New Professional Competencies and Skills Leaning towards Industry 4.0

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Abstract: Industry 4.0, the so-called fourth industrial revolution, has been popularized by a German government project to promote digitization and automation, and has become a global strategy disseminated throughout several countries. It is widely used by researchers and mentors in different contexts and studies on opportunities, risks and challenges concerning employability. Therefore, this study aims to address the challenges of recruiters in the face of trends in new skills, profiles, and professional competencies for safeguarding jobs. Its method involves a systematic literature review using the keywords "Human and Machine Learning" and "Industry 4.0 and Education". Bibliometrics was performed on works published on the theme during the latest decade. Results demonstrate the importance of updating Human Resources and Educational policies within the development of new skills and competencies to meet the new professional profile requirements and ensure human employability.

1 INTRODUCTION

Mastery of technologies to produce goods and services is the backbone of a nation's economy (Sivathanu and Pillai, 2018). All industrial revolutions influenced methods of production, the labor market and the educational system, due to changes in the manner of producing (Longo, Nicoletti and Padovano, 2017).

In each of the four industrial revolutions, there have been resulting in the extinction of some professions and the generation of others, therefore it is necessary to update the way of teaching because of new technologies requires more qualified employees (Crawley et al., 2014; (Benešová and Tupa, 2017).

The fourth industrial revolution conceptually referred to as intelligent industry or simply Industry 4.0 (I4.0), marks the effect of digitization on the production system and integrates physical, digital and biological spheres through the Internet of Things (IoT), Cyber-Physical Systems (CPS), Artificial Intelligence (AI), robotics and biotechnology (Shamim et al., 2016).

I4.0 has modified production processes and effected a change in the necessary skills and competencies of human workforce in their jobs (Karre et al., 2017). Such disruptive modifications in the manufacturing system will allow the use of intelligent technologies, with processes monitored in real time and products and services developed in shorter and efficiently customized periods (Liboni et al., 2019).

Workers will no longer be mere operators who solve process deviation or failure problems and perform non-routine tasks dealing with a large amount of data (Karre et al., 2017) and combining technical and transversal skills to interact with modern, complex interfaces and take suitable decisions (Kazançoglu and Özkan Özen, 2018).

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Therefore, it is important to establish new criteria to recruit and evaluate the human workforce (Kazançoglu and Özkan Özen, 2018). I4.0 is not only about intelligent algorithms, artificial intelligence, machine learning and autonomous systems (Stachová et al., 2019), but also workers with autonomy and Education, as technology can provide support, but it still does not replace human skills (Zhao et al., 2019.

2 LITERATURE REVIEW

2.1 Industry 4.0 (I4.0)

Industry 4.0 (I4.0) is a term that was coined in Germany during the Hannover fair and has been influencing factories in different branches and segments worldwide (Gorecky et al., 2014; Gabor, Szabó and Ahmed, 2017; Fernández-Caramés and Fraga-Lamas, 2018).

It starts a one-way process to automate repetitive and monotonous activities performed by humans, while at the same time requiring human decisions in solving more complex problems (Bauer, Schlund and Vocke, 2017). Among the fundamental concepts of I4.0, it is interconnection to physical and virtual assets by sensors and actuators driven by microcomputers linked to autonomous machines (Spöttl, 2017).

Human participation in the development of I4.0 towards digitalization through studies that address different objectives indicate a lack of qualified workers concerning needed skills (Shamim et al., 2016). In addition to technological changes in Education and work organization, I4.0 brings changes regarding job profiles and competencies (Dumont, Rayp and Willemé, 2012), which leads to job losses according to the level of qualification (Daling et al., 2018) and how the individual achieves success in specific tasks (Holm, 2018).

2.2 Cyber Physical Systems (CPS)

This CPS is the foundation of I4.0 by connecting all physical devices to the IoT and incorporating the functions of computing, communications, control and coordination of a virtual environment integrated with the physical world (Zhou, Liu and Zhou, 2015).

CPS requires workers with technical skills due to its high degree of automation. A connection established between the real world and the cyber environment through sensors and actuators allows acquiring actual data to be fed to the cyber elements that in turn provide feedback for professionals (Centea, Singh and Elbestawi, 2018).

2.3 Internet of Things (IoT)

The IoT is understood as a cloud of data and information which is similar to that of CPS (Gehrke et al., 2015). It is the point at which CPS interacts with the connection of elements (Fernández-Caramés and Fraga-Lamas, 2018) that are not only machines, but all devices and humans that are able to detect, identify and communicate via the internet (Mueller, Jaeger and Hanewinkel, 2019).

IoT plays an important role in I4.0, since devices and sensors spread throughout facilities allow interoperability through a multilingual and multiprotocol (Centea, Singh and Elbestawi, 2018). Managing the IoT in industrial environments implies a massive implantation of sensors, actuators and machines with remote detection and actuation capabilities (Fernández-Caramés and Fraga-Lamas, 2018).

2.4 Artificial Intelligence (AI)

AI is a field of computer science in which machines perform tasks that the human mind usually performs, such as learning and reasoning by combining software, logic and computing measures that do not depend on human decisions, thus becoming autonomous agents and affecting logistics and manufacturing processes due to providing greater safety, speed, precision and productivity (Kaasinen et al., 2019).

With the adoption of AI, there is an opportunity to discuss new demands for qualification and Education by focusing on the labor market (Venkatraman, Souza-Daw and Kaspi, 2018).

2.5 Machine Learning (ML)

AI encompasses ML that acquires knowledge and data patterns (Ciolacu et al., 2017) by focusing on autonomous knowledge acquisition which has been increasingly found in industrial environments (Pozdneev et al., 2019) due to the ease of algorithmic application in innovations (Longo, Nicoletti and Padovano, 2017).

ML plays a key role in Education and personalized training (Daling et al., 2018) by answering routine questions (Bauer, Schlund and Vocke, 2017) through computer technology and mathematical models without distorting folk knowledge (Li, Fast-Berglund and Paulin, 2019), such as problem recognition (Kinkel, Schemmann and Lichtner, 2017) and recommendations for possible preemptive solutions, thus allowing workers to develop their skills virtually (Antkowiak et al., 2017).

2.6 Deep Learning (DL)

DL is a branch of machine learning based on a set of algorithms that mathematically model abstractions using deep learning with multiple processing layers and linear and nonlinear transformations from an artificial neural network (Whysall, Owtram and Brittain, 2019) that recognizes visual objects, natural language processing and logical reasoning (Zhao et al., 2019).

2.7 Technical and Non-Technical Skills

Skill and competency are interrelated. Competency consists in a combination and coordination of knowledge, attitudes, skills and ethics (Enke et al., 2018) and it comprises a set of technical and non-technical skills that individuals must develop (Gabor, Szabó and Ahmed, 2017) so as to perform coordinated, strategic and creative activities (Longo, Nicoletti and Padovano, 2017) while the concept of skill is to apply acquired theories and concepts into practice (Hecklau et al., 2016).

Educational institutions must gather information on competencies required in the future (Crawley et al., 2014) for imparting knowledge, developing skills and assigning responsibility to students (Enke et al., 2018), therefore this development process requires a set of skills necessary for an education process considered qualification (Benešová and Tupa, 2017). For example, guaranteeing the collective competence of working as a team to achieve a higher level of synergy (Holm, 2018).

Some authors classify competencies into four main categories (Benešová and Tupa, 2017). The first one refers to the technical competencies that encompass knowledge and mastery, the second one comprises the methodological competencies that include problem solving and decision making (Cvetic, Vasiljevic and Danilovic, 2017), the third one is the social skills that encompasses attitude and communication and the fourth one is associated with personal competencies, which include the concept of values and motivation (Hecklau et al., 2016). Non-technical competencies are also known as transversal or behavioral skills (Longo, Nicoletti, and Padovano, 2017).

Skill is the quality of someone who is skilled at performing activities using dexterity, mastery or aptitude (Hecklau et al., 2016), which can be classified as technical and non-technical skills (Kazançoglu and Özkan Özen, 2018). Non-technical skills (soft skills) refer to personal and social skills such as knowing how to lead, express oneself, listen and be empathetic (Hecklau et al., 2016).

Unlike technical skills (hard skills), non-technical skills (soft skills) are recognized as transversal skills (Cotet, Balgiu and Zaleschi, 2017) found between technical and behavioral skills (Gehrke et al., 2015). Relatively, technical skills assist the candidate in succeeding in an interview, but without transversal skills, they do not remain employed and do not reach professional success (Shamim et al., 2016), therefore it is recommended that qualification and technical skills should also be developed towards personal Education, such as teamwork (Crawley et al., 2014).

Technical skills (hard skills) are enhanced through professional courses and technical learning, and their development is predicated on the time spent and dedication. Technical skills are those possessed by specialists and technicians who are able to handle events and technological demands that affect production systems, in addition to controlling and monitoring technological developments (Bruno and Antonelli, 2018), identifying boundaries, understanding roles and systemic relationships, thus promoting wholistic functioning (Holm, 2018) by considering its complexity and interconnectivity (Benešová and Tupa, 2017) and carrying out maintenance and repairs to solve technological problems (Karre et al., 2017).

Hecklau et al. (2016) classified of technical skills which can be learned and assimilated through training and in school institutions (Crawley et al., 2014), and non-technical or transversal skills that must be developed through relationship (Cotet, Balgiu and Zaleschi, 2017).

2.8 Education and the Teaching of New Competencies and Skills

There is a lack of qualified workers to meet the I4.0 requirements, which makes it a critical factor in the process of adjusting companies to a I4.0 environment, thus compelling executives and recruiters to seek innovative behavior, critical thinking, knowledge and adaptation to technology during the recruitment and screening of applicants during selection processes (Hecklau et al., 2016).

Adding technical job skills to transversal skills (Shamim et al., 2016) improves creativity and leads to innovative problem solving. The process of developing and assembling a mini baja vehicle for academic-professional purposes by gathering a multifunctional and multidisciplinary work team involving individuals of both genders that together will create, develop, implement and operationalize a project for assembling a vehicle represents a clear example of this. In this sense, ML (Ciolacu et al., 2017), Virtual Reality (Pozdneev et al., 2019) and exoskeletons play a vital role to develop technical skills and competencies (Cotet, Balgiu and Zaleschi, 2017).

3 MATERIALS AND METHODS

Bibliographic research was adopted with detailed scientific reports and reviews in order to better analyze the past and thus prepare for the future (Kinkel, Schemmann and Lichtner, 2017), as in Education, in the development of skills so as to safeguard employability and the use of technologies.

Specific and multidisciplinary themes were searched on the databases of Scientific Electronic Library Online (SciELO), Web of Science (WoS), Science Direct (SD) and Scopus (Jerman, Bach and Bertoncelj, 2018).

SciELO (http://www.scielo.org/php/ index.php) allows access to over 544 journals at WoS (https://www.webofknowledge.com), which is organized and run by Reuters, and provides access to a file with over 925 journals and the SD (https://www.sciencedirect.com) makes 2558 journals available. Scopus (https://www.scopus.com) has a multidisciplinary content with a range of over 4300 documents in the areas of life sciences and more than 6800 in the area of health sciences that have been filtered by categories (Li, Fast-Berglund and Paulin, 2019).

On the Scopus, WoS, SciELO and SD databases, it was performed a bibliometric analysis by combining several keywords and areas of I4.0, which support the types of competencies and the manner to acquire them as shown in Table 1.

It can be observed that technology exerts a worldwide impact on the production system due to predicting the participation of humans and machines in shared environments (Prifti et al., 2017). While combining the keywords “Human and Machine” on the Scopus, WoS, SCIELO and SD databases, over 20,000 publications were found between the years 2010 and 2020, as shown in Fig. 1.

Table 1: Bibliometric analysis combining keywords.

Keywords	Scopus	WoS	SciElo	SD
Human x Machine	188.137	58.566	292	218.763
World Impact x Technology	70	11.530	147	254.181
Knowledge management x Technology	20.170	31.681	891	200.929
Industry 4.0 x World Impact	0	164	3	24.366
Industry 4.0 x World Economy	24	169	2	11.137
Industry 4.0 x Adaptation	261	184	9	9.115
Industry 4.0 x Industrial Revolution	2.001	1.225	12	4.147
Education x Industry 4.0 x World Impact	0	20	0	5.900
Industry 4.0 x IoT	1.927	1.178	5	1.901
Industry 4.0 x Autonomy	120	79	2	2.147
Industry 4.0 x Unemployment	46	36	2	2.095
Industrial Revolution x Autonomous Machines	7	42	0	2.058
Skilled Worker x Industry 4.0	17	3	0	1.809
Standalone x Human Resource Machines	0	7	0	1.374
H R x Standalone Machines x World Impact	0	0	0	972
Educational x Autonomous Machines x Adaptation	0	0	0	812
Professional Profile x I4.0 x Job Generation	0	0	0	639
IoT x Education x Adaptation	23	12	0	510
Educational Changes x IoT x Skills	0	4	0	273
Qualification x Human Resources x Machines	0	0	0	75
Standalone Machines x Unemployment	0	0	0	34
Infrastructure x Machines x Unemployment	0	0	0	16
Human Resources x IoT	0	0	0	2

Source: Scopus, WoS, SciELO e SD (2021).

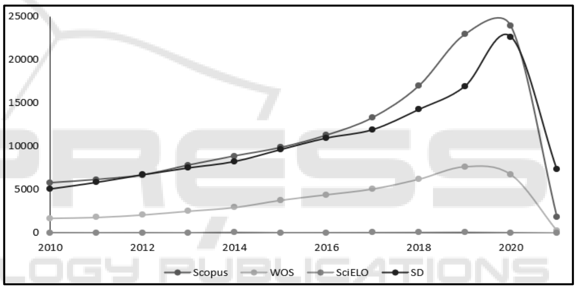

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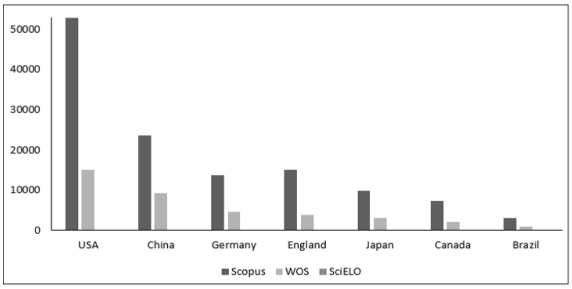
Figure 1: Publications with: “Human” and “Machine”.

The countries that published the largest number of studies using the keywords “Human and Machine” between 2010 and 2021 are shown in Fig. 2.

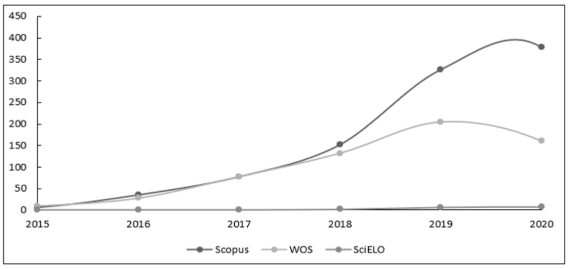


Source: Authors (2021).

Figure 2: Countries that published using the keywords “Human and Machine”.

As follows, a bibliometric analysis was also carried out by searching the terms "Industry 4.0 and

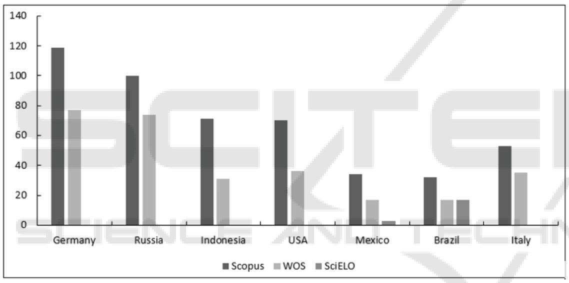
Education". Over 350 publications were found between the years 2010 - 2020, according to Fig. 3.



Source: Authors (2021).

Figure 3: Publications using the keywords: "Industry 4.0 and Education".

In Fig. 4, the countries that published the most by using the keywords "Industry 4.0 and Education" between 2010 and 2020 were researched. It should be noted that SciELO database generated no significant results, since their articles are mostly published in South America, Portugal and Spain (Jerman, Bach and Bertoncelj, 2018).



Source: Authors (2021).

Figure 4: Countries that most published the keywords "Industry 4.0 and Education".

It is observed that technology has had a worldwide impact on Education, as well as on human resources, replacing human participation to make decisions and resolve conflicts in I4.0 environments (Prifti et al., 2017), and literature data demonstrates such a scenario in related studies that these have been an increasingly interesting subject in recent years and a trend towards future research involving terms associated with Education, Machines and Humans in I4.0, e.g. the skills and competencies required for the human workforce in an I4.0 environment.

4 DISCUSSIONS

A bibliometric analysis allowed observing the evolution of scientific literature along the years (Jerman, Bach and Bertoncelj, 2018) by covering several areas of knowledge in publications to identify opportunities and gaps, once literature on I4.0, as well as its required competencies and skills, are still in the process of transition. However, bibliometric results indicate that most works are conceptual and technological, and there is still a lack of studies on the themes of educational changes, employment and infrastructure to develop new competencies and skills for digital age (Li, Fast-Berglund and Paulin, 2019).

The researched documents contextualize the development of I4.0 by highlighting how technology and knowledge (Liboni et al., 2019) can be applied in organizations (Ras et al., 2017) and presenting risks, opportunities and challenges (Shamim et al., 2016). Regarding risks (Liboni et al., 2019), possible job losses (Grenciková and Vojtovic, 2017) and distance between the economies of emerging and developed countries are related, which suggests an update of HRM (Schroeder et al., 2017), as digital transformation demands changes in the way of working and qualification (Bauer, Schlund and Vocke, 2017), such as teamwork and decision-making to resolve conflicts (Ciolacu et al., 2017).

As for technological developments, the implementation of new forms of working that involve an interaction between humans and machines (Shamim et al., 2016; Daling et al., 2018), the dissemination of information will assist human beings cognitively (Li, Fast-Berglund and Paulin, 2019), e. g. self-configured layouts specifically aimed to activities controlled by sensors, actuators and CPS (Fernández-Caramés and Fraga-Lamas, 2018) such as the use of scanners to measure human well-being (Pozdneev et al., 2019) and check their position in a shared cellular layout (Bruno and Antonelli, 2018).

Currently, management is beginning to realize that it needs to be transformed and recruit through group dynamics based on a model that combines technical skills with non-technical skills (Ras et al., 2017), thus suggesting that specialists and technicians should also develop a transversal competence profile that requires multifunctionality (Gehrke et al., 2015) with technological support so as to creatively solve problems in real time (Gorecky et al., 2014).

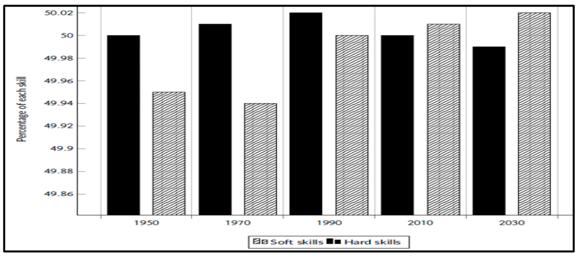
Oriented and didactic group dynamics will explore non-technical competencies, such as ethical creativity (Shamim et al., 2016), willingness to learn (Gabor, Szabó and Ahmed, 2017) and responsible data sharing (Hecklau et al., 2016; Cotet, Balgiu and Zaleschi, 2017) in which heterogeneous and multidisciplinary teams will enhance their creativity and productivity (Bauer, Schlund and Vocke, 2017). Thus, a new educational system by combining the real and virtual world will improve skills (Benešová and

Tupa, 2017), as workers are going to have a decisive role in connection and control (Hirsch-Kreinsen, 2016), as maestras (Bauer, Schlund and Vocke, 2017) in the era of digitalization and technological transformation (Störmer et al., 2014).

Individuals possessing highly technical expertise are fit for the competitive culture of an organization, however, they are often not hired on account of not knowing how to demonstrate non-technical skills, such as adjusting to a teamwork environment and flexible production (Crawley et al., 2014) and the update or creation of curricula and disciplines (Benešová and Tupa, 2017), and rethinking how to teach (Antkowiak et al., 2017) through technology or learning factories to develop technical and transversal skills during the design and operationalization of projects (Enke et al., 2018). The concept of educating and teaching, mainly aimed at new generations (Crawley et al., 2014), should be reviewed and updated by creating experiences that promote the learning of technical fundamentals (hard skills) and a behavioral manner to develop transversal skills (soft skills) through a modern pedagogical approach (Stachová et al., 2019).

A good example is shown in literature regarding the CEO of Apple Inc. According to many scholars, the brand success was achieved due to transversal leadership skills and how Steve Jobs extracted the best results and ideas from his employees, instead of harnessing their technical skills (Shamim et al., 2016).

From the year 2000, three generations started being present in the labor market, the so-called baby boomer generations, X and Y (Comazzetto et al., 2016), with their competencies and divergent skills in relation to technology and work organization (Grenciková and Vojtovic, 2017). As a consequence, conflicts and questions about the relationship between generations will arise, especially regarding Y (Comazzetto et al., 2016) on account of features, such as an ambitious personality for professional growth (Grenciková and Vojtovic, 2017), being easily frustrated and not staying long in their jobs, which leads to a turnover that affects intellectual capital and financial aspects of an organization (Comazzetto et al., 2016), in addition to loss of knowledge (Shamim et al., 2016). In this context, from the advent of generation Y (Comazzetto et al., 2016), personal or non-technical competencies have led employers to start seeking workers who have transversal skills as illustrated in Fig. 5.



Source: Authors (2021).

Figure 5: Relationship between technical and non-technical skills.

For several decades, practice and science prevailed with a strong emphasis on technical foundations (Crawley et al., 2014). In the 90s and following years, representatives of industries started expressing concern about technical competencies by articulating the need for a broader view that also emphasized (Antkowiak et al., 2017) transversal skills and competencies, recognizing the need for change in knowledge (Cotet, Balgiu and Zaleschi, 2017), training and attitudes towards reaching a balance (Pfeiffer, 2016; Müller and Hopf, 2017) between teaching personal, interpersonal and technical skills (Crawley et al., 2014).

As a reaction to the high levels of job turnover, employers and recruiters revised selection criteria and their group dynamics (Shamim et al., 2016) to hire applicants with transversal skills and competencies aimed to avoid replacement costs or conflicts between workers (Sivathanu and Pillai, 2018).

5 CONCLUSIONS

Since the very first studies by German academics, I4.0 is undergoing a rapid transition process that has been exerting impacts through opportunities to modernize the means of production, employment profile and education, and new technological infrastructure resources have been proposed which demonstrates the need to develop new skills and competencies.

The I4.0 trends reflect the non-technical skills (soft skills) required to maintain good interactions and relationships between workers which aredifficult to be taught, but with the primary aim of complementing the technical skills (hard skills) that can be acquired through vocational education or training.

In this context, technical competencies and skills can be taught and trained with the aid of technology and machines (ML, DL and RV). Non-technical or transversal skills can be better developed and improved with the assistance of recruiters and behavioral activities in state-of-the-art learning factories.

Thus, in order to help individuals to remain employed, especially the new generations, there is a need for a review of the content of the curriculum of educational institutions when sending out their undergraduates to the labor market in order to allow a more modern and attractive education, rethinking Education in the sense of conceiving, designing, implementing and operationalizing processes, and combining technical skills with non-technical or transversal skills.

Therefore, it is important to establish new criteria for recruiting and assessing the human workforce, although there are still few studies about it in literature, since I4.0 is not only about intelligent algorithms, artificial intelligence and autonomous systems, but also regarding workers having autonomy and qualification, as technology does not replace human skills yet, such as emotion and creative problem solving. Future work, should research and investigate how new skills and abilities, can be developed on the job training in the context of human behavior in a real-time transfer process of learning, reducing the time interval and increasing safety in Manufacturing 4.0.

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CONFLICT OF INTEREST

The authors are responsible for researching and writing this article, and there is no conflict of interest on the part of them.

REFERENCES

Antkowiak D., Luetticke D., Langer T., Thiele T., Meisen T. and Jeschke S. (2017). Cyber-Physical Production Systems: Teaching Conception Engineering Education, 6th IIAI International Congress on Advanced Applied Informatics. Hamamatsu, Japan, pp. 681-686.

Bauer W., Schlund S. and Vocke C. L. (2017). Working Life Within a Hybrid World - How Digital Transformation and Agile Structures Affect Human Functions and Increase Quality of Work and Business Performance, International Conference on Applied Human Factors and Ergonomics, Springer, Cham, pp. 3-10.

Benešová, A. and Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0, Procedia Manufacturing, 11, pp. 2195-2202.

Bruno G. and Antonelli D. (2018). Dynamic task classification and assignment for the management of human-robot collaborative teams in workcells, The International Journal of Advanced Manufacturing Technology, 98(9), pp. 2415-2427.

Centea D., Singh I. and Elbestawi M. (2018). Framework for the Development of a Cyber-Physical Systems Learning Centre, Online Engineering & Internet of Things, Springer, Cham, September, 13th, pp. 919-930.

Ciolacu M., Tehrani A. F., Beer R. and Popp H. (2017). Education 4.0 â" Fostering student's performance with machine learning methods, IEEE 23rd International Symposium for Design and Technology in Electronic Packaging (SIITME), Constanta, Romania, October, 26-29th, pp. 438-443.

Comazzetto L. R., Vasconcellos S. J. L., Perrone C. M. and Goncalves J. A. (2016). Geração Y no mercado de trabalho: Um estudo comparativo entre gerações, Psicologia, Ciência e Profissão, 36(1), pp.145-157.

Cotet, G. B. ; Balgiu B. A. and Zaleschi, V. C. (2017). Assessment procedure for the soft skills requested by Industry 4.0, MATEC web of conferences - EDP Sciences, 121, pp. 07005.

Crawley, E.; Malmqvist, J.; Östlund, S.; Brodeur, D. R. K. (2014). 2nd Edition. Rethinking Engineering Education-The CDIO Approach, Springer, Cambridge, MA, pp. 60-62.

Cvetic B., Vasiljevic D. and Danilovic M. (2017). Competence requirements for logistics managers in the Republic of Serbia, Management: Journal of Sustainable Business and Management Solutions in Emerging Economies, 22(2), pp. 37-46.

Daling L. M., Schröder S., Haberstroh M. and Hees F. (2018). Challenges and Requirements for Employee Qualification in the Context of Human-Robot-Collaboration, IEEE Workshop on Advanced Robotics and its Social Impacts, Genova, Italy, September, 27-29th, pp. 85-90.

Dumont M., Rayp G. and Willemé P. (2012). The bargaining position of low- skilled and high-skilled workers in a globalising world, Labour Economics, 19(3), pp. 312-319.

Enke J., R. Glass, Kreß A., Hambach J., Tisch M. and Metternich J. (2018). Industrie 4.0 - Competencies for a modern production system: A curriculum for learning factories, Procedia Manufacturing, 23, pp. 267-272.

Fernández-Caramés T. M. and Fraga-Lamas P. (2018). A Review on Human-Centered IoT-Connected Smart Labels for the Industry 4.0, IEEE. p.p. 25939– 25957.

Gabor A., Szabó I. B. and Ahmed F. (2017). Systematic Analysis of Future Competences Affected by Industry 4.0. International Conference on Research and Practical

Issues of Enterprise Information Systems, Springer, Cham, October, pp. 91-103.

Gázquez J. R. and Delgado M. (2018) Software Architecture Solution Based on SDN for an Industrial IoT Scenario, Wireless Communications and Mobile Computing, 2018, pp. 12.

Gehrke L., Kühn A. T., Rule D., Moore P., Bellmann C., Siemes S., and Standley M. (2015). A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective, VDI/ASME Industry, 4, 1-28.

Gorecky D., Schmitt M., Loskyll M. and Zühlke D. (2014). Human-machine-interaction in the industry 4.0 era, 12th IEEE international conference on industrial informatics (INDIN), 27-30 July, Porto Alegre, Brazil, pp. 289-294.

Grenciková A. and Vojtovic S. (2017). Relationship of generations X, Y, Z with new communication technologies, Problems and Perspectives in Management, 15(2), pp. 558–564.

Hecklau F., Galeitzke M., Flachs S. and Kohl H. (2016). Holistic Approach for Human Resource Management in Industry 4.0, Procedia CIRP, 54, pp. 1-6.

Hirsch-Kreinsen H. (2016). Digitization of industrial work: development paths and prospects, Journal for Labour Market Research, 49(1), pp. 1-14.

Holm M. (2018). The future shop-floor operators, demands, requirements and interpretations, Journal of Manufacturing Systems, 47, pp. 35-42.

Jerman A., Bach M. P. and Bertoncelj A. (2018). A Bibliometric and Topic Analysis on Future Competences at Smart Factories, Machines, 6(3), pp. 41.

Kaasinen E., Aromaa S., Heikkilä P. and Liinasuo M. (2019). Empowering and Engaging Solutions for Operator 4.0 - Acceptance and Foreseen Impacts by Factory Workers, International Conference on Advances in Production Management Systems (IFIP), Production Management for the Factory of the Future, Springer, Cham, August, 24th, pp. 615-623.

Karre, H; Hammer, M.; Kleindienst, M. and Ramsauer, C. (2017). Transition towards an Industry 4.0 State of the Lean Lab at Graz University of Technology, Procedia Manufacturing, 9, pp. 206-213.

Kazançoglu Y. and Özkan Özen Y. (2018). Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective fuzzy DEMATEL, Journal of Enterprise Information Management, 31(6), pp. 891-907.

Kinkel S., Schemmann B. and Lichtner R. (2017). Critical Competencies for the Innovativeness of Value Creation Champions: Identifying Challenges and Work Solutions, Procedia Manufacturing, 9, pp. 323-330.

Li D., Fast-Berglund Å. and Paulin D. (2019). Current and future Industry 4.0 capabilities for information and knowledge sharing, The International Journal of Advanced Manufacturing Tech, 105(9), pp. 3951-3963.

Liboni, L. B., Cezarin L. O., Jabbour C. J. C., Oliveira B. G. and Stefanelli N. O. (2019). Smart industry and the pathways to HRM 4.0: implications for Supply Chain Management: International Journal, 24(1), pp. 124-146.

Longo, F.; Nicoletti, L. and Padovano, A. (2017). Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context, Computers Industrial Engineering, 113, pp. 144 - 159.

Mueller F., Jaeger D. and Hanewinkel M. (2019). Digitization in wood supply - A review on how Industry 4.0 will change the forest value chain, Computers and Electronics in Agriculture, 162, pp. 206-218.

Müller E. and Hopf H. (2017). Competence Center for the Digital Transformation in Small and Medium-Sized Enterprises, Proc. Manufacturing, 11, pp. 1495-1500.

Pfeiffer S. (2016). Vocational training 4.0? Reflections on an innovative system and its contribution to the German labour market, Rainer Hampp Verlag, 23(1), pp. 25-44.

Pozdneev B., Tolok A., Ovchinnikov P., Kupriyanenko I., Levchenko A. and Sharovatov V. (2019). Digital transformation of learning processes and the development of competencies in the virtual machine-building enterprise environment, Journal of Physics: Conference Series, 1278(1), pp. 012008.

Prifti L., Knigge M., Kienegger H. and Krcmar H. (2017). A Competency Model for "Industrie 4.0" Employees, 13th Int. Conference on Wirtschafts informatik, St. Gallen, Switzerland, February 12-15, 2017, pp.46-60.

Ras E., Wild F., Stahl C. and Baudet A. (2017). Bridging the Skills Gap of Workers in Industry 4.0 by Human Performance Augmentation Tools: Challenges and Roadmap, Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments, Island of Rhodes, Greece, June, 21-23th, pp. 428-432.

Schou C., Andersen R. R., Chrysostomou D., Bøgh S., and Madsen O. (2018). Skill-based instruction of collaborative robots in industrial settings, Robotics and Computer-Integrated Manufacturing, 53, pp. 72-80.

Schroeder H., Friedewald A., Kahlefendt C. and Lödding H. (2017). Virtual Reality for the Training of Operators in Industry 4.0, International Conference on Advances in Production Management Systems, Springer, Cham, August, 31th, pp. 330-337.

Shamim, S.; Cang, S.; Yu, H. and Li, Y. (2016). Management approaches for Industry 4.0: A human resource management perspective, IEEE Congress on Evolutionary Computation (CEC), Vancouver, BC, Canada, July 24-29, pp. 5309-5316.

Sivathanu, B. and R. Pillai, R. (2018). Smart HR 4.0 - How industry 4.0 is disrupting HR, Human Resource Management International Digest, 26(4), pp. 7-11.

Spöttl G. (2017). Development of "Industry 4.0" - Are Skilled Workers and Semi- Engineers the Losers? 7th World Engineering Education Forum (WEEF), 13-16 November, Kuala Lumpur, pp. 851-856.

Stachová K., Papula J., Stacho Z. and Kohnová L. (2019). External Partnerships in Employee Education and Development as the Key to Facing Industry 4.0 Challenges, Sustainability, 11(2), pp. 345.

Störmer E., Patscha C., Prendergast J., Daheim C. (2014). The future of work: jobs and skills in 2030, UKCES, Wath-upon-Dearne, England.

Venkatraman S., Souza-Daw T. and Kaspi S. (2018). Improving employment outcomes of career and technical education students, Higher Education, Skills and Work-Based Learning, 8(4), pp. 469-483.
Whysall Z., Owtram M. and Brittain S. (2019). The new talent management challenges of Industry 4.0, Journal of Management Development, 38(2), pp. 118-129.
Zhao R., Yan R., Chen Z., Mao K., Wang P. and Gao R. X. (2019). Deep learning and its applications to machine health monitoring, Mechanical Systems and Signal Processing 115, pp. 213–237.
Zhou K., Liu T. and Zhou L. (2015). Industry 4.0: Towards future industrial opportunities and challenges, 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), Zhangjiajie, China, August, 15-17th, pp. 2147-2152.