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PROFESSIONAL STANDARDS AS A FACTOR FOR ADAPTING HUMAN RESOURCES TO INDUSTRY 4.0: APPROACHES FOR DEVELOPMENT AND IMPLEMENTATION IN PUBLIC ADMINISTRATION

PADRÕES PROFISSIONAIS COMO FATOR DE ADAPTAÇÃO DOS RECURSOS HUMANOS À INDÚSTRIA 4.0: ABORDAGENS PARA O DESENVOLVIMENTO E IMPLEMENTAÇÃO NA ADMINISTRAÇÃO PÚBLICA

LOS ESTÁNDARES PROFESIONALES COMO FACTOR DE ADAPTACIÓN DE LOS RECURSOS HUMANOS A LA INDUSTRIA 4.0: ENFOQUES PARA EL DESARROLLO E IMPLEMENTACIÓN EN LA ADMINISTRACIÓN PÚBLICA

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ABSTRACT

The progressive advances experienced in the production chain throughout history have placed us before the 4th Industrial Revolution, also known as Industry 4.0 (I4.0), marked by the extensive use of the Internet, robotics and digitization. There is a great perspective that governments promote I4.0 technologies in order to improve the management of public resources, as well as to allow overcoming the limitations of processes and state bureaucratic structures. However, the technological transformations introduced by this concept fundamentally change the working conditions of organizations and bring serious implications for jobs and professions. In this sense, the objective of the present study is to investigate the essential skills and abilities of the workforce for the implementation of I4.0 in the public sector. For this, a literature review was carried out in the Google Scholar (GA), Web of Science (WoS) and Scopus database. Content analysis showed that, in addition to the need for technical knowledge, it is imperative that workers have the ability to work under pressure, coordinate and solve complex problems, in addition to personal responsibility in decision-making. In the end, it was possible to derive a synthesized table, which identifies the dimensions that should be considered when evaluating professional standards for adaptation to I4.0.

RESUMO

Os avanços progressivos experimentados na cadeia produtiva ao longo da história nos colocaram diante da Quarta Revolução Industrial, também conhecida como Indústria 4.0 (I4.0), marcada pelo uso extensivo da internet, robótica e digitalização. Há uma grande perspectiva que governos promovam tecnologias da I4.0, a fim de aperfeiçoar a gestão dos recursos públicos, bem como permitir a superação das limitações de processos e estruturas burocráticas estatais. Todavia, as transformações tecnológicas introduzidas por esse conceito mudam fundamentalmente as condições de trabalho das organizações e trazem sérias implicações para empregos e profissões. Nesse sentido, o objetivo do presente estudo é investigar as competências e habilidades essenciais à força de trabalho para implementação da I4.0 no setor público. Para isso, foi realizada uma revisão da literatura na base de dados Google Acadêmico (GA), Web of Science (WoS) e Scopus. A análise de conteúdo demonstrou que, para além da necessidade de conhecimento técnico, é imperioso que os trabalhadores possuam capacidade de trabalhar sob pressão, coordenar e resolver problemas complexos, além da responsabilidade pessoal na tomada de decisões. Ao final, foi possível derivar um quadro sintetizado, o qual identifica as dimensões que deverão ser consideradas ao se avaliar os padrões profissionais para adaptação à I4.0.

RESUMEN

Los progresivos avances experimentados en la cadena productiva a lo largo de la historia nos sitúan ante la 4ª Revolución Industrial, también conocida como Industria 4.0 (I4.0), marcada por el uso extensivo de Internet, la robótica y la digitalización. Existe una gran perspectiva de que los gobiernos promuevan las tecnologías I4.0, con el fin de mejorar la gestión de los recursos públicos, así como permitir superar las limitaciones de procesos y estructuras burocráticas estatales. Sin embargo, las transformaciones tecnológicas introducidas por este concepto cambian fundamentalmente las condiciones de trabajo de las organizaciones y traen serias implicaciones para los trabajos y profesiones. En este sentido, el objetivo del presente estudio es investigar las competencias y habilidades esenciales de la fuerza laboral para la implementación de I4.0 en el sector público. Para ello se realizó una revisión bibliográfica en la base de datos Google Scholar (GA), Web of Science (WoS) y Scopus. El análisis de contenido mostró que, además de la necesidad de conocimientos técnicos, es imperativo que los trabajadores tengan la capacidad de trabajar bajo presión, coordinar y resolver problemas complejos, además de la responsabilidad personal en la toma de decisiones. Al final, fue posible derivar una tabla sintetizada, que identifica las dimensiones que deben ser consideradas al evaluar los estándares profesionales para la adaptación a I4.0.

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INTRODUCTION

The transformations introduced in the industry, resulting from the relentless pursuit of competitiveness, changed the organization of the production process throughout history and became known as Industrial Revolutions (Avitia-Carlos et al., 2019). England was the birthplace of the first industrial revolution and introduced steam machines, hydraulic energy and mechanization into the production system. With the second industrial revolution, the use of electricity and the development of mass production techniques and rationalization of the productive process through division of labor were introduced. (Rabbit, 2016). The use of robotics was the major milestone of the third industrial revolution, whose focus was manufacturing automation, as evidenced by Ghobakhloo (2018) and Sakurai and Zuchi (2018).

The progressive advances experienced by the first three revolutions, which lasted almost 200 years, placed us before a new industrial milestone, which was conventionally called the Fourth Industrial Revolution or also Industry 4.0 (I4.0) strongly marked by the extensive use of technology (Internet, robotics and digitalization), in an integrated way, in the production environment. (Kagermann, Wahlster & Helbig, 2013). This concept was approached for the first time at the Hannover Fair, in 2011, in Germany, based on the idea that the integration of machines, systems and assets would allow the creation of "smart factories", which would have the autonomy to schedule maintenance, predict failures and make changes. in the productive processes, as mentioned by the authors Liao et al. (2018) and Oesterreich and Teuteberg (2016).

The principles of this new industry are solidified in virtualization, interoperability, decentralization, agility, service orientation, business process integration and real-time data management. In addition, nine disruptive technology trends form the basis of I4.0, namely: big data analytics, cloud computing, simulation, horizontal and vertical integration systems, robots, augmented reality, additive manufacturing and Internet of Things – IoT (Ustundag & Cevikcan, 2017; Vaidya, Ambad & Bhosle, 2018).

The innovations brought by I4.0 made production more autonomous and dynamic, since it is based on the integration of technologies, information and communication, allowing the production of extremely customized products, oriented to offer a higher level of customization per customer, combined with speed and large-scale production. This is possible due to the systematic collection and analysis of data on all machines, which makes processes more flexible, more dynamic, more efficient, and is reflected in increased product quality and cost reduction (Santos et al., 2017; Tortorella & Fettermann, 2018).

The implementation of the I4.0 concept in the production chain fundamentally changes the working conditions of organizations and brings serious implications for skills, competences, jobs and professions, given the complexity of future production systems. Intelligent manufacturing systems automate repetitive procedures, while requiring the development of extremely complex, interconnected activities with the processing of large volumes of data, which demand critical analysis (Erol et al., 2016; Mohelska & Sokolova, 2018).

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As in the private sector, public organizations are increasingly seeking the efficiency of their processes and the rationalization of expenses, in order to make it possible to improve the provision of services to society, as well as to promote accountability. This movement has driven the digitization of the public sector, requiring a profile of servers capable of interacting with various systems, performing data analysis and making smarter decisions in the face of a scenario of resource constraints. In this context, it requires organizations to adopt strategies for the development and qualification of the current and future workforce, so that employees are able to take on more strategic, coordinating and creative activities (Fitsilis, Tsoutsa & Gerogiannis, 2018; Hecklau et al., 2016; Stern et al., 2018).

In view of this, the need to adapt the professional profile of public servants to perform specific and up-to-date technological skills emerges, as well as the need to form more agile and multidisciplinary teams, capable of leading the public sector to I4.0. In this scenario, human capital is recognized as the country's strategic resource, playing an important role in creating the necessary conditions for the performance of innovation in public administration (Chulanova, 2019; Stern et al., 2018).

By approaching the social aspects of I4.0, studying the competencies and skills essential to the workforce to implement this concept in the public context, from the perspective of increasing efficiency and high performance, this study proves to be relevant, given the challenging task of manage professionals in public sector organizations.

In this direction, this study proposes to identify the competencies and skills essential to the workforce for the development of I4.0, aiming to apply these assumptions to the public sector. To achieve this objective, a literature review was carried out in order to gather the most important set of competences mentioned by the authors who study the subject, outlining the dimensions that must be observed to enable the adaptation of human resources to this new reality.

INDUSTRY 4.0

The Industry 4.0 concept appeared for the first time in Germany, during the Hannover Fair, in 2011, and was presented as a government strategy to increase the productivity and efficiency of the German industry, making use of high-tech innovations, in order to guarantee the strong competitive position of that country in the world market (Avitia-Carlos et al., 2019; Kagermann & Wahlster; Helbig, 2013).

Hermann, Pentek and Otto (2016) and Sacomano et al. (2018) mention that the fundamental elements of I4.0 represent the technological basis on which the concept itself is based and without which it would be unfeasible to consider its own existence, namely: Cyber-physical systems, Internet of Things (IoT), Internet of Services (IoS) and, specifically for Hermann, Pentek and Otto (2016), Smart Factory.

The authors explain that cyber-physical systems (CPS) control physical processes, through a virtual copy, within the modular structure of Intelligent Factories (smart factories), thus allowing the definition of solutions and decisions. The IoT makes possible, in real time, the

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communication and cooperation of the CPS among themselves and with humans, helping people and machines in the execution of their tasks. And, through IoS, participants in the value chain offer and use internal and external services to the organization.

In this sense, Müller, Buliga and Voigt (2018) corroborate by evaluating that I4.0 integrates all elements through the CPS, and that this level of interconnection allows the emergence of the Machine-Machine (MM), Human-Machine (HM) connection) and Machine-Human-Machine (MHM), which generates efficiency and results in the creation of value for the industry. Indeed, this new form of interaction presupposes the analysis and storage of data that are too large (Big Data) throughout the entire production chain, in order to enable preventive and corrective actions and adaptability, in real time, to altered conditions (Benešová & Tupa, 2017).

For Rübel et al. (2018), I4.0 enables a proactive business model, based on the management, optimization and integration of entire value networks, which carry out intelligent monitoring and allow autonomous decision-making. In view of this, I.4.0 favors customization, interaction and hybridity.

Still in this perspective, according to Li and Lau (2019), the actual monitoring of mass production in different locations, digitalization and the ability to solve problems proactively are fundamental components for understanding the concept of I4.0. In this logic, Dombrowski, Richter and Krenkel (2017) point out that I4.0 is an intelligent network, connected in real time, that interconnects people and equipment and its main objective is to improve process management and generate value in the production chain.

Based on the concepts presented, Hermann, Pentek and Otto (2016) defined I4.0 as a collective term for technologies and concepts of value chain organization. In Smart Factories, structured in a modular way, the CPS monitors and controls the physical processes, from a virtual copy, which enables decentralized decision-making. In IoT, CPS interact and cooperate with each other and with humans in real time, to achieve common goals. Through IoS, internal and interorganizational services are offered and used by participants in the value chain, allowing production processes to be autonomous.

The ability to predict failures, self-correction and flexibility of the production process are evidenced as characteristics of the I4.0, and are possible through the integration and connection, along the entire value chain, between sensors, work environments, machines and Information Technology systems using Internet protocols. In this way, the processes will be more agile, more flexible and more efficient, allowing the products to have reduced costs, but with high quality (Rüssmann et al., 2015).

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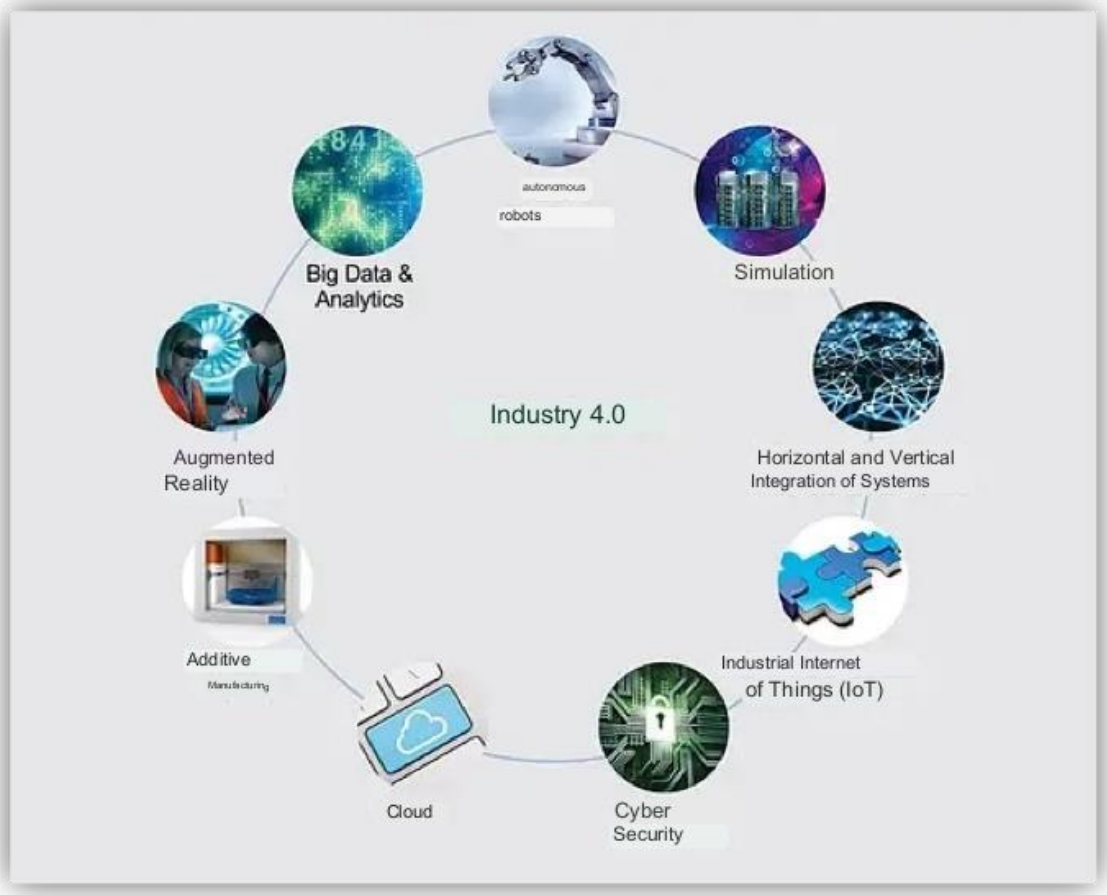
The transformations promoted by the technological advances of recent years are considered the pillars for the construction of I4.0 and are already being used, in large part, in production processes, but without exploring their potential for action when they interact with each other in real time and interconnected. Now, with the advent of I4.0, these technologies will transform production: isolated cells will come together providing a fully integrated, automated and optimized production flow, raising the level of efficiency and promoting changes in traditional production relationships. Figure 1 presents the nine fundamental technological advances that form the basis of I4.0 (Ejsmont, 2021; Rüssmann et al., 2015).

Figure 1. The 9 Enabling Technologies.



Source: Adapted from Rüssmann et al. (2015).

INDUSTRY 4.0 AND THE CHALLENGE OF HUMAN RESOURCES

Faced with this scenario, with highly interconnected and digitized production processes, in which the capacity for innovation becomes the competitive differential, given the constant and rapid changes in customer expectations and needs, it is imperative, in addition to investment in technology, the adoption of new qualification strategies for employees who will need to develop skills and knowledge to take on more strategic, coordinating and creative activities (Hecklau et al., 2016). Mohelska and Sokolova (2018) point out that most studies on I4.0 focus on technical aspects, without considering managerial approaches and organizational culture, according to which they are decisive for the conception of this concept.

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Despite the important theoretical construct around the concept of competence, this study considered the definition used by Chulanova (2019), which classifies competence as a set of knowledge, skills, attitudes and values necessary for the effective performance of a given activity. It involves the ability to apply knowledge and skills in an integrated way to achieve desired results. In the context of Industry 4.0, skills go beyond technical skills and also include socio-emotional skills such as critical thinking, creativity, adaptability, teamwork and communication skills (Avitia -Carlos et al., 2019).

One of the major challenges to be overcome for successful implementation of I4.0 is the proper education and training of the workforce. A survey conducted by PWC (2016), between November 2015 and January 2016, entitled “Global Industry 4.0”, in which around 2,100 companies from the industrial sector were interviewed around the world, indicated that among the most important challenges to be faced are: (1) lack of digital culture and training; (2) lack of clear vision for digital operations and leadership support; and (3) insufficiency of talents.

The study developed by Hartmann and Bovenschulte (2013) recognized that the necessary skills for I4.0 are numerous and diverse, and that similar or even identical technologies may require different human skills, depending on the organizational environment in which they are being applied. Therefore, the analysis of skills needs must consider the different effects of the same technologies in different sectors. Kusmin, Tammets and Ley (2018) highlight that these new practices oriented towards I4.0 technologies require skills and competences that are not yet known or taught by educational systems and training and recruitment institutions today.

Aires, Moreira and Freire (2017), point out that the profile required of workers was being changed with each industrial revolution, moving from manual work to increasingly intellectual work, which forced organizations to progressively worry about the training of its employees. In this sense, Romero et al. (2016) explain that the interaction of operators with these different industrial and digital production technologies can be understood as a generational evolution, which the authors define each generation of operators (Figure 2).

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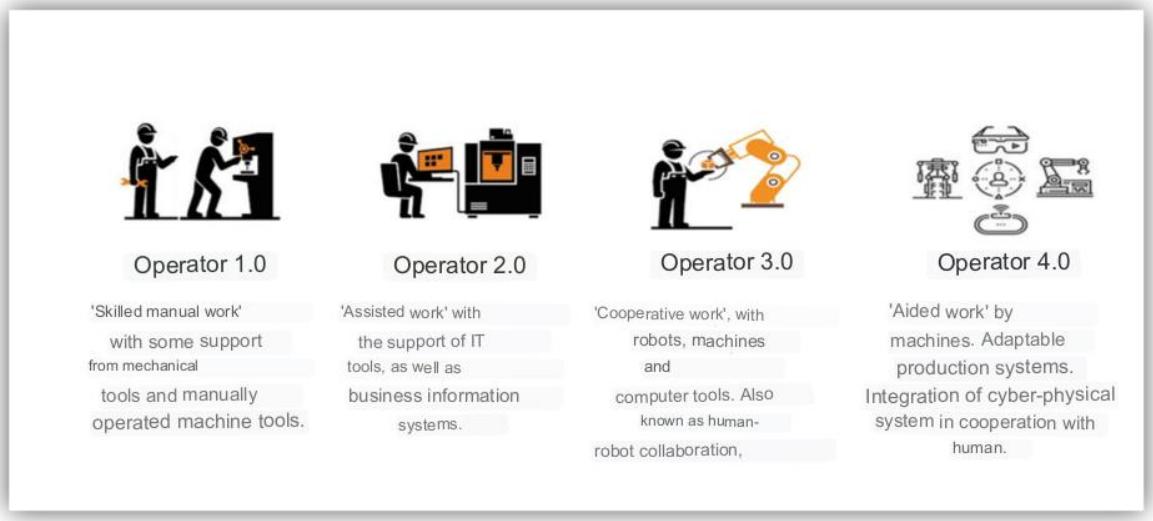
Figure 2. Evolution of generations of operators.



Source: Adapted from Romero et al. (2016, p. 25).

In this context, the abilities required in the production system, due to the use of these technologies in new combinations, demand additional skills and deeper knowledge from the future workforce, which will need to expand its proficiency in digitization, robots, technical computing, simulation, etc. Organizations will need to add to their technological transformation planning investments with workforce training and development programs, in order to guarantee the qualification of the personnel to use new tools and technologies (Fitsilis, Tsoutsa & Gerogiannis, 2018; Kusmin, Tammets & Ley, 2018).

In this sense, Hecklau et al. (2016) point out that in order to develop a workforce that meets the present and future needs of the market, it is fundamental to identify the essential competencies that meet these technological transformations and in the organization of work. Atzori, Iera & Morabito (2010) corroborate this by highlighting the need to develop a skills management method to educate and train employees, considering best practices based on experience and IT tools.

For Ghobakhloo (2018) and Hecklau et al. (2016), competency management requires organizations to carefully assess the set of skills present in their workforce, recognizing digital skills among current employees, in addition to identifying qualifications that company employees do not yet have. Therefore, it is still necessary that the result of this analysis, that is, the identified competences, be classified into pre-defined groups in order to guarantee greater clarity and transparency, thus allowing the definition of levels of knowledge and indication of areas for improvement.

INDUSTRY 4.0 AND PUBLIC ADMINISTRATION

The convergence of I4.0 technologies has the potential to help governments to improve efficiency in the use of resources, provides conditions to develop accountability, promoting institutional control of government activities through transparency and quality of accountability. The implementation of advanced technologies allows organizations to make

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decisions based on the data produced through big data analysis to solve challenges effectively. In this sense, the qualification of the workforce for this digital scenario is essential to achieve organizational strategic goals and a higher level of performance in the public sector (Al Amiri & Abu Shawali, 2021; Long et al., 2021).

However, the public sector often faces challenges related to the traditional bureaucratic model, which can interfere with the introduction of I4.0 technologies, especially with regard to the rigid hierarchical structure, with centralized decision-making, in addition to rules and procedures that can hinder the flexibility needed to adopt disruptive technologies. The introduction of Industry 4.0 often requires agility and adaptability, which can conflict with bureaucratic rigidity (OECD, 2018; Stern et al., 2018).

The idea of Digital Government arises from the new opportunities brought by the Fourth Industrial Revolution, which transform the way governments make use of technologies to effectively improve public management, as well as to create value by providing services to society. The digitization of public administration has enormous potential for improving the citizen's relationship with the government, in addition to enabling the optimization of the workforce, which will no longer perform repetitive activities, as happens in the private sector (Stern et al., 2018).

The use of Information and Communication Technologies (ICTs) in public organizations, based on computer, software and network, are no longer new, but the fusion of these technologies is causing disruptions globally and nationally, which demand from these institutions new professional standards that meet speed and breadth of the innovations that are taking place. The collaborative use of these technologies is capable of providing transformative experiences of delivering public services to citizens. The I4.0 paradigm projects a new face of future governments, realigning public service delivery processes according to the personal and contextual needs of citizens (Malhotra, Anand & Soni, 2020; Schwab, 2019).

For Stern et al. (2018), new technologies will require new professional skills, new professions will emerge and need professionals, while others will be extinct. Thus, the participation of the government becomes essential to allocate human capital properly and encourage it to qualify for it. Human resource management departments in public organizations will need to adapt to the demands arising from advances associated with I4.0, understanding that some skills have become obsolete, while other skills, especially those related to digital innovation, have emerged.

The study developed by the Organization for Economic Cooperation and Development (OECD) (2018) demonstrated that in the Brazilian public sector, people are insufficiently qualified in data analysis, and that there is a lack of personnel to implement the policies outlined in the Digital Governance Strategy. Digital competences are still seen as a technical skill and not as a fundamental strategic competence for most professional profiles.

Public authorities normally interact with a large amount of data and the information is available in different formats and can be published and manipulated easily. Therefore, it is

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essential that public servants have the ability to properly analyze the data and information generated, in order to transform them into useful knowledge for decision-making (Fredriksson et al., 2017). In addition, as today's society is being technologically oriented, it is necessary that public servants have at least basic ICT skills in computer packages, internet and other emerging technologies to adapt to this new scenario of digital services (Van Laar et al., 2020).

Digitizing service interactions in the public sector is a complex challenge that requires coordination between different levels of government. However, public organizations have been subjected to progressively stricter financial regimes, in addition to the increase in competitive market forces and greater control by society regarding the use of public resources. This scenario imposes the replacement of traditional management characteristics by more efficient techniques, which demonstrate to society the effectiveness of government actions. Therefore, it is important that HR practices act in a way that enhances individual and organizational performance in public sector institutions (Knies et al., 2015; Stern et al., 2018).

METHODOLOGY

Initially, a narrative bibliographic review was carried out in order to understand the emergence, origin and concepts of I4.0, identifying the trends of disruptive technologies that support its implementation. In addition, the research also focused on studies that address human capital in the context of this new industrial revolution, highlighting the impacts on jobs.

The choice of this method of scientific investigation is based on the acquisition and updating of knowledge, making it possible to obtain a comprehensive view of the publications that address this topic, in order to describe and synthesize, in narrative terms, the state of the art, in addition to discussing opportunities for development and improvement of human resources, within the scope of the public service (Rother, 2007).

For the narrative review, Google Scholar and Scopus were used as a scientific database, using the keyword "Industry 4.0" associated with terms such as "Human Capital", "Human Skills" and "Human Resources", essentially in Portuguese and English. Also, studies of countries strongly marked by the use of I4.0 technologies were considered, such as Germany, Poland and Estonia, in the latter, mainly with regard to digital governments.

The selection of studies was based on a careful analysis of the content, with the aim of identifying documents that addressed the relationship between I4.0 and human skills and abilities, as well as actions that contribute to its development. It was decided to select only the studies whose available version was in full text. The selected studies were entered into the Mendeley software and duplicates were eliminated.

The analysis of the texts considered the frequency of occurrence of certain competences and professional profiles, in order to allow the condensed presentation of the information. In this sense, this article made use of synthesized tables, which associated the findings of the literature, the main definitions and constructions on the subject and the authors who cited these concepts, in order to demonstrate the state of the art and the perspective of adapting resources humans at I4.0 (Figure 3).

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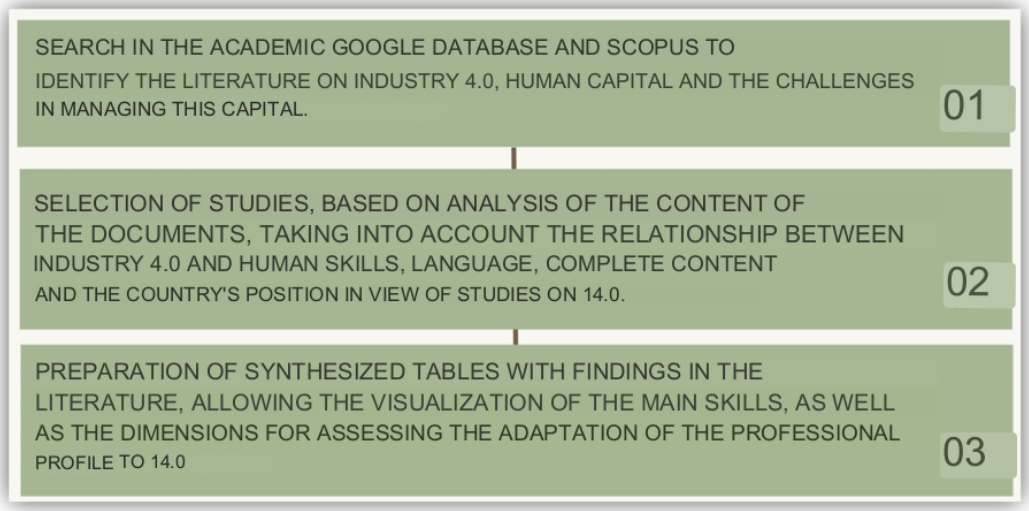
Figure 3. Research Steps.



Source: Authors (2022).

RESULTS AND DISCUSSION

Most authors identify four main categories to classify competences, namely: technical, methodological, social and personal. The definition of the characteristics of each classification is reflected in Table 1 with the respective identification of some of these authors.

Table 1. Classification of I4.0 competences derived from the literature.

Skills	Definition	Authors
Techniques	They involve cutting-edge knowledge, process understanding, technical skills and all job-related skills.	(Fitsilis et al., 2018; Hecklau et al., 2016; Imran & Kantola, 2019)
Methodological	They include all skills and abilities for general problem solving and decision making. In addition, this concept involves creativity, entrepreneurial thinking, analytical skills, research skills and efficiency orientation.	
Social	They cover attitudes of cooperation and communication, as well as intercultural and linguistic skills, ability to work in a team, capacity for commitment, ability to transfer knowledge and leadership skills.	
Personal	They comprise social values, individual motivations, flexibility, tolerance for ambiguity, motivation to learn, ability to work under pressure and sustainable mindset.	

Source: Authors, based on the literature (2022).

For Erol et al. (2016), workforce skills for future production are classified based on their relationship with some type of task and the ability to fulfill that task. In this sense, the author defined these skills as follows: (1) personal skills, which include acting in a reflective and autonomous way; (2) social/interpersonal skills, which involve the ability to communicate and cooperate and to establish connections with other individuals and groups; (3) competences related to action, which concerns the realization of individual or socially constructed ideas, in addition to the ability to successfully transform plans into reality; and (4) domain-related competencies, which refer to the ability to access and use domain knowledge for a specific job or task.

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Chulanova (2019), in a study carried out in Australia on the impact of I4.0 on employees, identified that the most important individual skills are: technical skills, problem solving, coding skills, analytical skills and the ability to work under pressure.

Jerman, Bach and Bertoncelj (2018) developed a study in which they reviewed the topic of competencies that will be present in I4.0 smart factories, through a bibliometric analysis and topic mining in 43 journal articles and conference papers. The results of the study indicated the necessary future competences (Table 2).

Table 2. Classification of skills.

Technical Skills	Methodological Skills	Social Skills	Personal Skills
Understanding of IT security	Creativity	Overview (overview competency, integration competency)	Commitment to lifelong learning
Coding Features	Problems solution	Ability to lead	Personal flexibility
Process understanding	Creativity to solve problems	Effective communication skills in complex situations	Motivation to learn
technical capabilities	Conflict resolution	Network Competency	Adaptability
Understanding the analogies of how new technologies work	Ability to act as mediators in decision-making processes	Ability to participate and work in a team	Ability to work in stressful situations
Ability to solve complex challenges	Analytical Skills	Language Skills	Social Responsibility
-	Research Skills	Ability to transfer knowledge to others	The correct distinction between important and less important information

Source: Adapted from Jerman, Bach e Bertoncelj (2018, p. 9).

The new skills required due to changes in business models will result in a major rupture in the organization's human resources management, given that these new technology-oriented practices still do not make up the methodological basis of today's educational institutions, and even, nor are they fully known, since changes are constant and dynamic. New job categories will emerge, partially or totally replacing others, which will substantially challenge the current way organizations carry out recruitment, training and talent management. The impact of these disruptive changes in employment increases the possibility of simultaneous unemployment and a shortage of skilled labor (Kusmin, Tammets & Ley, 2018; Shevyakova et al., 2021; World Economic Forum, 2016).

Kusmin, Tammets & Ley (2018) point out that the difficulties in recruiting qualified labor are related, among many other reasons, to the considerable difference between what is offered by the educational system and what the labor market really needs. The report prepared by the World Economic Forum (2016) shows that efforts aimed at filling skills gaps need to start from a close collaboration between companies and governments, in an action aimed at managing the transition of the workforce to I4.0.

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Karre et al. (2017) also made contributions in this area when they elaborated a list of skills and abilities of I4.0 employees, which the authors structured into technical and personal skills that the worker "must have", "should have" and "could have" (Table 3).

Table 3. Classification of Required Skills and Qualifications.

	MUST HAVE	SHOULD HAVE	COULD HAVE
Personal skills	IT knowledge and skills; Processing and analysis of data and information; Statistical knowledge; Organizational and procedural knowledge; Ability to interact with modern interfaces.	Knowledge Management; Interdisciplinarity / Generic knowledge about technologies; Awareness for security and data protection; Specialized knowledge of manufacturing activities and processes.	Coding and Computer Programming Skills; Specialized knowledge about technologies; Awareness about ergonomics; Understanding of legal matters.
Technical skills	Time management; Adaptability/Ability to change; Ability to work in a team; Social Skill; Communication Skill.	Believing in new technologies; Continuous Improvement and Lifelong Learning.	-

Source: Adapted from Karre et al. (2017, p. 209).

The Future of Jobs Report (WEF, 2016) highlighted the need to make broader and longer-term changes in basic and lifelong education systems, in addition to highlighting the need to undertake specific, urgent and focused reskilling efforts. In each sector. In this sense, the study concluded that there are four areas with short-term implications and three that are critical for the long term (Table 4).

Table 4. Recommendations for Action.

immediate focus	Reinventing the HR Role	Requires proactively adapting to the new talent landscape, managing skills disruption as a pressing concern.
	Making use of data analysis	It suggests that companies and institutions implement a new approach to workforce planning and talent management, based on forecasting data and metrics.
	talent diversity	Enable an approach that encourages workforce diversity, allowing companies to adapt and thrive in a changing marketplace.
	Leveraging flexible working arrangements and online talent platforms	Companies need to be agile in the way they think about managing and organizing people's work and the workforce as a whole, as they will increasingly connect with freelancers and independent professionals through digital talent platforms.
ong term focus	Rethinking educational systems	It imposes efforts to reform the existing education system, which are impeding progress on current talent and labor market issues. The challenge is to prepare the curriculum for the 21st century, equipping today's students to meet tomorrow's skill needs.
	Encouraging lifelong learning	Promotion of the total requalification of the aging workforce and implementation of initiatives that motivate the workforce to recycle throughout life.
	Interprofessional and public-private collaboration	Development of cross-sector partnerships and collaborations to leverage each partner's expertise in a complementary way to produce scalable solutions to jobs and skills challenges.

Source: Authors, based from World Economic Forum (2016).

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Rapid transformations require agile and interdisciplinary teams, capable of adapting to changes, in order to lead the institution to higher levels of efficiency. To ensure and maintain a workforce acting efficiently, with regard to the development of skills and competencies, it is necessary to engage them before the implementation of I4.0 strategies, assessing the perception of workers in undertaking these changes and adapting to the fourth industrial revolution (Chulanova, 2019; Grzelczak, Kosacka & Werner-Lewandowska, 2017; Stern et al., 2018).

Thus, the first step to be considered is the readiness of human resources to I4.0, identifying the skills that already make up the work team and which individual skills need to be developed. In addition, it is imperative that workers have training opportunities through training and continuing education policies in the environments they are inserted in and from government initiatives, in the medium and long terms, that enhance the formation of qualified human capital that corresponds to the new professional standard demanded by the market (Avitia-Carlos et al., 2019; Haleem & Javaid, 2019).

From the narrative review of the literature, it was possible to identify seven dimensions that should be considered when evaluating professional standards for I4.0 (Table 5).

Table 5. Dimensions for evaluating the adaptation of the professional profile to I4.0.

Dimension	Goal	Variables	Theoretical Basis
1. Human Capital Recognition	Identify knowledge and skills needs within the scope of the activities carried out	- Self-perception of current and desired training and qualification; - Technical qualification requirements of the position; - Specialized human capital gaps.	(Antosz, 2018; Chulanova, 2019; Hecklau et al., 2016; Imran & Kantola, 2019; Jerman et al., 2018)
2. Education, Learning and Knowledge	Check the level of training and qualification of the workforce	- Academic education; - Specialization and Curriculum Update; -Technical and Vocational Courses.	(Arun, Krishnakumar e Das, 2020; Avitia-Carlos et al., 2019; Chulanova, 2019; Hecklau et al., 2016)
3. Digital Culture	Identify the dimension of interaction of activities with systems and machines and the adherence of human capital to the digitization of processes	- Number of systems used in the execution of activities; - Level of domain of activities in information systems; - Knowledge and mastery of ICTs; - Internet access, machinery, suitable equipment.	(Mohelska & Sokolova, 2018)
4. Leadership Support	Evaluate senior management's commitment to implementing policies to encourage qualification and investment in innovation	- Training programs in digital skills; - Clearly defined policy and long-medium and long-term planning; - Initiative to spread knowledge about how exponential technologies work and what is their importance for management; - Support for innovative solutions and adoption of new technologies.	(Chulanova, 2019; Mohelska & Sokolova, 2018)
5. Formation of Multidisciplinary Teams	Evaluate the ability to interact with different areas of knowledge and develop multiple skills	- Interdisciplinary programs of training;	(Chulanova, 2019; CNI, 2017; Karre et al., 2017)

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6. Behavioral Attitudes	Evaluate the self-perception of employees in relation to the required behavioral attitudes necessary for I4.0.	- Critical Thinking; - Act under pressure; - Team work; - Communication; - Adaptability.	(Fitsilis et al., 2018; Hecklau et al., 2016; Imran & Kantola, 2019; Jerman et al., 2018; Karre et al., 2017; van Laar et al., 2020)
7. Corporate Education	Evaluate the programs for the development of collective skills and the ability to transfer knowledge and skills developed in the activities performed.	- Existence of procedure manuals; - Existence of programs for sharing experiences and collaboration; - Recycling and Requalification Programs; - Benchmarking initiatives.	(Chulanova, 2019; Hecklau et al., 2016)

Source: Authors, based from literature (2022).

The result of the analysis of skills needed for I4.0 showed that, in addition to the need for technical knowledge, which involves information technology, digitization, processing and data analysis, it is also necessary for workers to have problem-solving skills, personal responsibility in decision-making, ability to coordinate complex work processes and ability to work under pressure.

In this way, the result presented in Table 6 can be understood as a strategic roadmap of common steps, which current managers can consider in their search for the transition and adaptation to I4.0, paying attention to the different configurations of each work environment, from in order to avoid generalizations, since the analysis of the desired professional standards may vary according to the specific characteristics and needs of each public organization, as well as the established objectives and priorities.

FINAL CONSIDERATIONS

Successive industrial revolutions significantly changed work processes and, consequently, transformed the way workers interact in production environments. The technologies that support I4.0 require organizations to have human resources with skills and competencies that enable the development of an innovation ecosystem, capable of keeping up with the global modernization trend. One of the great challenges to be overcome for the successful implementation of I4.0, in any organizational environment, is the adequate education and training of the workforce.

The specificities present in the work environment directly affect the set of skills that professionals must possess. For example, in a government context, civil servants may need to develop specific competencies related to public policy management, inter-agency collaboration, public service delivery and accountability to citizens. These competences are shaped by the particularities of the public sector and the demands of the public service.

Furthermore, based on this study, it is possible to infer that the evaluation of the professional standard of human resources for adaptation to I4.0 permeates seven dimensions, which involve 1) Recognition of Human Capital; 2) Education, Learning and Knowledge; 3) Digital Culture; 4) Leadership Support; 5) Performance of Multidisciplinary Teams; 6) Behavioral Attitudes; and 7) Corporate Education.

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Skills and abilities are fundamental pillars of a digitally enabled state. In this sense, it is salutary that governments and companies, in addition to financial investments in technology and innovation, adopt measures based on competence management and the use of common professional standards, preparing a plan for the development of workers' competences aimed at filling skills gaps, implementation of qualification incentive policies, talent management, recruitment, training and specific technical requalification, complemented with approaches for developing social skills and collaboration.

Furthermore, implementing digital government requires significant changes in public sector structures and processes. This may be resisted by civil servants accustomed to traditional practices. To overcome these challenges, managers need to prioritize the dissemination of an organizational culture that values and encourages the development of new skills, especially digital ones. Public servants should be encouraged to pursue development opportunities, and the organization should provide support and resources to facilitate this process.

Adoption of I4.0 technologies requires effective governance and careful change management. It is important to establish adequate governance structures, involve public servants in the planning and implementation stages, and clearly communicate the benefits and objectives of adopting these technologies in the workplace.

This article is not intended to deepen the understanding of the enabling technologies of I4.0, nor its use. However, it is important to understand how complex these new technologies can be, as their introduction into the work environment will determine the skills to be required of workers who will use them.

REFERENCES

Aires, R. W. do A., Moreira, F. K., Freire, P. de S. (2017). Indústria 4.0: Competências requeridas aos profissionais da quarta revolução industrial. Foz do Iguaçu/PR. [*Anais do Congresso Internacioanal de Conhecimento e Inovação-ciki*]. Foz do Iguaçu/PR: ciki, 1-15. Recuperado de https://proceeding.ciki.ufsc.br/index.php/ciki/article/view/314%0A.

Al Amiri, N. & Abu Shawali, A. (2021). *Talent management strategies of a public uae hospital in the industry 4.0 Era: A qualitative analysis.* [S. l.]: LLC CPC Business Perspectives.

Antosz, K. (2018). Maintenance–identification and analysis of the competency gap. *Eksploatacja Niezawodność, Rzeszów*, Poland, 20(3), 35-959.

Arun, K., Krishnakumar, U., & Das, D. (2020). Convergence of csr and industry 4.0. recent trends in indian public sector enterprises. Detroit, Michigan. *Proceedings of the International Conference on Industrial Engineering and Operations Management.* Detroit, Michigan: [s. n.]. 3955-3961.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks*, [s. l.], 54(15), 2787-2805.

Avitia-carlos, P. et al. (2019). Conditions for the Development of Industry 4.0 from the Human Capital Technological Competences Perspective. *Revista de Ciencias Tecnológicas*, [s. l.], 2(4), 159-165.

Citation (APA): Araújo, B. de J. M. & Souza, A. A. de, Jr. (2023). Professional standards as a factor for adapting human resources to industry 4.0: approaches for development and implementation in public administration. *Brazilian Journal of Production Engineering,* 9(3), 114-131.

Benešová, A. & Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manufacturing*, [s. l.], 11. 2195-2202.

Chulanova, Z. K. (2019). Professional standards as a factor of adaptation of human resources to the Industry 4.0: approaches to development and implementation. *Journal of Human Resource Management,* Slovakia, 22(1), 12-20. Recuperado de www.jhrm.eu

Coelho, P. M. N. (2016). *Rumo à Indústria 4.0 Towards Industry 4.0.* 65 f. Universidade de Coimbra, Coimbra. Recuperado de http://hdl.handle.net/10316/36992

Confederação Nacional da Indústria. (2017). *Relações trabalhistas no contexto da indústria 4.0*. Brasília: CNI. Recuperado de http://conexaotrabalho.portaldaindustria.com.br/media/publication/files/Relacoes_trabalhistas_web.pdf

Dombrowski, U. Richter, T., & Krenkel, P. (2017). Interdependencies of Industrie 4.0 & Lean Production Systems: A Use Cases Analysis. *Procedia Manufacturing*, [s. l.], 11, 1061-1068.

Ejsmont, K. (2021). The impact of industry 4.0 on employees—insights from Australia. *Sustainability*, [s. l.], 13(6), 3095.

Erol, S. et al. (2016). Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production. *Procedia CIRP*, [s. l.], 54, 13-18.

Fitsilis, P., Tsoutsa, P., & Gerogiannis, V. (2018). Industry 4.0: Required personnel competences. *International Scientific Journal "Industry 4.0",* [s. l.], 3(3), 130-133.

Fredriksson, C., et al. (2017). Big Data in the Public Sector: A Systematic Literature Review. *Scandinavian Journal of Public Administration*, 21(3), 39-62. Recuperado de http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed14&NEWS=N&AN=365050985

Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910-936.

Grzelczak, A., Kosacka, M., & Werner-lewandowska, K. (2017). Employees competences for industry 4.0 in Poland–preliminary research results. *24th International Conference on Production Research, ICPR 2017*, Poznan, Poland, 139-144.

Haleem, A. & Javaid, M. (2019). Additive Manufacturing Applications in Industry 4.0: A Review. *Journal of Industrial Integration and Management*, 4(4), 1930001.

Hartmann, E. A. & Bovenschulte, M. (2013). Skills Needs Analysis for "Industry 4.0" based on Roadmaps for Smart Systems. Using Technology Foresights for Identifying Future Skills Needs. *Global Workshop Proceedings,* Moscow, 24-36. Recuperado de http://www.bmbf.de/pubRD/Umsetzungsempfehlungen_Industrie4_0.pdf

Hecklau, F., et al. (2016). Holistic Approach for Human Resource Management in Industry 4.0. *Procedia CIRP*, [s. l.], 54, 1-6.

Hermann, M., Pentek, T., & Otto, B. (2016). Design principles for industrie 4.0 scenarios. *49th Hawaii international conference on system sciences (HICSS),* [s. l.], 3928-3937. Recuperado de www.snom.mb.tu-dortmund.de

Imran, F. & Kantola, J. (2019). Review of industry 4.0 in the light of sociotechnical system theory and competence-based view: A future research agenda for the evolute approach. *Advances in Intelligent Systems*

Citation (APA): Araújo, B. de J. M. & Souza, A. A. de, Jr. (2023). Professional standards as a factor for adapting human resources to industry 4.0: approaches for development and implementation in public administration. *Brazilian Journal of Production Engineering,* 9(3), 114-131.

and Computing. [S. l.]: Springer Verlag. 118-128.

Jerman, A., Bach, M. P., & Bertoncelj, A. (2018). A bibliometric and topic analysis on future competences at smart factories. *Machines*, 6(3), 41.

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Securing the future of German manufacturing industry recommendations for implementing the strategic initiative industrie 4.0. *Germany: Federal Ministry of edu-cation and research, Final report of the Industrial 4.0 working group*. Frankfurt.

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative industrie 4.0: Securing the future of German manufacturing industry. *Final report of the Industrie 4.0 Working Group*. Berlim, Germany: Forschungsunion.

Karre, H., et al. (2017). Transition towards an Industry 4.0 State of the LeanLab at Graz University of Technology. *Procedia Manufacturing*, 9, 206-213.

Knies, E., et al. (2015). Special issue of international journal of human resource management, strategic human resource management and public sector performance. *The International Journal of Human Resource Management*, [s. l.], 26(3), 421-424.

Kusmin, K. L., Tammets, K., & Ley, T. (2018). University-industry Interoperability Framework for Developing the Future Competences of Industry 4.0. *Interaction Design and Architecture(s)*, 38, 28-45.

Li, C. H. & Lau, H. K. (2019). A critical review of maturity models in information technology and human landscapes on industry 4.0. *IEEE International Conference on Industrial Technology (ICIT*). [S. l.]: IEEE. 1575–1579.

Liao, Y., et al. (2018). The impact of the fourth industrial revolution: A cross-country/region comparison. *Production*, [s. l.], 28.

Long, C. K., et al. (2021). *A big data framework for E-Government in Industry 4.0*. [S. l.]: Walter de Gruyter GmbH.

Malhotra, C., Anand, R., & Soni, V. (2020). Creating Public Services 4.0: Sustainable Digital Architecture for Public Services in India. *Indian Journal of Public Administration*, [s. l.], 66(3), 327-342.

Mohelska, H. & Sokolova, M. (2018). Management approaches for industry 4.0 – The organizational culture perspective. *Technological and Economic Development of Economy*, [s. l.], 24(6), 2225-2240.

Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, [s. l.], 132, 2-17.

OECD (2018), *Digital Government Review of Brazil: Towards the Digital Transformation of the Public Sector*. OECD Digital Government Studies, OECD Publishing, Paris, Recuperado de https://doi.org/10.1787/9789264307636-en

Oesterreich, T. D. & Teuteberg, F. (2016). *Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry*. [S. l.]: Elsevier B.V.

Pwc. (2016). *Indústria 4.0: Construir a empresa digita*l. Portugal: PricewaterhouseCoopers. Recuperado de www.pwc.pt/industria40

Citation (APA): Araújo, B. de J. M. & Souza, A. A. de, Jr. (2023). Professional standards as a factor for adapting human resources to industry 4.0: approaches for development and implementation in public administration. *Brazilian Journal of Production Engineering,* 9(3), 114-131.

Romero, D., et al. (2016). The operator 4.0: Human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems. *IFIP Advances in Information and Communication Technology*, Springer, Cham, 488, 677-686.

Rother, E. T. (2007). Revisão sistemática X revisão narrativa. *Rev. Acta Paulista de Enfermagem*. 20(2), v-vi.

Rübel, S., et al. (2018). *A maturity model for business model management in industry 4.0*. Lüneburg, Germany: Leuphana Universität Lüneburg, Institut für Wirtschaftsinformatik.

Rüssmann, M., et al. (2015). *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*. Boston consulting group, [s. l.], 9(1), 54-89.

Sacomano, J. B., et al. (2018*). Indústria 4.0: conceitos e fundamentos*. São Paulo: Blücher.

Sakurai, R. & Zuchi, J. D. (2018). As revoluções industriais até a indústria 4.0. *Revista Interface Tecnológica*, [s. l.], 15(2), 480-491.

Santos, K., et al. (2017). Opportunities Assessment of Product Development Process in Industry 4.0. *Procedia Manufacturing*, [s. l.], 11, 1358-1365.

Schwab, K. (2019). *A Quarta Revolução Industrial*. [S. l.]: Edipro.

Shevyakova, A., et al. (2021). Competence development for Industry 4.0: Qualification requirements and solutions. *Insights into Regional Development*, [s. l.], 3(1), 124-135.

Stern, S., et al. (2018) *Public Services Government 4.0–the public sector in the digital age, Leading in a disruptive World.* [S. l.]: McKinsey & Company Visual.

Tortorella, G. L. & Fettermann, D. (2018). Implementation of industry 4.0 and lean production in brazilian manufacturing companies. International *Journal of Production Research*, 56(8), 2975-2987.

Van Laar, E., et al. (2020). *Determinants of 21st-Century Skills and 21st-Century Digital Skills for Workers: A Systematic Literature Review*. [S. l.]: SAGE Publications Inc.

World Economic Forum. (2016). *The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution.Global Challenge Insight Report.* Geneva, Switzerland: WEF. Recuperado de http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf