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Systematic Review

Digital competences of the industrial engineer in industry 4.0 a systematic vision

Walter Rosas Quintero[a*]

[a]Universidad Nacional Santiago Antunez de Mayolo, Escuela de Ingeniería Industrial, Facultad de Ingeniería de Industrias Alimentarias, Huaraz, Peru

*arosasq@unasam.edu.pe

Abstract

Paper aims: Propose digital skills that industrial engineers must possess to face the industry 4.0 challenges, through the integration of technological strategies and people in complex processes that transform factories, cities, and organizations into smart and flexible ones.

Originality: Due to the lack of clarity in the existing literature, this research aims to reframe the role of industrial engineers to face the industry evolution.

Research method: A systematic review of the publications made between 2016 and 2021 in indexed databases was carried out. After filtering, the selected articles were analyzed and compared to answer the aim of the work.

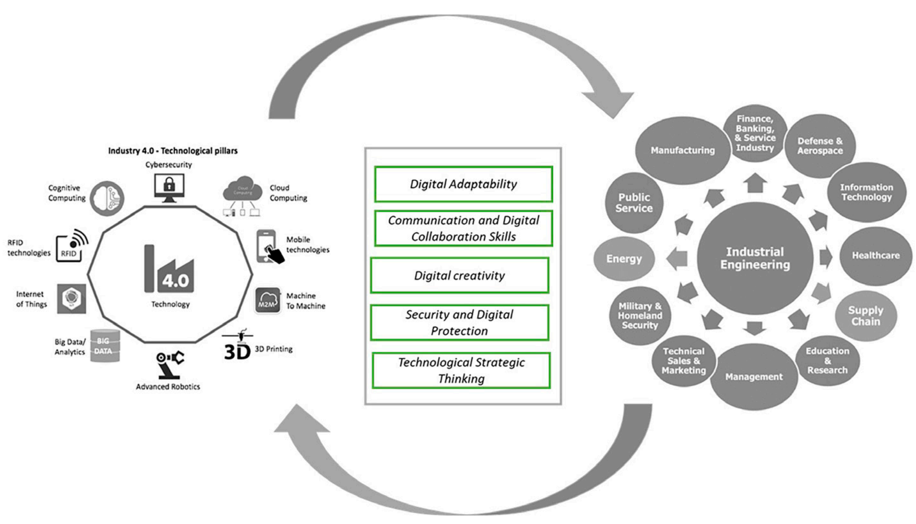
Main findings: There is no consensus on the digital skills required for industrial engineers to face the industry 4.0 challenges.

Implications for theory and practice: The technological strategies, pillars of industry 4.0, are in constant change, forcing us to rethink future research on the digital skills demanded by industrial engineering professionals.

Keywords

Industrial Engineer. Digital skills. Industry 4.0. Smart organizations.

Graphical Abstract



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1. Introduction

Driven by scientific progress and economic and cultural globalizing interests, the impact of new technologies has spread in a very volatile, uncertain, changing, and wide-ranging way. When we talk about the rapid development of digitalization, robotics, Artificial Intelligence, cybernetic systems, the Internet of Things (IoT), Cloud Computing, Big Data, Analytics, etc, the organizations, industries, cities, manufacturing systems are moving towards the fourth industrial revolution, known as Industry 4.0. According to Ynzunza et al. (2017), the concept of Industry 4.0 is relatively new, although some of these technologies have been used for years in an isolated way. Their integration and possible capabilities empower them to transform the industry with fully integrated, automated, and optimized processes in organizational performance, as indicated by Liboni et al. (2019), the industry is becoming smart, connected, and integrated. According to Klaus Schwab (2016), it implies the radical transformation of the production system but also business and society. Kagermann et al. (2016) state that the concept of Industry 4.0 aims to create smart factories due to the strong integration of information and communication technologies to connect the physical world with the virtual world.

Technological advances provide great opportunities to integrate and connect companies and their respective resources to increase their performance in terms of time, money, and use of resources. Erceg & Zoranović (2020) point out that the success of digital business transformation and survival in the global market is determined by the digital strategy executor skills who nurture culture and can change the existing and establish a new business model.

Engineering is an activity that is essential to meet the needs of people, economic development, and the provision of services to society. It involves using mathematics, natural sciences, engineering knowledge, technologies, and engineering techniques. Engineering seeks to produce solutions whose effects are anticipated in often uncertain contexts. A holistic view of engineering training integrates three main axes: the object of the profession and the training of professional skills, the scientific approach to solving professional problems, and the ethical training of the contemporary engineer (Capote et al., 2016). According to Schutte et al. (2016), he cites the Institute of Industrial Engineers who defines "industrial engineering as the engineering that deals with the design, improvement, and installation of integrated systems of men, materials, equipment energy. Relying on specialized knowledge and skill in the mathematical, physical, and social sciences, together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results achieved by such systems." Industrial Engineering is an interdisciplinary career that, with the integration of technologies, and the contributions of operations research, computing, and cybernetics, has taken a body of knowledge that transforms it into a conclusive profession to contribute to technological development, balancing the man with the machinery, promoting efficient human activity systems to improve the productivity and processes necessary to produce goods or services. Mesquita et al. (2015) mention that an industrial engineer can perform production management, automation, quality assurance and control, economic engineering, operations research, information and communication technology systems, human and ergonomic factors, logistics, maintenance, project management, sustainability, product design and simulation among other areas.

Digital competence is the set of knowledge, skills, attitudes, strategies and awareness that the use of TIC´s and digital media requires to perform tasks, solve problems, communicate, manage information, collaborate, create and share content, and generate knowledge in an effective, efficient, adequate, critical, creative, autonomous, flexible, ethical, thoughtful way for work, leisure, participation, learning, socialization, consumption, and empowerment.

Faced to the knowledge society, industrial engineers' role is to successfully implement digital transformation and survive in the changing competitive market, where companies must have adequate intellectual capital. Apart from techniques and skills, employees must adapt to new digital strategies, structural organizations, and company culture. In response to this trend, it is necessary to establish new competencies in industrial engineers. In this sense, this systematic review aims to answer the following question: What digital skills or abilities are required for an industrial engineer to be successfully inserted into Industry 4.0 organizations?

1.1. Definitions

When we talk about digital skills or abilities that an industrial engineer must have in industry 4.0, we refer to the ability to integrate the technological pillars on which industry 4.0 is based, such as: handling large amounts of data; development of algorithms or technological creations that allow solving complex problems of industrial engineering; the ability for communication and digital collaboration between men and machines; the creation and innovation of digital content; security and digital protection in the organization's environments.

Table 1 presents some definitions referring to the pillars of industry 4.0, digital skills according to the European Commission, and the industrial engineer's profile according to the Washington Agreement for the Accreditation of Engineering Programs, which we consider necessary for a better understanding of our research.

Table 1. Main definitions of Industry 4.0, digital skills, and profile of the industrial engineer.

Topic	Criteria	Attribute	Description
Industry 4.0	1	Integration systems	They allow the integration of operational technologies with information and communication technologies. They connect machines with machines (M2M), devices with products, and integrate the production unit's different areas, impacting its internal management.
	2	Autonomous machines and systems (robots)	Smart machines that automate tasks that were previously restricted solely to the human domain. The aim is to increase collaborative robotics to move towards smart factories where all company areas can work in a connected manner and with a high level of automation in tasks.
	3	Internet of things (IoT)	It allows multidirectional communication between machines, people, and products, facilitating decision-making based on the information that technology collects from its environment.
	4	Additive manufacturing	It allows parts to be manufactured from the superposition of layers of different materials, taking a previous design as a reference, without molds, directly from a virtual model.
	5	Big data and big data analysis	It refers to data characterized by volume (large amount), speed (at which it is generated, accessed, processed, and analyzed), and a variety of structured and unstructured data. This data can be reported by machines and equipment, sensors, cameras, microphones, mobile phones, production software and can come from various sources, such as companies, suppliers, customers, and social networks.
	6	Cloud Computing	It offers storage, access, and use of computer services online. It can be expressed at three levels, depending on the service provided: infrastructure as a service, platform as a service, and software as a service.
	7	Simulation of virtual environments	It allows to adjust and virtually represents the joint operation of machines, processes, and people in real-time before being put into operation, preventing breakdowns, saving time, and evaluating the final result in a controlled environment.
	8	Artificial intelligence	It is based on the development of algorithms that allow computers to process data at an unusual speed (a task that previously required several computers and people), also achieving machine learning.
	9	Cybersecurity	The evolution towards an smart industry and the growing integration of value chain actors through the internet, cloud computing, and digital platforms make it necessary to develop cybersecurity mechanisms in industrial environments.
	10	Augmented reality	It allows complementing the real environment with digital objects. These systems combine simulation, modeling, and virtualization allowing new formulas for product design and process organization, providing flexibility and speed in the production chain.
Digital Skills	1	Information and data literacy	Articulate information needs, locate and retrieve data and digital content. Judge the relevance of the source and its content. To store, manage and organize digital data, information, and content.
	2	Communication & Collaboration	Interact, communicate and collaborate through digital technologies while being aware of cultural and generational diversity. Participate in society through public and private digital services and participatory citizenship. Manage your own identity and digital reputation.
	3	Digital content creation	To create and edit digital content To enhance and integrate information and content into an existing body of knowledge while understanding how copyright and licenses should be applied. Know how to give understandable instructions for a computer system.
	4	Safety	To protect devices, content, personal data, and privacy in digital environments. Protect physical and psychological health, and learn about digital technologies for social well-being and social inclusion. Learn about the environmental impact of digital technologies and their use.
	5	Troubleshooting	Identify needs and problems and solve conceptual problems and problematic situations in digital environments. Use digital tools to innovate processes and products. To keep up to date with digital evolution.
Industrial Engineer Profile	1	Engineering knowledge	Apply knowledge of mathematics, natural sciences, engineering fundamentals, and an engineering specialization, respectively, to solve complex engineering problems.
	2	Analysis of the problem	Identify, formulate, conduct literature research, analyze complex engineering problems and reach informed conclusions using the first principles of mathematics, the natural sciences, and the engineering sciences.
	3	Design / Development of Solutions	Design solutions to complex engineering problems and design systems, components, or processes to meet specific needs with appropriate public, cultural, social, environmental health, and safety considerations.
	4	Research	Carry out investigations of complex engineering problems using inquiry-based knowledge and research methods, including the design of experiments, the analysis and interpretation of data, and the synthesis of the information to provide valid conclusions.
	5	Use of modern tools	Create, select, and apply the appropriate modern engineering and IT techniques, resources, and tools, including prediction and modeling, to complex engineering problems, understanding the constraints.
	6	The engineer and the society	Apply to reason informed by the contextual knowledge to assess social, health, safety, legal, and cultural issues and consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
	7	Environment & Sustainability	Understand and evaluate the sustainability and impact of professional engineering work in solving complex engineering problems in social and environmental contexts.

Source: Industry 4.0 (Basco et al., 2018); Digital skills (Elías, 2017); Engineer profile criteria (Basir et al., 2019).

Table 1. Continued...

Topic	Criteria	Attribute	Description
	8	Ethics	Apply ethical principles and commit to professional ethics and the responsibilities and standards of engineering practice.
	9	Individual work and on team	Function effectively as an individual and as a member or leader in diverse teams and multidisciplinary settings.
	10	Communication	Communicate effectively about complex engineering activities with the engineering community and society at large, such as understanding and writing effective reports and design documentation, making effective presentations, and giving and receiving clear instructions.
	11	Project and finance management	Demonstrate knowledge and understanding of engineering management principles and economic decision-making and apply them to one's work to manage projects in multidisciplinary environments as a member and leader of a team.
	12	Lifelong learning	Recognize the need for and have the readiness and ability to engage in independent and lifelong learning in the broader context of technological change.

Source: Industry 4.0 (Basco et al., 2018); Digital skills (Elías, 2017); Engineer profile criteria (Basir et al., 2019).

2. Methodology

In this work, a systematic review was carried out to locate relevant studies based on previously formulated research questions, to evaluate and synthesize their respective contributions. (Gusmão Caiado et al., 2020). This research aims to analyze in the different studies how they determine the digital skills that industrial engineers need for their labor insertion in the Organizations of the 21st century. For this purpose, there were considered the academic bases published in the scientific literature between 2016 and 2021. According to Sampaio & Mancini (2007), the systematic review of the literature is a form of research that uses as a source of information data from the literature on a given topic and that allow the researcher to identify in an agile and summarized way the outstanding theories, in the area of interest, identify key concepts, the most outstanding authors, the methodologies that have been used, the most important findings and that provides a summary of the evidence related to a specific intervention strategy, through the application of explicit and systematic search methods, critical appraisal and synthesis of the selected information.

2.1. PIO approach

The search strategy was based on the PIO acronym: P (population), I (intervention), and O (outcom, outcome, or result), a review technique widely used in investigations of systematicor bibliographic reviews since it favors information with which you want to work can be factored from the well-structured research question, the search strategy is built (Moncada-Hernández, 2014). To answer the research question, what digital skills or abilities are necessary for an industrial engineer to be successfully inserted into Industry 4.0 organizations? the following limiting factors are considered based on the PIO acronym (Table 2).

Table 2. Search strategy (PIO).

Topic / Description	Population	Intervention	Outcom
	The role of the Industrial Engineer	Digital Skills or Competences	Labor Insertion in the Organizations of the 21st Century
Topic 1	"Industrial Engineer"	"Competencies"	"Industry 4.0"
Topic 2	"Engineer"	"Digital Skills"	"Smart industry"
Topic 3	"Professionals"	"skills"	"Smart organizations"

A search of studies was carried out in the platforms and academic databases of Scopus, ScienceDirect, Redaylc, and Ebsco, according to the search algorithm generated by Table 2 ("Industrial Engineer" or "Engineer" or "Professionals") AND ("Competencies" or "Digital Skills" or "skills") AND ("Industry 4.0" or "smart industry" or "smart organizations"). Table 3 presents the search results according to the databases and selected period

2.2. Selection criteria and article filtering

A total of 3,456 records were retrieved from all the selected databases, and these were filtered following the filtering protocol established in the PRISMA methodology, considering inclusion and exclusion criteria during the

Table 3. Search Paths*.

Database	Search terms	2016	2017	2018	2019	2020	2021	Total
Scopus	TITLE-ABS-KEY ((“ Industrial Engineer” O ” Engineer” O ” Professionals”) Y (“ Competencies” O ” Digital Skills” O “skills”) Y (“ Industry 4.0” O “smart industry” O ” smart organizations” “)) Y (LIMIT-TO (PUBYEAR, 2022) O LIMIT-TO (PUBYEAR, 2021) O LIMITADO A (PUBYEAR, 2020) O LÍMITE DE (PUBYEAR, 2019) O LÍMITE DE (PUBYEAR, 2018) O LÍMITE DE (PUBYEAR, 2017) O LÍMITE DE (PUBYEAR, 2016)) Y (LÍMITE DE (DOCTYPE, “ar”))	0	6	3	10	41	33	93
Scielo	(“Industrial Engineer” or “Engineer” or “Professionals”) AND (“Competencies” or “Digital Skills” or “skills”) AND (“Industry 4.0” or “smart industry” or “smart organizations”)	0	0	0	0	3	0	3
Redalyc	“(“Industrial Engineer” or “Engineer” or “Professionals”) AND (“Competencies” or “Digital Skills” or “skills”) AND (“Industry 4.0” or “smart industry” or “smart organizations”)”	1	1	5	63	12	3	28
Science Direct	(“Industrial Engineer” or “Engineer” or “Professionals”) AND (“Competencies” or “Digital Skills” or “skills”) * Se excluye AND (“Industry 4.0” or “smart industry” or “smart organizations”)”	0	0	1	0	1	2	4
EBSCO	(“Industrial Engineer” or “Engineer” or “Professionals”) AND (“Competencies” or “Digital Skills” or “skills”) AND (“Industry 4.0” or “smart industry” or “smart organizations”) Limiters - Publication Date: 20160101-20221231 Magnifiers - Search also within the full text of articles; Apply equivalent subjects Search modes - Find all my search terms	43	125	306	620	1033	1201	3328
		44	132	315	636	1090	1239	3456

*Date of consultation: December 03 to 10, 2021

process. The first inclusion criterion was referred to the area or discipline, only including articles belonging to the subject of engineering and education; as a second criterion, only those works published in English, Spanish and German were included. In this process, 3,336 works were eliminated, leaving 125. Immediately, 39 articles were eliminated because they were repeated, leaving 86 as preselected articles. Once the title and abstract were examined, 56 were excluded either because the subject matter clearly belonged to other areas or in those cases in which there could be some doubt as it was multidisciplinary. The use of filtering diagrams (Figure 1) is useful

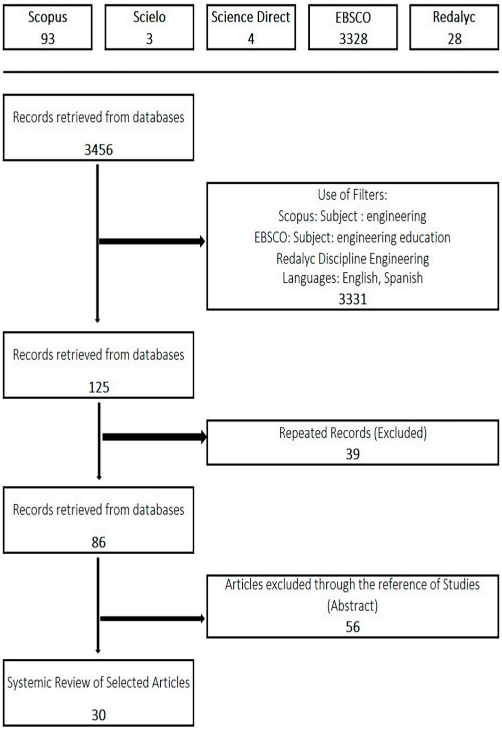

Figure 1. Flowchart of the selection process methodology.

to present the article selection process, where it is specified from the initial number of potentially eligible articles according to the search carried out to those finally included, specifying the reasons why the articles were excluded.

2.3. Selected articles

Table 4 shows the 27 documents that were selected according to the methodology described above.

3. Result/Development

3.1. Descriptive analysis of selected articles

When carrying out the descriptive analysis of the selected articles over the years, it was possible to observe that as of 2016, there is a growing trend of this type of research on the engineer's profile in the face of the fourth industrial revolution (Figure 2). This exponential growth of publications in recent years is attributed to organizations are experiencing the advent of innovative trends brought about by digital transformation. González & Calderón (2018) point out that "One of the reasons for the fascination of Industry 4.0 is that it is an industrial revolution predicted a priori, which offers various opportunities for companies and research institutes to form the future actively".

On the other hand, regarding the geographical distribution of the number of publications carried out by country, it can be seen from Figure 3 that most of the research is concentrated in European countries with 47%,

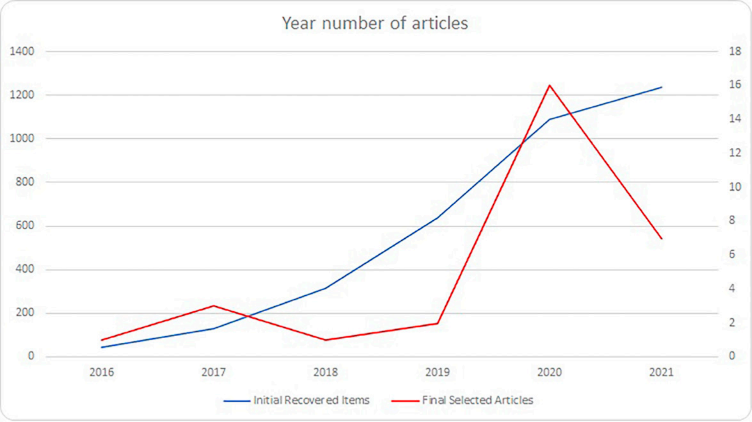

Figure 2. Trends of selected publications over time (Number of articles vs year).

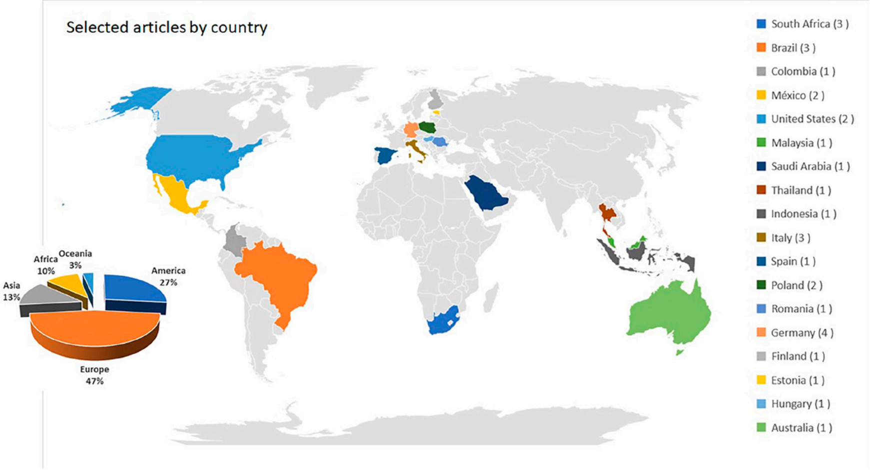

Figure 3. Information on the continent and country of origin of the research.

Table 4. Selected articles.

Items	Writers	Year	Title	Journal	Country	Others (DOI)
1	Baena, F., Guarin, A., Mora, J., Sauza, J., & Retat, S.	2017	Learning factory: The path to industry 4.0.	Procedia Manufacturing, 9, 73-80.	Italy	10.1016/j.promfg.2017.04.022
2	Basir, Noordin, Oh Chai Lian, Ja'afar Muhd Salmizi, y Hamid Shaharin.	2019	Assessment Of Outcome-Based Integrated Design Project.	*Journal of Technology & Science Education* 9(1):77-77-84.	Malaysia	10.3926/jotse.541.
3	Becerra, L. Y.	2020	Tecnologías de la información y las Comunicaciones en la era de la cuarta revolución industrial: Tendencias Tecnológicas y desafíos en la educación en Ingeniería.	*Entre Ciencia e Ingeniería* 14(28):76-76-81.	Colombia	10.31908/19098367.2057.
4	Bischof-dos-Santos, C., & de Oliveira, E.	2020	Production engineering competencies in the industry 4.0 context: Perspectives on the brazilian labor market.	Production, 30, 1-10.	Brazil	10.1590/01036513.20190145
5	Brezeanu, Tania-Mihaela, Y Elisabeth Lazarou.	2020	Alignment Between Engineering Curriculum And Skills Development For Industry 4.0.	*eLearning & Software for Education* 2:328-328-34.	Rumania	10.12753/2066-026X-20-127.
6	Chikasha, P. N., K. Ramdass, K. Mokgohloa, y R. W. Maladzhi.	2020	Aligning Industrial Engineering Education With Industry Through Atomic Curriculum Manipulation.	*South African Journal of Industrial Engineering* 31(4):92-92-103.	South Africa	10.7166/31-4-2393.
7	Eppes, T. A., Milanovic, I., Jamshidi, R., & Shetty, D.	2021	Engineering curriculum in support of industry 4.0. International Journal of Online and Biomedical Engineering, 17(1), 4-16.	doi:10.3991/ijoe.v17i01.17937	United States	10.3991/ijoe.v17i01.17937
8	Fareri, S., Fantoni, G., Chiarello, F., Coli, E., & Binda, A.	2020	Estimating industry 4.0 impact on job profiles and skills using text mining.		Italy	10.1016/j.compind.2020.103222
9	Goecks, L. S., Santos, A. A. dos, & Korzenowski, A. L	2020	Decision-making trends in quality management: a literature review about Industry 4.0	Production, 2020,30	Brazil	https://doi.org/10.1590/0103-6513.20190086
10	González, Isaías, y Antonio José Calderón.	2018	Development of Final Projects in Engineering Degrees around an Industry 4.0-Oriented Flexible Manufacturing System: Preliminary Outcomes and Some Initial Considerations.	*Mathematics (2227-7390)* 6(12):214-214-214.	Spain	10.3390/educsci8040214.
11	Gonz323ález-Hernández, I. J., & Granillo-Macías, R. (	2020	Competences of industrial engineers in industry 4.0.	Revista Electrónica De Investigación Educativa, 22	México	doi:10.24320/REDIE.2020.22.E30.2750
12	Gumparthi, S.	2020	Industry 4.0 evolutions - technical education for sustainable social development. International Journal of Advanced	Science and Technology, 29(3 Special Issue), 770-778. Retrieved from www.scopus.com	Thailand	
13	Hernandez-de-Menendez, Marcela, Carlos A. Escobar Díaz, y Ruben Morales-Menendez.	2020	Engineering education for smart 4.0 technology: a review.	*International Journal on Interactive Design & Manufacturing* 14(3):789-789-803.	México	10.1007/s12008-020-00672-x.
14	İsa Gerekli, Tarık Ziyad Çelik, İbrahim Bozkurt	2021	Industry 4.0 and Smart Production	TEM Journal. Volume 10, Issue 2, Pages 799 - 805, ISSN 2217 - 8309,	Germany	10.18421/TEM102-37

Table 4. Continued...

Items	Writers	Year	Title	Journal	Country	Others (DOI)
15	Kammerl, Rudolf; Dertinger, Andreas	2019	Competencies in a digital world: Approaches to an empirical operationalization of the KMK competency model.	Medien & Erziehung	Germany	https://web.p.ebscohost.com/ehost/detail/detail?vid=0&sid=48bca41e-50d8-4c39-ab24-162b8f4e195d%40redis&bdata=JkF1dGhUeXBlPWlwLHNzbyZsYW5nPWVzJnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#db=asn&AN=136079578
16	Katarzyna Piwowar-Sulej	2021	Human resources development as an element of sustainable HRM – with the focus on production engineers.	Journal of Cleaner Production, 278	Poland	10.1016/j.jclepro.2020.124008
17	Maisiri, W., van Dyk, L., & Coetzee, R.	2021	Development of an industry 4.0 competency maturity model. SAIEE Africa Research	Journal, 112(4), 189-197. Retrieved from www.scopus.com	South Africa	https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9580772
18	Motyl, B., Baronio, G., Uberti, S., Speranza, D., & Filippi, S.	2017	How will change the future engineers' skills in the industry 4.0 framework? A questionnaire survey.	Procedia Manufacturing, 11, 1501-1509.	Italy	10.1016/j.promfg.2017.07.282
19	Muszyńska-Łanowy, M.	2021	Technical and soft competencies in teaching architecture in the context of industry 4.0.	World Transactions on Engineering and Technology Education, 19(2), 203-208. Retrieved from www.scopus.com	Poland	http://www.wiete.com.au/journals/WTE&TE/Pages/Vol.19,%20No.%202%20(2021)/08-Muszynska-Lanowy-M.pdf
20	Sackey, S. M., & Bester, A.	2016	Industrial engineering curriculum in industry 4.0 in a south african context.	South African Journal of Industrial Engineering, 27(4), 101-114.	South Africa	doi:10.7166/27-4-1579
21	Salah, Bashir, Sajjad Khan, Muawia Ramadan, y Nikola Gjeldum.	2020	Integrating the Concept of Industry 4.0 by Teaching Methodology in Industrial Engineering Curriculum.	*Processes* 8(9):1007-1007-1007.	Saudi Arabia	10.3390/pr8091007.
22	Schaupp, Simon Diab, Ramón	2020	From the smart factory to the self-organisation of capital: 'Industrie 4.0' as the cybernetisation of production	*Ephemera: Theory & Politics in Organization*	Germany	https://web.p.ebscohost.com/ehost/detail/detail?vid=0&sid=a1f3afd3-68f3-4b6c-8c5d-acf5e41bde0a%40redis&bdata=JkF1dGhUeXBlPWlwLHNzbyZsYW5nPWVzJnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#AN=14902-8146&db=asn
23	Sedelmaier, Yvonne, y Dieter Landes.	2017	How Can We Find Out What Makes a Good Requirements Engineer in the Age of Digitalization?	*International Journal of Engineering Pedagogy* 7(3):147-147-64.	Germany	10.3991 / ijep.v7i3.7424
24	Souza, R. G., Quelhas, O., Marchisotti, G., Neto, J., Anholon, R., & Marinho, C. A.	2020	Production engineering curriculum in industry 4.0 in a brazilian context. South African	Journal of Industrial Engineering, 31(4), 136-150.	Brazil	10.7166/31-4-2033
25	Tan, H. -., Ivander, Oktarina, R., Reynaldo, V., & Sharina, C.	2020	Conceptual development of learning factory for industrial engineering education in indonesia context as an enabler of students' competencies in industry 4.0 era.	Paper presented at the IOP Conference Series: Earth and Environmental Science,, 426(1)	Indonesia	doi:10.1088/1755-1315/426/1/012123 Retrieved from www.scopus.com

Table 4. Continued...

Items	Writers	Year	Title	Journal	Country	Others (DOI)
26	Thirunavukarasu, Gokul, Siva Chandrasekaran, Varsha Subhash Betageri, y John Long.	2020	Assessing Learners' Perceptions of Graduate Employability.	*Sustainability (2071-1050)* 12(2):460-460-460.	Australia	10.3390/su12020460.
27	Tihinen, Maarit, Ari Pikkarainen, y Jukka Joutsenvaara.	2021	Digital Manufacturing Challenges Education—SmartLab Concept as a Concrete Example in Tackling These Challenges.	*Future Internet* 13(8):192-192-192.	Finland	10.3390/fi13080192.
28	Torok, L.	2020	Industry 4.0 from a few aspects, in particular in respect of the decision making of the management/Will the new industrial revolution change the traditional management functions?/.	International Review of Applied Sciences and Engineering, 11(2), 140-146.	Hungary	:10.1556/1848.2020.20020
29	Vodovozov, Valery, Zoja Raud, y Eduard Petlenkov.	2021	Challenges of Active Learning in a View of Integrated Engineering Education.	*Education Sciences* 11(2):43-43-43.	Estonia	10.3390/educsci11020043.
30	Zeidan, S., & Bishnoi, M. M.	2020	An effective framework for bridging the gap between industry and academia.	International Journal on Emerging Technologies, 11(3), 454-461. Retrieved from www.scopus.com	United States	https://www.researchgate.net/publication/341830407_An_Effective_Framework_for_Bridging_the_Gap_between_Industry_and_Academia

we must highlight that the concept of "Industry 4.0 " arises in Germany at the beginning of the 2010s, coined by a multidisciplinary group of specialists convened by the German government to design a program to improve the productivity of the manufacturing industry, becoming a central axis of the High Technology Strategic plan to 2020 of the German government (Basco et al., 2018). In addition, Amaya Rodríguez & Sibrián Sanchez (2019) indicates European countries, such as Germany, Switzerland, Sweden, Austria, Ireland, and Finland, as more advanced in terms of connectivity, industry 4.0, capital human. The second place is occupied by America with 27%, with Brazil being the country with the largest number of investigations selected for our research. It could be related to the high Brazilian industry development since it is the ninth place in the manufacturing industry, the world's second-largest ethanol producer, the world's largest exporter, and is considered the international biofuels leader (Kearney, 2018).

3.2. Correlation of articles: development of topics

To answer the research question, what digital skills or abilities are necessary for an industrial engineer to be successfully inserted into Industry 4.0 organizations? Three topics were built: the first is based on the pillars of industry 4.0 in industrial organizations where we focus on the integration of information technology and communications with industrial advances to develop digital, efficient, green, and flexible factories (Hernandez-de-Menendez et al., 2020); In the second topic, digital skills were discussed according to Bischof-dos-Santos & Oliveira, (2020), who define it as the ability to adopt and use new or existing information and communication technology to critically analyze, select and evaluate digital information to research and solve work-related problems; and finally, the third topic dealt with the profile of the industrial engineer to function successfully in industry 4.0, involving the intentional use of mathematics, natural sciences, engineering knowledge, engineering technologies, and techniques. Table 5 shows the articles compared in each topic.

Table 5. Distribution of articles by topics to be treated.

Topic	Definition	References
Industry 4.0	Integration of information and communications technology with industrial advances to develop digital factories will transform production processes making them more efficient, green, and flexible.	Basir et al. (2019); Chikasha et al. (2020); Hernandez-de-Menendez et al. (2020) ; Salah et al. (2020); Vodovozov et al. (2021); Garcia-Moran et al. (2021); Bischof-dos-Santos & Oliveira (2020); Fareri et al. (2020); Maisiri et al. (2019); Motyl et al. (2017); (Török (2020); Goecks et al. (2020); Madakam et al. (2019); Mena-Vargas et al. (2019) ; Eppes et al. (2021); Kammerl & Dertinger, (2019)
Digital Competences	The ability to adopt and use new or existing information technology to critically analyze, select and evaluate digital information to investigate and solve work-related problems and develop a collaborative body of knowledge.	Sedelmaier & Landes (2017); Tihinen et al. (2021); Vodovozov et al. (2021) ; Pittich et al. (2020); Bischof-dos-Santos & Oliveira (2020); Maisiri et al. (2021); Muszyńska-Łanowy (2021); Souza et al. (2020); Zeidan & Bishno (2020); Bischof-dos-Santos & Oliveira (2020); Brezeanu & Lazarou, (2020)
Industrial Engineer	The professional profile of the Industrial Engineer constitutes the frame of reference for professional performance; it is expressed in terms of labor competencies and allows us to identify if the professional is qualified to successfully function in industry 4.0 by designing, implementing, improving, and optimizing processes. Complexes of an integrated system consisting in people, money, knowledge, information, equipment, energy, and materials.	Basir et al. (2019); Becerra (2020); Chikasha et al. (2020); González & Calderón (2018); Salah et al. (2020); González-Hernández & Granillo-Macías (2020); Sackey & Bester (2016); Tan et al. (2020); Piwowar-Sulej (2021); Baena et al., (2017); Gumparthi (2020); Török (2020)

3.2.1. P1: Pillars of industry 4.0 in industrial organizations.

Since the beginning of industrialization, technological leaps have given rise to paradigmatic changes called "industrial revolutions": first, in the field of mechanization; second, in the intensive use of electrical energy; and third, in automation with the use of the computer, and the fourth revolution known as Industry 4.0, according to the referenced researchers (Goecks et al., 2020; Becerra, 2020; González & Calderón, 2018; González-Hernández & Granillo-Macías, 2020; Török, 2020; Zeidan & Bishno, 2020; Tihinen et al., 2021), based on digitalization and connectivity, generating important changes in the manufacturing industry, in consumer behavior, and business, leading them towards smart systems that efficiently use the potential of new technologies. digital technologies (Salah et al., 2020; Baena et al., 2017; Bischof-dos-Santos & Oliveira, 2020; Motyl et al., 2017; Török, 2020; González-Hernández & Granillo-Macías, 2020; Sackey & Bester, 2016; Tan et al., 2020), a highlight in their studies the combination of physical and technological supports that offers the possibility of developing truly digital companies. Consequently, Industry 4.0 should be implemented interdisciplinary and in close cooperation with the other key areas and using different technology drivers. These are known as the pillars of Industry 4.0 and comprise the following technologies: Big Data; autonomous robots; Simulation; Universal system integration; Industrial IoT; artificial intelligence, cyber security; Cloud Computing; Additive manufacturing, and augmented reality, conceptualized in the first part of the investigation.

3.2.2. P2: Digital skills necessary for engineering professionals in the context of industry 4.0

According to Bischof-dos-Santos and Oliveira, he cites Calvani et al. (2008), the characteristics of digital competencies are multidimensional. They integrated abilities and skills of a cognitive, relational, and social nature; complex, interconnected with key competencies such as problem-solving skills, logic, and arithmetic; sensitive to the sociocultural context and its various technological environments. We must highlight that Piwowar-Sulej, (2021) indicates that industry 4.0 combines people and technologies, and we must consider three scenarios (1) Optimization through automation. (2) human-machine collaboration and (3) digital transformation. (Motyl & Filippi, 2021); Digital skills comprise all skills related to the digital world, from basic digital literacy skills to specific digital skills for industrial professionals, suggesting a conceptual framework for digital skills that describes the coexistence of four dimensions: (1) technological, (2) cognitive, (3) ethical and (4) the integration of these three. González-Hernández & Granillo-Macías, (2020) cites the World Economic Forum (2018), which mentions that the ten generic skills or competencies necessary to prosper in Industry 4.0 are: complex problem solving, critical thinking, creativity, people management, coordination with others, emotional intelligence, judgment and decision making, service orientation, negotiation, and cognitive flexibility, and to specific skills, mentions that these should be focused on emerging technologies such as artificial intelligence and robotics, internet of things, virtual and augmented reality, additive manufacturing, blockchain, and distributed ledger technology, advanced materials, and nanomaterials, energy capture-storage and transmission, new computer technologies, biotechnologies, geoengineering, neuro-technology, and space technologies.

3.2.3. P3: Profile of the industrial engineer to function successfully in industry 4.0.

Tan et al. (2020) define industrial engineering as science related to the planning, design, development, improvement, implementation, installation, and evaluation of the performance of complex processes or systems that are integrated between people, equipment, technology, and information. However, other researchers, such as Bischof-dos-Santos & Oliveira (2020) and González-Hernández & Granillo-Macías (2020), indicate that the appearance of Industry 4.0, emerging technologies, and digitization entails that definitions on industrial engineering need to be reviewed and updated. The application of these pillar technologies of industry 4.0 implies a high level of complexity due to the convergence of several technologies and a multidisciplinary approach to face the challenges and interact in the smart environments proposed by the new organizations. The International Engineering Alliance (Washington Agreement) indicates that an engineer must have a minimum training base to ensure that they can design solutions to complex problems in the development of engineering activities, which is why it proposes twelve quality attributes, listed previously in the Table 1, ensuring a solid knowledge base, and professional performance as a Professional Competence Profile (Basir et al., 2019).

Chikasha et al. (2020), González & Calderón (2018), Salah et al., (2020), González-Hernández & Granillo-Macías (2020), Sackey & Bester (2016), Tan et al. (2020) and Piwowar-Sulej (2021) agree that the curriculum of universities is the main factor that defines the competence and skill level of graduate industrial engineers.

4. Discussions and Recommendations

4.1. Contribution of the article review

González-Hernández & Granillo-Macías, (2020), proposed that the specific competencies that industrial engineers must develop based on the Technologies of Information and Communication, lists the pillars of industry 4.0 such as big data, internet of things and simulation. Industrial engineering seeks to produce solutions whose effects are foreseen in often uncertain contexts with the integration of men, materials, and the most advanced technology, based on the fact that the line between humans and technology is less visible as the interaction of the physical and digital world increases. (Gerekli et al., 2021). The training of the industrial engineer must allow him to be able to face the challenges of industry 4.0. Faced with these transformations, organizations and universities must rethink their learning processes in the digital skills that the future industrial engineer must possess. In this case, we consider making it clear that we define digital skills as a set of knowledge, skills, attitudes, and strategies that with the use of technologies, we are going to identify, design, investigate, solve complex problems of industrial engineering, using modern connected, automated tools, and leading diverse multidisciplinary teams and in virtual environments to solve complex engineering problems. Considering these points, Table 6 shows our purpose as digital skills for industrial engineer. The proposed basic digital skills would be implemented during the curricular development of the first semesters of the industrial engineer's training through the continuous learning process, developing the ability to adapt and positively face new digital technologies such as handling large volumes of data, collaborative digital communication, security and digital protection. Digital transversal skills must be developed by future industrial engineers during their professional training according to the graduation profile of the engineering programs and be in accordance with the global context of technological progress, such as the resolution of complex engineering problems with the application of digital resources, critical technological thinking, among others.

Table 6. Digital skills of the industrial engineer.

Sort	Dimension	*Description*
Basic Digital Competencies	Information and Data Management	*Understands and effectively uses devices and systems typical of Technologies.*
		Browse, search, filter, compare and validate the information.
		Collect, process, store, and share information across multiple devices, apps, and cloud services.
	Communicative & Collaborative	*Interact through technologies.*
		Share information and content.
		Use social networks and communicate through ICT.
		Manage their digital identity.
		It is inserted into digital citizenship.
		This can communicate with others and collaborate using tag codes.
		Develop strategies to uncover inappropriate behaviors.
	Digital security	*This can protect yourself and others from threats and possible dangers online.*
		It has strategies for protecting personal data, health, and the environment.
Digital Transversal Competencies	Solving complex problems with the application of digital resources.	*Solve complex engineering problems with modern technology tools.*
		Identifies technological needs and responses.
		Use technology creatively and innovatively.
	Collaborative work in virtual and multidisciplinary environments	*Proactively participate in Virtual Learning Environments, social networks, and spaces for academic collaboration.*
		Maintains a positive attitude to collaborate, carry out projects and build learning collaboratively with digital tools.
	Critical Technological Thinking	*Distinguishes and uses different search tools according to the type and format of the information: text, image, numerical data, maps, audiovisual and audio.*
		Build, classify and organize information according to schemes or genre.
		Identifies and recognizes the appropriate time to incorporate digital tools and resources into learning.
		Identifies gaps in your digital competence.
	Digital Content Creation	*Develop, integrate, rework, work and publish, effectively, digital content as representations of knowledge.*
		Uses diverse digital media to represent knowledge (text, audio, video, graphics, images, etc.)
		Uses tools for the collective production of knowledge in educational tasks and projects.
		It can use office packages (or other applications related to study and work) and edit and create advanced content.
	Digital Responsibility	*Know, understand, and attend to the rules of Copyright and reproduction licenses.*
		Avoid health risks related to the use of technology in terms of threats to physical integrity and psychological well-being.
		Considers the impact of technologies on the environment.

4.2. Gaps, challenges, and research opportunities

Becerra, 2020; Brezeanu & Lazarou (2020), Salah et al. (2020), Sedelmaier & Landes (2017), Thirunavukarasu et al. (2020), Vodovozov et al. (2021), (Bischof-dos-Santos & Oliveira (2020), Fareri et al. (2020), Török (2020) and Zeidan & Bishno (2020), coincide as a key factor for the success of industry 4.0 are digital skills, and the lack of clarity regarding the concept of competition digital in the context of industry 4.0, further agrees that there is not enough knowledge about what skills engineers should have these days, and it is more likely that digitalization will bring new challenges and change the skills that are necessary for successful engineering Unfortunately, no selected article provides a complete description of the digital competencies required for industrial engineers. Therefore, a specific model of digital skills is urgently needed, which must be anchored in the curriculum of engineering programs and the offers to acquire skills must be adapted to the training of future industrial engineers (Schaupp & Diab, 2020). The closure of these gaps must be carried out through strategies to strengthen the teaching-learning process in the region's universities. Likewise, a new interpretation of the role of industrial engineering in today's organizations is required, in addition to joint work between business, academia and the State that is more committed to supporting experimental research. It remains to establish what is the training competency approach that predominates in the Industrial Engineering programs in the universities participating in this work, its theoretical references and how they seek to respond with their training models to the current social and labor situation. Today's organizations face several challenges in both industry and education. (Becerra, 2020).

In industry, the main challenge is to define the rules of a new productive space that has been born from the confluence between the physical world and the digital world (International Business Machines, 2019). According to Hernandez-de-Menendez et al. (2020) indicate that, in the next 10 years, the generation of more than 3.5 million new jobs available in the industry is expected 4.0.

In education, especially in engineering, it has brought the need to create a new profile of engineers who should have not only a deep knowledge of their specialization (Vodovozov et al., 2021), that is why it is essential to know the great variety of converging technologies, which blur the boundaries between the physical, the digital, and the biological (Basco et al., 2018). The training of the industrial engineer must be holistic, integrated by (1) the training of professional interpersonal skills, including: leadership, teamwork, creativity, innovation, communication and collaboration within multidisciplinary and digital teams; (2) for a solid scientific-technological training to solve complex professional problems with the application of technological resources, creating and innovating digital content; and (3) with the ethical training of the industrial engineer. (Capote et al., 2016) Universities will have a key role in the training of future industrial engineers. They must provide the necessary skills to face the new highly technological, multidisciplinary context interconnected in the management of complex industry 4.0 systems. They must assume leadership in the face of digital transformation processes and they must move towards new training processes based on academic innovations, intelligent, open and flexible curricula where novel and innovative learning predominates, and technological scientific innovations (Capote et al., 2016); which are necessary for the development of industry 4.0.

5. Conclusion

The systematic review of the scientific literature collected in the databases revealed the existence of a gap with reference to the digital skills or abilities of industrial engineers that are necessary for industry 4.0. Knowledge of new technology environments, new business models, in the culture of handling large amounts of data, autonomous learning, among others, has brought the need to create a new profile of the industrial engineer, who should not only have in-depth knowledge of their own specialization, but also of digital skills such as handling large volumes of data, collaborative communication in digital multidisciplinary teams, digital security and protection, solving complex engineering problems with the application of digital resources, technological thinking critic, creation of digital content, digital responsibility, among others. The industrial engineer is the main actor within this complex system that leads us to rethink their multidisciplinary, technological and holistic training that allows them to develop or enhance digital skills to successfully integrate into an industry 4.0. Universities will play a key role in the training of the future industrial engineer, contributing to the training of creative and technological industrial engineers who are carriers, not only of specialized knowledge, but also of skills and abilities to make decisions, allowing the development of a competent professional capable to interact and respond to economic, environmental and scientific-technological development problems. It is necessary to carry out new research on the digital skills that industrial engineers must be trained to face with speed, breadth and depth the great transformations that lie ahead. In this sense, the scientific debate is still open for future research on the digital skills or abilities that are necessary for an industrial engineer to successfully integrate into Industry 4.0 organizations.

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