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Conditions for the Development of Industry 4.0 from the Human Capital Technological Competences Perspective

Condiciones para el desarrollo de la industria 4.0 desde la perspectiva de competencias tecnológicas del capital humano

Avitia Carlos Patricia, Morales García Carlos Gerardo, Rodríguez Verduzco José Luis, Rodríguez Tapia Bernabe, Candolfi Arballo Norma

Facultad de Ciencias de la Ingeniería y Tecnología, Universidad Autónoma de Baja California, Blvd. Universitario 1000. Unidad Valle de las Palmas, Tijuana, Baja California. C.P. 21500

Autor de correspondencia: Patricia Avitia Carlos, Facultad de Ciencias de la Ingeniería y Tecnología, Universidad Autónoma de Baja California, Blvd. Universitario 1000. Unidad Valle de las Palmas, Tijuana, Baja California. C.P. 21500. Correo electrónico: patricia_avitia@uabc.edu.mx. ORCID: https://orcid.org/0000-0001-9448-7558.

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Resumen. - *La denominada Industria 4.0 sustenta su aparición y crecimiento en el empleo de técnicas de inteligencia artificial para el desarrollo de sistemas de producción cuya capacidad, eficiencia y adaptabilidad rebasen el desempeño de los sistemas actuales basados en computadora. La manufactura inteligente corresponde entonces a la digitalización e interconexión de dispositivos para la construcción de líneas de producción y proveeduría que compartan un flujo continuo de información. Esta revolución involucra el desarrollo de tecnologías tales como el Internet de las cosas, la analítica de datos y los cibersistemas con aprendizaje de máquina, entre otros. El desarrollo y sostenimiento de estos sistemas de manufactura avanzada representan un área de oportunidad para el crecimiento de la competitividad tecnológica de las economías regionales. Existen, sin embargo, necesidades formativas entre los profesionales de Ingeniería para el desarrollo de competencias tecnológicas específicas; así como de condiciones generales para el establecimiento de redes de innovación entre academia y sector productivo. El presente trabajo realiza, mediante el empleo de técnicas bibliográficas, una revisión de la literatura desarrollada en torno a la industria 4.0. Como resultado, presenta una revisión de las tendencias tecnológicas involucradas y discute el papel de las instituciones de educación superior en el desarrollo de capital humano competitivo. Se observan además múltiples áreas de oportunidad en el mediano y largo plazo para reforzar los programas de colaboración entre la universidad y la industria relacionados con esta adopción.*

Palabras clave: Industria 4.0; Capital humano; Competencias tecnológicas; Educación superior; Redes de innovación.

Abstract. - *The so-called Industry 4.0 supports its emergence and growth in the use of artificial intelligence techniques for the development of production systems whose capacity, efficiency and adaptability exceed the performance of current computer-based systems. Intelligent manufacturing corresponds to the digitization and interconnection of devices for the construction of production and supply chains that share a continuous flow of information. This revolution involves the development of technologies such as the Internet of Things, data analytics and cyber-systems aligned with machine learning, among others. The development and sustainability of these advanced manufacturing systems represent an area of opportunity for the growth of the technological competitiveness of regional economies. There are, however, training needs among engineering professionals for the development of specific updated technological competences; as well as a need of general conditions for the establishment of innovation networks between academia and the productive sector. This paper uses bibliographic techniques to examine existing literature and conducts a review on Industry 4.0. As a result, it presents an overview of the related technological trends and discuss the role of higher education institutions in the development of competitive human capital. There are also multiple areas of opportunity in the medium and long term to strength university-industry collaboration programs related to this adoption.*

Keywords: Industry 4.0; Human capital; Technological competences; Higher education; Innovation networks.

1. Introduction

The economic and social relevance of industrial revolutions lies in the fact that they not only technically modify the means of production, but also produce a social impact; which is located primarily in the labor market and the education system. As a result of the changes generated by these revolutions, some jobs and professions disappear as they become obsolete, while new jobs are emerging [1-2]. At the labor level, there is a need to strengthen specific technological competences in human capital, as well as to develop other emerging ones.

Industrial revolutions are identified as those disruptive changes that modify the goods production systems, market dynamics and organization labor. These changes have happened during the last two centuries as a result of a technological evolution. Thus, the first industrial revolution was the result of the introduction of steam engines in the manufacturing factories; the second arose from the use of electricity to develop technologies of mass production with the consequent division of labor; the third revolution used electronics and information technologies to develop greater automation of manufacturing [1,3-5]. On the other hand, the use of the Internet and various techniques of artificial intelligence places us now before a fourth industrial revolution, which has been called Industry 4.0 (I4.0).

We find that under the term I4.0 several intelligent technologies are included, which together affect the product manufacturing value chain; through the automation of production systems, the interconnectivity of digital devices, the flexibilization of manufacturing processes and, in general, the existing information communication and treatment among the different company levels and even outside it.

This fourth industrial revolution has also been constituted as a strategy for technological and economic competitiveness, sponsored by government agencies in various countries and devoted to the development of advanced manufacturing industry; among which are Germany (Industry 4.0), the United States (Nationwide Network for Manufacturing Innovation), China (Made in China 2025), France (La Nouvelle France Industrielle) and India (Make in India), among others [3,6-8].

The competition that countries such as China and India represent to manufacturing industries has forced developed countries to focus more on innovation, added value and services. Their companies are more willing to introduce new technologies that improve quality, make resources more efficient, reduce risks and allow them to remain competitive in the market. On the contrary, those companies that do not face technological challenges will also experience challenges to introduce new products and services, innovation and business models [9].

The present work realizes a revision of the technological competitions required in the human capital, from the emergent technologies that integrate the Industry 4.0; to explore the companies' competitive path for its establishment. An exploratory review of technologies, the suggested competencies and the role of higher education institutions is made.

The experiences collected point to the need to establish collaborations between the

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government-industry-university and the construction of specialized ecosystems that endow the value chain with human talent.

2. Methodology

A qualitative exploratory study is carried out. The Narrative Literature Review method is used, which consists in the completion of a narrative synthesis of previously published information that allows conclusions about the topic of interest to be drawn [10].

The main objective was to review existing literature and case studies, to extract and compare theories about the works' future as well as the required personnel competencies within the framework of Industry 4.0. Provided that in a Narrative Literature Review one of the possible purposes consists of the identification of problems or weaknesses within a research topic, and it is additionally considered useful to connect or relate different topics for reinterpretation [11]. Therefore, the selected methodology is considered adequate given the proposed objective.

Journal articles and conference proceedings about Industry 4.0 published in Scientific Databases were reviewed (Ebsco & IEEE) from year 2015 to date. Search terms included Industry 4.0 and Education or Competencies, for English or Spanish publications. Works describing experiences and / or implementation proposals were favored.

3. Discussion

3.1 Industry 4.0 context

The Industry 4.0 designation appears for the first time in Germany during the Hannover Fair 2011, as a term used to encompass the different disciplines and technologies associated with the development of intelligently interconnected, autonomous and flexible manufacturing processes [3-5].

I4.0 is frequently related to other terms such as Internet of Things (IoT), Cyberphysical Systems (CPS), Intelligent Systems and Digital Factories [9]; nevertheless, each of them constitutes a branch of its own technological development. Actually, I4.0 integrates nine different technological fields in industrial production processes: Autonomous Robots, Simulation, Horizontal and Vertical Systems Integration, Internet of Things, Cybersecurity, Cloud, Additive Manufacturing, Augmented Reality and Data Analytics [12].

Since its appearance, various definitions have been proposed around the I4.0, among which are those cited by [4]: *"the integration of com-plex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes";* or well, "*a new level of value chain organization and management across the lifecycle of products*". On the other hand, [9] define it as *"a revolution enabled by application of advanced technologies (like IT) at production level to bring new values and services for customers and organization itself".* As can be seen, the definitions vary from the perspective in which the I4.0 phenomenon is analyzed, whether it is technology, manufacturing or business. In summary, authors agree in the fact that there is no unanimous definition to date, given the broad field of technologies,

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manufacturing processes and business that it integrates [4,13].

Despite not having a universally accepted definition, it can be concluded that I4.0 generates disruptive changes in supply chains and business models. For it operates under the principles of interoperability, virtualization, decentralization, real-time capability, as well as an orientation to services and modularity [4]. The attributes commonly referred to as essential components of I4.0 are shown in Figure 1.

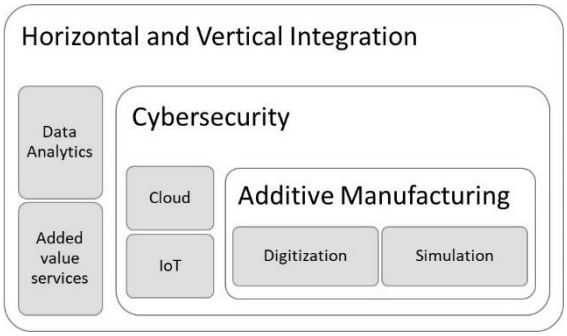

Figure 1. Industry 4.0 Attributes.

Although I4.0 has attracted increasing attention, there is still no detailed critical route for its realization [3]. For Hofmann & Rüsch [13], companies must be accompanied and supported in a practical way in this adoption path; since there is still a vague idea about the concept, the integrating technologies and its potential in financial terms. It has also been noted that the success in the implementation of these technologies will depend on the network integration capabilities and the engineering throughout the value chain [6]. The priority action areas to achieve I4.0 are listed in Table 1.

Table 1. Priority Action Areas according to Kagermann [3]

Priority Action Areas for I4.0
Standardization and Reference Architecture
Managing Complex Systems
Delivering a Comprehensive Broadband Infrastructure
Safety and Security
Work Organization and Design
Training and Continuing Professional Development
Regulatory Framework
Resource Productivity and Efficiency

3.2 Industry 4.0 human capital

There are several challenges associated with the 4.0 industry projects. One of these challenges is related to people, specifically the lack of qualified personnel [6, 12]. The qualifications and skills of employees will be greater than in the present, due to the use of new technologies and smart media in companies. Consequently, the work force will be key to the success of innovative factories [1].

In accordance with the review carried out, the formative features required to promote the establishment of I4.0 are presented in Table 2. It is believed that jobs that have to do with artificial intelligence' control and implementation will become more relevant, so there will be more job opportunities through specialized knowledge related to the technology to be implemented.

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Table 2. Proposed formative traits for the human capital development on I4.0

Authors	*Proposal*
Khan & Turowski, 2016 **[9]**	- Confidence and motivation. - Counteract change resistance. - Increase employee safety and awareness.
Ministry Economy, 2016 **[7]**	- Specialized professions in IoT and BigData will be required.
Demartini & Benussi, 2017 **[14]**	- Ability to self-organize central content of particular fields and master a large amount and variety of information. - Skills and competences for improvement and continuous and progressive self-regulation. - Transferable skills and competences that are directly applicable throughout various social, business and professional scenarios. - Skills and competences for lifelong learning, including knowledge construction, adaptability, ability to find, organize and obtain information, critical thinking and teamwork.
Benešová & Tupa, 2017 **[1]**	- One of the main problems will be the age and skills of the employees (for advanced information systems management). - The main required professions: Software Engineer, Programmers (Robot and / or PLC), Process and Manufacturing Engineers, Data Analysts, Cybersecurity, Technicians and Maintenance Engineers.
Moldovan, 2018 **[15]**	According to educational providers: - Creativity, cognitive flexibility, basic and social skills; According to SMEs: - Ability to solve complex problems, cognitive flexibility, critical thinking, technology and design of user experiences.
Martínez Ruiz **[2]**	- Future adaptation capacity. - Development of critical, creative and ethical skills for resilience.
Stankovski, 2019 **[16]**	- Multidisciplinary knowledge and experience.

From the human capital point of view, the different positions of the mentioned authors agree in the relevance of technological competencies for the development of I4.0, emphasizing the ability to learn and develop along with the appearance of new technical elements. In this sense, we take the definition of technological competence [17] in the companies context, as a "*set of cognitive, attitudinal and value dispositions that allows developing human capital inside of an organization, to interact and master the conscious or unconscious use of Information, Communication and Collaboration Technologies, as referred to the technological appropriation and incubation for innovation in services, processes or products that provide benefits and business growth, strictly based on the collaborative work of the personnel*". Thus, the development of transferable technological competences from the individual to the different levels of the company, from production to business management, would be part of the critical route towards I4.0.

3.3 Higher Education and I4.0

The participation of educational institutions is key in the development of national strategies to impulse I4.0 [1,3,6,7,8,16]. The educational framework that emerges must consider the complex relationship between all the ecosystem stakeholders (students, teachers, universities, companies, government). In this context, the main objective is to improve the efficiency of educational processes to make learning sustainable for any apprentice regardless of age or culture [14].

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The engineering education curriculum should then be rethought considering the design principles of Industry 4.0; merging theory with laboratory practices and the concepts of information technologies [12]. Incorporate virtual resources, virtual learning environments to transfer and develop knowledge and skills [1]. As well as enable appropriation of digital pedagogies, linked to unschooled training, through flexible, adaptive, multi-agent and resilient learning environments [2]. The indicated changes to the curriculum point to the need to provide flexibility (in time, space and contents), besides preparing the participant to face rapid technology changes, providing it with competences for self-learning and information technologies management.

In this human capital formation scheme, the companies preferred continuing education programs and / or workers retraining in collaboration with the academy; because the knowledge or *know-how* and the experience in the company' field is valued above the hiring of new employees [12,15]. To make possible the university-business collaboration for the I4.0 requires a revision of the collaboration mechanisms, including linking programs, science and technology communication and even education management [2]. It is necessary to clarify in this review the roles of the university and the company, as well as draw a detailed map of the collaborative projects [8]. The training of specialized consultants [6], international certifications and the construction of I4.0 clusters according to regional industrial vocations [7] are also suggested.

4. Conclusions

The empirical works that link higher education with the development of I4.0 are scarce, although it is pointed out as critical for its establishment. Likewise, the programs and strategies of different governments involve the development of technological vocations capable of joining the intelligent manufacturing industry and its value chain. The review carried out gathers reflections, experiences and strategies on I4.0. From these, we can observe the need for government support with a strategic project in the medium and long term for industries to develop the potential of I4.0. Despite not having a definitive route, it is clear that educational institutions have a determining role in the construction of competitiveness of human capital, from the technological educational programs offer, the curriculum update and the connection with the industry to offer continuous education programs and technical and professional certifications. The research future work on the subject should deepen in the collaboration schemes that involve the development of technological competitions, using flexible models and virtual learning environments, as well as virtual reality tools that could materialize in practical programs.

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