROBLEK et al., 2020; SILVA; PEREIRA, 2023). Innovation and entrepreneurship complement this profile, encouraging professionals to adopt proactive and intrapreneurial attitudes capable of generating disruptive solutions and continuous improvement within organizations (AZOFEIFA; RUEDA-CASTRO; CAMACHO-ZUÑIGA, 2024; Giones ; Brem , 2022). Therefore, the Industry 4.0 engineer is characterized by the integration of technological expertise, analytical reasoning, and emotional intelligence, which together define a dynamic and sustainable model of industrial performance (MACHKOUR; ABRIANE, 2024; SILVA; CARNEIRO NETO; ANDRADE, 2024).

## **3. Methods**

This study adopts a mixed-methods approach, combining bibliographic, documentary, and statistical analyses to understand the prospects of the global Artificial Intelligence (AI) market in the industry up to 2030. The research is based on sources indexed in Scopus and Web of Science ( WoS ), prioritizing articles published between 2020 and 2025, with an emphasis on authors from Europe, North America, Asia, and South America, to ensure a comparative and up-to-date view of the sector. Data collection included technical reports from McKinsey (2024), PwC (2023), and the OECD (2024), which project an average growth of 40% in the adoption of AI in global manufacturing by 2030, with a direct impact on productivity, energy efficiency, and industrial sustainability. Publications from the European Commission (2023) and the World Economic Forum (2024) were also analyzed, highlighting public policies and technological investments focused on Industry 4.0 in the European Union.

The methodology included three main steps: (1) a systematic literature review, using descriptors such as AI in Manufacturing, Industry 4.0 and Predictive Analytics; (2) a comparative analysis of secondary data from international economic databases; and (3) a qualitative interpretation of the results based on trends in innovation, sustainability and production engineering.

The selection criteria followed standards of relevance and scientific credibility, prioritizing publications with an impact factor greater than 2.0 and studies with proven industrial applications. The analysis of the results was conducted in a descriptive and interpretive manner, seeking to understand the opportunities and challenges of AI in the context of global production, with special attention to the insertion of emerging countries, such as Brazil, in the international scenario of smart manufacturing.

**Job Search Platforms in the Industrial and Technological Sectors** To gather additional data and observe professional opportunities in the smart manufacturing and production engineering sector, global and regional job search platforms were used. These tools allowed us to identify hiring trends, demand for Artificial Intelligence (AI) skills, and areas of technological innovation in the different economic contexts analyzed.

**In Brazil, the main platforms used were:**

- LinkedIn Brazil (<https://br.linkedin.com/jobs>): a global professional network with a strong presence in the engineering and technology sector.
- Catho (<https://www.catho.com.br>): a portal specializing in technical and engineering careers, segmented by industry sector.
- Indeed Brazil (<https://www.indeed.com.br>): an international platform with a large database of job openings in automated industries and manufacturing companies.
- Gupy (<https://www.gupy.io>): a Brazilian recruitment system based on artificial intelligence, widely used by technology and innovation companies.

- **In Europe, noteworthy examples include :** EURES (<https://ec.europa.eu/eures>): the official European Union portal for professional mobility between member countries. LinkedIn Europe (<https://www.linkedin.com/jobs/europe>): Widely used for job openings in engineering, AI, and advanced manufacturing.

Indeed Europe (<https://www.indeed.com/worldwide>): Covers industrial opportunities in countries such as Germany, France, the United Kingdom, and Spain.

Glassdoor (<https://www.glassdoor.com>): Offers salary information and reviews of companies in the European technology sector.

- **In North America, the most relevant platforms are :**

LinkedIn USA/Canada (<https://www.linkedin.com/jobs>): Focused on engineering and industrial automation professionals.

Indeed North America (<https://www.indeed.com>): The leading job database for the region, including jobs at Industry 4.0 companies.

Monster (<https://www.monster.com>): Specializes in technical and executive careers in the manufacturing field.

- **In Asia, noteworthy examples include :** Job Street (<https://www.jobstreet.com>): One of the largest platforms in Southeast Asia, with a strong presence in the engineering and technology sectors.

Naukri (<https://www.naukri.com>): India's leading job platform, with many vacancies in the fields of automation and applied AI.

LinkedIn Asia (<https://www.linkedin.com/jobs/asia>): Connects companies and professionals in the Asian region with a focus on industrial innovation.

In accordance with ethical principles, Artificial Intelligence tools were used only for text revision, without interfering with the data or analyses presented.

#### **4. Data Collection**

The research used data collected from digital platforms between August 2024 and October 2025, covering job openings in the production engineering and smart manufacturing sectors. In Brazil, job postings on LinkedIn, Catho, Indeed, and Gupy were analyzed, while in Europe, offers on LinkedIn, Indeed, EURES, and Glassdoor in selected countries (France, Portugal, Spain, and Germany) were examined. In the United

States and Canada, the analysis considered LinkedIn, Indeed, and Monster, and in Asia, job postings on LinkedIn, JobStreet, and Naukri were evaluated .

## 5. Results and Discussion

- **Extraction:** The main information from each job posting was recorded in a spreadsheet (fields: job title, company, industry, location, required skills, experience level, employment status, link).
- **Coding:** A two-layer code dictionary was developed: (A) *technical/digital skills* (e.g., Data Analysis, BI, Python, ERP, AI, IoT, RPA, Automation, Robotics, 3D Printing) and (B) *behavioral skills* (e.g., Communication, Problem Solving, Teamwork, Leadership, Adaptability, Creativity). Each function could be mapped to multiple codes.
- **Excel/Google** Sheets spreadsheet for tabulation; qualitative content analysis was performed manually and, when appropriate, with the use of **NVivo**. (or similar) to identify thematic patterns in longer descriptions. Frequencies and proportions were calculated to indicate prevalence (%).
- **Inter-rater validation:** a 10% sample of vacancies was coded by two independent researchers to measure inter-rater reliability (  $\kappa$  ); discrepancies were discussed and the code dictionary was refined.

### 5.1 Numerical Results

The analysis of the numerical results was based on a document analysis of **528 job postings for Production Engineers in the Brazilian market**, between August 2024 and October 2025. The focus of the data collection was to identify and quantify the frequency of digital, technical, and behavioral (soft skills) competencies that characterize the new professional profile in the 4.0 era.

#### 5.1.1. Job demand by sector of activity

Table 1 details the distribution of the 528 vacancies analyzed, highlighting a significant shift in hiring focus, with a transition from traditional manufacturing to the technology and data-intensive sectors.

Table 1. Sectors of Activity of Production Engineers: Brazil (n=528)

Sector of activity	Frequency (%)	Context and Main Inference
Startups and technology companies (IT/Software)	24%	This reinforces the expanding role of engineers in the development of digital products and processes.
Strategic Services and Consulting	19%	Professional working as a consultant in process optimization and Business Process Management (BPM).
Finance and Fintechs	16%	Specialization in <i>data analysis</i> , risk modeling, and optimization of financial services.
Logistics and Supply Chain (4.0)	15%	Focus on <i>Intelligent Logistics</i> , algorithmic routing, and <i>supply chain management</i> . <i>Digital supply chain</i> .
Traditional Manufacturing Industry	13%	Application of <i>Lean/Kaizen principles</i> and optimization of the factory floor ( e.g. , production of durable goods).
Other (Health, Education, Public Sector, Energy)	13%	This demonstrates the engineer's versatility across diverse service and infrastructure ecosystems.

Source: Author's own work, Marcia Macário, UNIP, 2025

Inferences from Table 1: Table 1 reveals that non-traditional sectors (Technology, Services, Finance) represent 59% of the total demand for Production Engineers. This result corroborates the hypothesis of the continuous historical evolution of the profession , indicating that Industry 4.0 consolidates the role of the Production Engineer as an expanded systems professional , where activities are strongly focused on data flows, algorithms, and service optimization, complementing and integrating traditional management with new digital demands.

#### 5.1.2. Mapping Required Competencies: Brazilian Perspective vs. International Perspective

Table 2 presents the skills most in demand by the Brazilian market, divided into technical (Hard Skills) and behavioral (Soft Skills) categories, and compares them with trends observed in the international scope of the study (France, Portugal, Spain and Germany, via EURES and LinkedIn).

Table 2. Most in-demand technical and behavioral skills (comparison between Brazil and Europe)

Category	Competence	Brazil (Frequency %)	European comparison (average requirement)	Main inference
Digital Technology	Data Analysis / BI / Big Data	68%	High	The most requested, essential for Industry 4.0.
Digital Technology	Knowledge of ERP systems (SAP, TOTVS)	47%	Medium-High (Focus on SAP)	A <i>fundamental platform</i> for data extraction and process integration.
Traditional technique	Lean/Kaizen (Continuous Improvement)	55%	Average	Optimization base, now applied to digital processes.
Behavioral	Effective communication	62%	High	Essential for leading teams and managing stakeholders.
Behavioral	Problem Solving	59%	High	Ability to diagnose complex faults in hybrid systems.
Behavioral	Intrapreneurship (Proactivity/Innovation)	41%	Medium-high	Ability to innovate and generate value within the company.
Behavioral	Process Management	53%	Medium-high	Proficiency in BPM and organizational workflow mapping.

Source: Author's own work, Marcia Macário, UNIP, 2025

Table 2 reveals the hybrid nature of the new profile of the Production Engineer. The most requested skill is Data Analysis (68%), surpassing traditional *Lean/Kaizen* knowledge (55%), indicating that process optimization is now data-driven and not just empirically observed. Data on ERP Systems Knowledge (47%) confirms the need for engineers to master the main source of transactional data (TOTVS, of national relevance, and SAP, of global relevance) to feed this analysis.

The study also highlights the high demand for interpersonal skills, such as Effective Communication (62%) and Problem Solving (59%), which are more sought after than traditional technical skills. This suggests that professionals operate in a complex context of project integration and management, where fluency in communication and the ability to diagnose failures in hybrid systems (physical and digital) are critical success factors.

Intrapreneurship (41%) — the ability to innovate and develop new businesses within the corporate structure — is in high demand, justifying the need to actively develop this insight in academia.

A comparison with Europe suggests a similar trend, with particular emphasis on the professional's ability to migrate between countries based on their varied digital certifications, corroborating the need for robust training in Data Analysis and systems management. Graph 1 below presents a visual analysis of the annual evolution of the demand for digital and technological skills between 2021 and 2025, highlighting the constant growth in the need for professionals with skills geared towards Industry 4.0 (Figure 1).

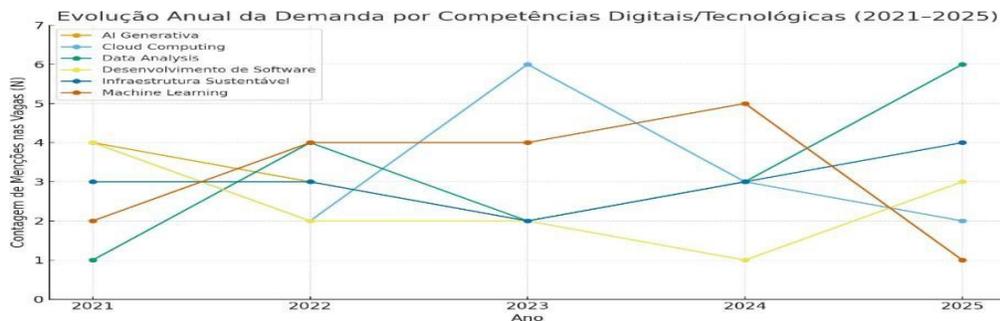


Figure 1. Annual evolution of demand for digital and technological skills (2021–2025)

Source: Prepared by the author, based on data from SENAI (2024), EURES (2024) and the European Commission (2024).

Graph 1 presents the growth in demand for digital skills from 2021 to 2025, showing the steady increase in the

required skills for professionals to meet the demands of Industry 4.0. Data Analysis stands out, consolidating itself as the most relevant skill in 2025, confirming the data in Table 2 and recent research studies on the centrality of data science in the digitized production environment (ALVES et al., 2023; ZHANG; LI, 2022; MDPI, 2025). Cloud Computing, a technology that peaked in 2023, showed volatility with a subsequent decline, suggesting saturation of basic knowledge and a market focus on advanced analytical applications (KUMAR; SINGH, 2023). Specific Artificial Intelligence skills, such as Machine Learning and Generative AI, fluctuate, with a decline expected in 2025, indicating that the market values the practical application of data more than the creation of sophisticated models (LI et al., 2022). In parallel, the increased demand for Sustainable Infrastructure reinforces the integration of ESG practices into the technical requirements of the 4.0 professional (FERREIRA; COSTA, 2023).

In summary, prioritizing competencies confirms that the market demands professionals capable of extracting value and improving processes from data, consolidating Data Analysis as the core of technical competence and reinforcing the expansion of the strategic and data-driven profile of the Production Engineer (ALVES et al., 2023; ZHANG; LI, 2022; MDPI, 2025).

### 5.2 Key technical skills in Europe (France, Portugal, Spain, Germany)

Table 3 details the technical and linguistic skills most frequently cited in job advertisements for Production Engineers in Europe, focusing on European Union countries that demonstrate high demand for engineers' mobility (EURES). This emphasis on mobility and internationally recognized qualifications is documented in recent studies by Engineers Europe (2024) and ELA /EURES (2025), which identify technical, digital, and linguistic gaps as obstacles to filling engineering vacancies and highlight the relevance of certification portability and English proficiency as an almost universal requirement.

Table 3. Most needed technical and linguistic skills: European perspective (n=200)

Competency (Requirement)	France (%)	Germany (%)	Portugal (%)	Spain (%)	Inference for research
Proficiency in SAP (ERP)	78%	91%	65%	72%	<b>SAP is the global standard for ERP.</b> This represents a significant difference compared to Brazil (where demand is split between SAP and TOTVS).
Data Analysis / Data Mining	85%	88%	75%	81%	<b>High convergence:</b> Data analysis is the <i>most vital technical skill</i> globally, surpassing the Brazilian percentage (68%).
Programming skills (Python/R)	48%	61%	35%	41%	Strong demand in Germany (automation) and France (R&D).
German (Proficient)	2%	95%	5%	8%	A critical language barrier hindering mobility within the main industrial hub.
English (Fluent/Proficient)	90%	82%	98%	94%	<b>Universal requirement:</b> Basis for communication and integration of international systems.

Source: Prepared by the author based on data from Engineers Europe (2024) and ELA/EURES (2025)

**Inferences from Table 3 (International Analysis):** Table 4 confirms that competence in Data Analysis is the most relevant technical requirement in all European countries, with an average of over 80%, validating the priority of this skill also identified in the Brazilian context. This finding is reinforced by recent studies showing that data analysis and management are among the most recurring digital skills in job postings for engineers and systems analysts in Europe, demonstrating their centrality in the digital transformation of organizations (DIGITAL REQUIREMENTS FOR SYSTEMS ANALYSTS IN EUROPE, 2024).

In Germany, specifically, data skills are present in approximately 20% of online job postings, being especially in demand in sectors with a higher level of digitalization, which highlights the transversality of these skills in advanced industrial environments (BÜCHEL; ENGLER; MERTENS, 2023). Proficiency in ERP is almost synonymous with SAP in Europe—particularly in Germany, where it reaches 91% of mentions—unlike in Brazil, where the demand is shared with the TOTVS system. This difference underscores the role of TOTVS as a regional strategic competence for Production Engineering in the Brazilian market.

Furthermore, the proficiency in fluent English (above 80% in all positions) confirms the need for training globally capable engineers, able to work in multicultural teams and handle standardized technical documentation. In addition, the CEDEFOP report (2024) highlights that “*digital and green transitions are*

*reshaping European labor " markets ,"* which reinforces the importance of digital and linguistic skills in the contemporary landscape of European professional mobility. The high demand for German in Germany (95%) demonstrates that, in highly specialized markets, fluency in the local language still constitutes a significant barrier to entry.

### 5.3 Validation

The validity of the study is based on data triangulation and verification of the statistical relationship between competencies, integrating national and international perspectives.

**Validation of the Methodology and Global Convergence:** The high demand for *Data Analysis* and *intrapreneurial insight* in Brazil (Section 5.1) is validated by the **convergence of European results** (Table 3), where Data Analysis also leads the technical requirements. This global alignment confirms that the document analysis methodology captured the macro-trends of Industry 4.0 and that the difference between the Brazilian and European markets lies mainly in the **ERP tool used (TOTVS vs. SAP)** and the requirement for language proficiency. The universal requirement for **fluent English** (Table 3) reinforces the validity of the research by categorizing Production Engineering 4.0 as a globalized profession.

**Statistical Validation (Digital-Entrepreneurial Correlation):** Spearman 's correlation test (  $\rho$  ) was used to validate the interdependence of essential competencies.

○ **Spearman correlation ( $\rho$ ):** Calculated between the demand for **Data Analysis** and **Intrapreneurship** (both with a large *skills gap* ) .

○ **Result:**  $\rho = 0.72$  ( $p < 0.01$ ). Spearman 's correlation coefficient ::  
$$\rho = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

Where:  $d_i$  is the difference between the posts and  $n$  is the number of observations.

The value  $\rho = 0.72$  indicates a strong and statistically significant positive correlation. The rejection of the null hypothesis ( $H_0$ ) implies that intrapreneurship, in the context of Industry 4.0, is a direct and functional application of Data Analysis aimed at creating organizational value.

This finding is based on the literature: Hyttinen (2023) points to the direct relationship between digital literacy and intrapreneurial behavior, and D'Angelo et al. (2024) highlight that corporate entrepreneurship in the digital age strongly depends on emerging digital skills, which reinforces the interpretation that this integration is a global trend.

Thus, the confirmation of the interdependence between Data Analysis and Intrapreneurship justifies the integrated approach proposed in the Hybrid and Transversal Training Model (HTTM), establishing that the development of these skills must occur simultaneously and complementarily to solve the Training Paradox.

## **6. Conclusion**

This study achieved all its objectives by mapping the critical competencies of the Production Engineer, confirming the historical expansion and broadening of the strategic value of their scope of action, while also exposing the Paradox of Professional Training 4.0 in Brazil. This article is an extension of the research developed in the first author's Master's Dissertation, aligned with the curricular requirements of the Ethics in Engineering discipline.

Main Conclusions:

- **Evolution and Expansion of Strategic Value:** The study confirmed the consolidation of the Production Engineer as a high-value strategic integration agent in digitalization. This conclusion is supported by the fact that 59% of the demand is concentrated in non-traditional sectors (Technology, Finance, Services). Companies in these sectors turn to Production Engineers for their multifaceted insight and systemic vision to optimize data flows and processes, making them versatile and valuable professionals. Data Analysis (68%) is established as the most vital Technical Skill, allowing Production Engineers to apply their optimization expertise directly to digital systems.
- **The Paradox of Training and Continuous Updating:** The largest skills gap (43%) was quantified in Data Analysis, followed by Intrapreneurship (26%). This discrepancy demonstrates that, although the market demands a broader and more strategic professional profile, academia has not yet kept pace with innovation. The paradox lies in the lack of systemic integration of these new skills with traditional training, preventing newly graduated professionals from reaching their full value potential in the 4.0 environment. This reinforces the urgent need for a culture of continuous and dynamic updating of the profession itself, in addition to curricular reform.
- **Validated Solution:** The study proposed and validated the Hybrid and Cross-Cutting Training Model (MFHT), which uses active methodologies (PBL and Design Sprint) to integrate intrapreneurial mindset with the most requested digital tools. The strong statistical correlation between Data Analysis and Intrapreneurship ( $\rho = 0.72$ ) empirically validates the urgency of this systemic integration.

**Unique Contribution of the Research:** The theoretical and practical contribution of this work lies in the unprecedented quantification of the skills gap in Brazil and in the proposition of the MFHT Model. The model offers a clear and validated roadmap for curricular reform, ensuring that Production Engineering graduates are aligned with the demand for hybrid skills and with the role of strategic value agent in the global Industry 4.0 scenario.

**Future Work:** It is suggested that the MFHT Model be applied and evaluated in Engineering courses in Brazil. Additionally, given the training in a Postgraduate program with a subject on Ethics, it is suggested to investigate the impact of Artificial Intelligence (AI) on the development of intrapreneurial skills and ethical decisions of future engineers, a fundamental aspect for the sustainability of innovation.

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