Industry 4.0 and the human asset: skills 4.0

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Abstract: In 2011, the world got to witness the birth of the fourth industrial revolution otherwise known as Industry 4.0 (I4.0). Being centralized on advanced technologies introduction, it could be considered as a systemic transformation in manufacturing and economy which is also influencing society, governance, and human identity. Within this context, the issue of the impact of such revolution on the human asset and whether a need for a skill adaptation is essential, has been raised and has been the center of discussion of the research world, as well as the managerial one. The article aims at mapping the challenges that I4.0 has imposed on the manufacturing world with a focus on the human asset, providing a comprehensive set of hard and soft skills to be acquired amid this new paradigm. **Design /methodology/approach:** The research is based on a systematic literature review (SLR) of peer-reviewed articles discussing the themes of I4.0 and skills. The papers used in the SLR follow the timeline of 2011 onward, the year the term "Industry 4.0" was brought to light, up until and including the year 2020. **Findings:** The expected outcome of the study is a list of needed human skills in the era of I4.0. **Research limitations:** The research relies on the Scopus database, being the most exhaustive one, and the review is based on qualitative analysis. **Practical implications:** The results of the study could help practitioners understanding which skills are needed to adapt to I4.0 requirements and direct their efforts into acquiring such skills, thus ensuring a solid implementation of I4.0 technologies.

Keywords: Industry 4.0, skills

1.Introduction

The concept of a fourth industrial revolution was initially promoted by the German Government through the program "Industrie 4.0", then it has been revisited and supported by other policymakers in several countries and regions respectively (Fantini, Pinzone and Taisch, 2020). There are different definitions and implementations of Industry 4.0 (I4.0) since it is continuously evolving. It could be described as the vision of "intelligently" automated factories, in which workers, the production system itself, products and even customers are connected (Sanders *et al.*, 2017; Buer, Strandhagen and Chan, 2018).

I4.0 definition could be extended and considered as a systemic transformation in manufacturing and economy which is also influencing society, governance, and human identity (Fareri *et al.*, 2020). In this sense I4.0 technologies not only do they influence the technical factors of an organization but also impact the sociocultural ones (Tortorella *et al.*, 2020). Here, the discussion opens onto the possible impacts I4.0 could have on human resource management since the labor force needs to adapt to new industrial working conditions which create a strong shift in the job structure among sectors (Anh *et al.*, 2018). When it comes to the most assuring aspect about the "future of work is that routine work will be taken over by machines and the intellectual work would be taken care of by human beings" (Bhattacharyya and Nair, 2019), it is very important to understand this kind of upcoming changes and design a plan for adapting to these changes to save the labor force. In this case, companies who want to apply industry 4.0 technologies could benefit from a more comprehensive status of the workforce in the era of the new revolution to gain the full potential of the technologies as well as the workforce itself.

The increase in the degree of automation promised by I4.0, though it reduces costs of production and improves productivity, human operators remain essential elements and assets of the manufacturing system (Ruppert *et al.*, 2018). It is seen that activities deemed difficult to evolve in the cyber world are the very ones that humans naturally perform (Krugh and Mears, 2018). Moreover, research shows that investing in employees helps to retain them and gain a competitive advantage hence, the nation's economic development will be influenced by the ability to adapt and meet the increasing demand for highly qualified and skilled talent that is critical during the I4.0 era (Azmi *et al.*, 2019; Ahmad, Segaran and Sapry, 2020).

Today, the proactive adaptation which leaders must begin to consider also embraces the need to manage skill requalification and possible disruption (Benitez, Ayala and Frank, 2020). A skill can be defined as "the ability to access knowledge from a domain-specific knowledge base and use that knowledge to perform an action or carry out a task" (Matteson, Anderson and Boyden, 2016). Soft skills are the so-called people skills from communication to character and personality traits employed to perform a task in all professions while hard skills are profession-specific(Azmi *et al.*, 2018). Companies need to understand what the requirements are to comprehend what is missing, what is required more, and what kind of actions could be taken to satisfy the needs for I4.0 transformation. The frequent changes in manpower and skill requirements of industries lead to the development of both 'horizontal and vertical

mismatch' between education and various industries (Alam, Forhad and Ismail, 2020). In this case, experts highlight that the most important challenge appears to be the skill gap issue in the labor market. To be able to manage such gap, the current skills and the required ones should be sculped as today's students will work and deal with an increasingly globalized, automatized, virtualized, networked and flexible world (Motyl *et al.*, 2017). They will also compete in a technological, diverse, multi-cultural world and they must be prepared to thrive in this futuristic environment (Umachandran *et al.*, 2019).

The focus of the literature is mainly on technical skills (Karr et al., 2017; Marengo, 2019; Sousa and Wilks ,2018) but is it enough?

This article aims at presenting the skills needed to give the insight to be able to understand and fill the skill gap issue to firstly stay competitive and then increase competitiveness in this new disruptive era. The paper is organized as follows: after the introduction, the methodology is introduced followed by the key findings of the research and a discussion section before ending with a conclusion along with future research.

2. Systematic Literature Review

The research methodology adopted relies on a Systematic Literature Review (SLR). Considering the novelty of the topic spanning over 10 years, the SLR allows capturing all relevant and high-quality studies (Buer, Strandhagen and Chan, 2018) discussing the theme of I4.0 and skills. This methodology allows us to explore peer and non-peer-reviewed articles and extract necessary knowledge to develop the research. The search phase starts with 2011, the year the term I4.0 was born up until 2020, and explores peer-reviewed journal articles and conference proceedings written in English in the areas of business and management fields to fit the scope of the paper. It relies on Scopus as it is a comprehensive scientific database with the following search query (("industry 4.0" OR "smart manufacturing" OR "cyber-physical system" OR "internet of things" OR "smart production") AND (skills OR educat* OR human OR operator)).

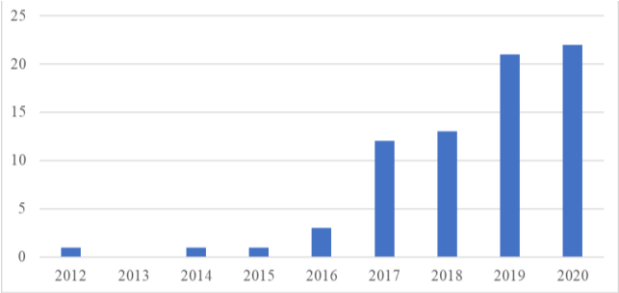

Figure 1: Number of analyzed publications per year

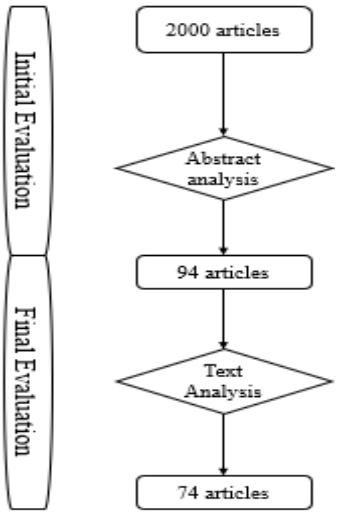

Figure 2: Literature Review Flow Map

The search process depicted in figure 2 started from around 2000 papers that were screened initially by reading their abstracts. All papers that did not tackle I4.0 impact on skills and vice-versa were eliminated. Indeed, most articles tackle I4.0 applications with no reference to the topic at hand, resulting in at the end with 94 articles. The next screening step included full-text reading and at the end 72 articles were eligible. Two documents were added to the list of articles obtained: the World Manufacturing Reports of 2018 and 2019 as they focused heavily on the subject.

3.Research findings

The article aims at highlighting the challenges that I4.0 has imposed on the manufacturing world with a focus on the human asset, providing a comprehensive set of hard and soft skills to be acquired amid this new paradigm. This section explains research findings reporting the motive behind specific skills in the factory of the future followed by explaining the various skills categories and their importance.

3.1 The need for skills

The notion of operators being classified as unqualified in the digital era is highly correlated to what this era demands as supposed to what the current tasks are. The gap in skills is due to an introduction of a disruption that rendered the normal way of performing tasks in operations no longer sufficient (Anh *et al.*, 2018). Table 1 shows the list of tools categorized according to the literature, we have grouped the various skills under two main streams, Hard and Soft skills, and each of those streams constitutes of several categories. The categories resulted from analyzing the various articles discussing those categories and providing examples of the most cited skills within the category itself. It is believed that I4.0 transformation will enable manufacturing companies to have their factories as smart ones (Sanders, Elangeswaran and Wulfsberg, 2016; Shiyong Wang *et al.*, 2016).

Table 1: Most Demanded Skills Based on the SLR

Macro Category	Category	Sub-category
1. Hard skills	Technological Skills	IT skills and security
		Computer skills, software knowledge
		ICT and IOT skills
		Digital skills
	Language Skills	
	Genric Engineering Skills	Optimization
		Customer Management
		Understanding Systems and Flows of information
2. Soft Skills	Cognitive Skills	Problem-solving and decision making
		Lifelong and Quick Learning
		Critical thinking
		Creativity
		Flexibility and Adaptability, ability to work under stress
		Openness to diversity
		Agility
		Conflict resolution
		Collaboration, teamwork, and leadership
		Empathy, ability to listen
		Communication skills

To be able to make the production time to market improved, in the smart factories, the Internet of Things systems link robots and process control systems together which creates a higher level of technological complexity, therefore challenging the current workers to understand these new systems and manage them. Even though there is an ongoing discussion around the possibility of eliminating the need for operators in the long run, currently it cannot be denied that the need for an operator who manages for example the robots is still an essential pre-requisite for companies since the codification of some cognitive abilities are not possible yet (Wittenberg, 2016; Benešová and Tupa, 2017).

In the case of human-robot collaboration (HRC), the physical limitations of human workers are compensated as robots help workers lift heavy items or take over other physical tasks (Kadir, Broberg and Conceição, 2019). This collaboration mostly aims at supporting the operators to complete their work with high efficiency, high success rate, and low burden by allowing the integration of information and decision capabilities into industrial production. One of the biggest requirements of these systems is defined as huge diagnostic functionalities (Wittenberg, 2016). Therefore, workers will face less physically demanding tasks, but more soft skills and cognitive tasks coupled with required technical skills. Besides, organizations will have to create social competencies for workers to invest in, to be able to gather and transfer the knowledge to different actors through different areas of the complex organization (NA, 2018). With automation on the other hand that is aimed at replacing the repetitive tasks of the operator, it is expected to have fewer operators in the production area (Marengo, 2019).

Table 2: Skills Definitions

Skill	Definition
1.Hard skills	Specialized knowledge or understanding of a given task or a job that requires specific talent, education, or experience, also the abilities and knowledge required for performing (Flores et al., 2020). Teachable scientific and technical abilities, that can be defined and measured, and related to the specific education one has received (Motyl et al., 2017). Ability to use specialized tools, procedures, and techniques. Skills needed to achieve service delivery tasks, including expertise in using tools (Ahmad et al., 2019).
1.1 Technological and Digital Skills	Having knowledge and abilities to use in practice, for a job that is related to technologies. (Serafin, 2019) Specific abilities for understanding and using digital content, devices, and systems to perform activities related to digital de=vices (Flores et al, 2020) Skills needed to work across ICT sectors, new digital technologies, and product/services related to these industries (Motyl et al., 2017)
1.2 Generic Engineering skills	Various skills and capabilities are considered important in preparation for work in almost any engineering job (Ahmad et al, 2020)
1.3 Language skills	The ability to learn new languages fast (Flores et al., 2020)
2. Soft Skills	The mix of traits that reflects social views from a person in each environment and profession (Flores et al.,2020) Useful skills within a wide range of professions

	without differentiating environments (Gotz, 2019)
2.1 Cognitive Skills	The ability to learn to support the mastery, dexterity, and performance of a particular subject or task (Flores et al., 2020)
2.2 Social skills	Skills to get proficient in managing relationships and building networks (Vaidra et al., 2020)

With time, these repetitive tasks are going to be managed by the robots and the operator will stay as an observer of the system. The need for fewer operators, however, translates into less knowledge for the company: while letting go of redundancies might be beneficial in the short term to achieve required effectiveness and cost savings, it eliminates an abstract asset that cannot be replaced by robots or machines totally, or at least not in the short term (Lööw et al., 2019). This means companies should try to retrain the workforce or at least focus on changes in the job tasks to be able to avoid losing knowledge. The OECD estimates that 9% of jobs in OECD countries could be automated and 25% could change significantly because of the automation of 50%-70% of the associated tasks (Policy brief on The Future of Work, 2018).

The list of skills extracted from the literature includes skills classified under soft and hard skills. Besides IT skills, the following top 5 skills mentioned by experts are mostly soft and cognitive skills: collaboration/teamwork, social skills, problem-solving abilities, critical/systematic thinking, and creativity. It appears that the first 6 skills cover up to more than %50 of all the competencies mentioned in the sources extracted. This percentage is calculated based on the number of articles that discuss a specific skill. The relative weight of appearance of these skills reflects on their relative importance in the I4.0 era. Therefore, we focus on those most important skills: Technological and Digital Skills, Social skills, and Cognitive skills.

3.2 Technological and Digital Skills

Technological and digital skills cover the understanding of IT security, coding capabilities, ICT skills, computer skills, information technology control, and more. They can be simply defined as required skills for people to be able to use computers and technologies This is also extended to disruptive technological skills that cover competencies mostly related to artificial intelligence, nanotechnology, robotization, the internet of things, and augmented reality (Sousa and Wilks (2018).

The importance of technological and digital skills is explained mainly due to the requirements of future jobs. These future tasks as forecasted will have significant data dependency, the requirement to analyze, and synthesize big data to be able to sense-make and interpret (Bhattacharyya and Nair, 2019). In future facilities, interpretation of digital data is needed as manufacturing processes are becoming more complex and the operator must rely on data and secondary information instead of "seeing and feeling" themselves (Jerman, Bach, and Bertoncelj, 2018). Therefore, the worker needs to extract and interpret information in these new automated, technological systems. Artificial Intelligence AI workers for example will need skills to work with and critically interpret the data provided (Umachandran *et al.*, 2019).

Therefore, the order qualifier for graduates would be to get accustomed to computer-based technologies (Serafín, 2019) while the order winner is data literacy and technological literacy expanding the knowledge to new and disruptive technologies such as AI (Marengo, 2019). Karr et al. (2017) classify technical skills under 3 categories, which are "must-have", "should have" and "could have" skills. The must-have skills are the necessities for humans, mostly covering up generic basic skills of IT knowledge, the ability to interact with data information, and modern interfaces. This shows that every worker is needed to work with computers as it was claimed before and to understand technical information independently from their tasks. When it comes to "should have" skills, the awareness of IT security and data protection is very important, therefore it is better for workers to be equipped with them if they want to understand the security issues. Finally, the "could have" skills are computer programming and coding and the reason for that may be that they are not necessary for every specialization but only some jobs therefore, there is not a high requirement for these skills at least for now.

3.3 Social Skills

Collaboration, teamwork and the ability to coordinate with others appear as the second most important set of skills. The social skills that cover human management skills, relationships, ability to listen, empathy skills, and the willingness to collaborate and especially teamwork abilities are defined as personal must-have skills by Karr et al. (2017). There is a tendency to highlight the importance of collaboration and social skills even more than main cognitive skills like decision making and problem-solving for the new I4.0 environment. The motive behind this lies in the fact that future workers will need to be able to interact with several different stakeholders across departments, processes, or even levels of the supply chain in a highly diverse, multicultural environment. Therefore, social skills are fundamental to manage this upcoming horizontal and vertical interaction (Waschull *et al.*, 2020). Similarly, it is believed that jobs remaining after automation, involve more human interactions, require interpreting the data into knowledge, and transfer it through different hierarchical levels both inside and outside the organizations. In addition to the level of sophistication, modern engineering projects entail which rely heavily on social aptitude (Marengo, 2019; Whysall, Owtram and Brittain, 2019).

3.4 Cognitive Skills

Cognitive skills must be present in the workers of the future. Problem-solving, even though is known as a cognitive skill, it could be also considered as a hard skill because it is a competence, which is teachable and measurable for a given occupation such as generic

engineering fields like mechanical engineering and electrical engineering (Flores, Xu and Lu, 2020). However, the World Manufacturing Forum Report Skills For The Future of Manufacturing, 2019 postulates that cognitive skills though teachable and acquired in a specific time, that doesn't make them hard skills, they are still generic competencies. This paper follows the approach of the World Manufacturing Report.

In this case, humans, compared to robots, are best prepared to develop creative solutions that address root causes of smart manufacturing systems, taking the input of supporting analytical tools into consideration when appropriate. It is claimed by Waschull et al. (2020) that as CPS creates new tasks related to the adjustment and maintenance of automation systems, workers need to deploy their problem-solving skills to solve potential problems.

Besides problem-solving ability, another soft and cognitive skill to consider is creativity. The analysis of the SLR demonstrates that approximately %70 of articles that discuss problem-solving, couple it with creativity. Dealing with complexity and making the right decisions is key to the I4.0 era but relies not only on sound reasoning but on a creative one as well (Jerman, Pejić Bach and Aleksić, 2020). Decision-making competence is also tackled in the literature under the umbrella of decentralized decision-making. The abundance of data exchange and interconnection is a source of knowledge to I4.0 production elements that have evolved from passive players in previous revolutions into active ones where they can analyze those data and accordingly make decentralized decisions about their performance. At the same time, the amalgamation of data and their complexities need not only high computational powers provided by technical drivers but high human-level expertise in analytics and data interpretation necessary for an optimal operative as well as managerial decision making. Experts tend to highlight the decentralization trend by merging it with decision-making skills(Chang and Yeh, 2018).

Since dynamicity, diversity, and uncertainty are the key characteristics of future organizations, cognitive skills like the aforementioned ones, critical thinking, and decision making become the most demanded and core skills to be instilled in workers (Amiron, Latib and Subari, 2019). Therefore, increasing the cognitive load of workers and balancing the ratio between physical and cognitive load will be the investment to conduct for companies that want to succeed in their operations (Kadir, Broberg and Conceição, 2019).

Flexibility, adaptability, openness to diversity and agility for Karre et al. (2017) are considered must-have skills, pointing out that they are very vital since workers in I4.0 are required to adapt to a comprehensive change from perception to action (Anh *et al.*, 2018; Flores, Xu and Lu, 2020).

Lifelong learning defined as learning different things quickly and having a motivation to learn is another cognitive skill to be had (Ahmad *et al.*, 2019; Azmi *et al.*, 2019). I4.0 is dynamic and requires not only having aptitude and ability to learn new skills but also continuously upgrading the existing ones in a short time frame (Umachandran *et al.*, 2019). In addition to that, since technology life cycles have shortened dramatically as pointed by World Manufacturing Forum Report Skills for The Future of Manufacturing, 2019, multi-skilled operators are a must. This extends to be able to adapt and assume different positions on the manufacturing floor (Bhattacharyya & Nair, 2019).

4. Further Discussion

The research highlights two different views, we might call the first one optimistic and the second one pessimistic. According to the supporters of the pessimistic idea, robots and technology could take over not only dangerous jobs but all jobs. Simply put, automation will no longer be limited to physical or manual tasks, the dirty, dangerous, or boring tasks, but could also threaten many intellectual, cognitive, or analytical white-collar jobs that involve some routine tasks, ranging from transportation, office support, or consumer services (Marengo, 2019). This implies that with automation, a large majority of the working population would become unemployed, leading to mass unemployment. This concept creates fear among most of the workers, so they are not willing to learn and work with these new technologies as they do not want to lose their jobs in the future. This topic was also discussed at The World Manufacturing Forum Conference 2020 by pointing to the recent data that 1/3 of people are afraid of working with AI. Based on this view, there is, therefore, a high need to prepare workers and accommodate their fears by showing the usefulness of those technologies to them in improving the way they work. However, when it comes to the optimistic approach, although it is already acknowledged that some of the jobs will be lost, experts also point out that the new jobs and skill changes will be in favor of the market (Marengo, 2019). It is argued by The World Manufacturing Forum Report 2019 that while only 5 % of jobs will be lost, the digitization of work will generally involve an upskilling or upgrading of the skills. They assume that innovation and technology would not reduce the volume of employment but would expand the market by introducing new segments. They believe that transformation will create many more highly skilled jobs in the future, supporting stronger wage growth and a healthier labor market. This will serve as a crucial touchstone to see if new technologies can complement human skills in new and better jobs, rather than simply displacing workers (Lööw et al., 2019). Therefore, the way Industry 4.0 is applied to the organization depends on the organization's own characteristics, the impact of the changes depends on a series of decisions that management makes. We believe that the focus should not be on the conflict between humans and robots, but on the idea of a human-centric approach.

On the other hand, a growing skills shortage could prevent the potential of digitization from being realized if it is not managed appropriately. Recently, companies have been struggling to find workers with enough skills to work with new technologies. In addition, they also have problems with new graduates, especially in technical fields, because

some skills they are looking for are not taught in universities, so students cannot succeed in the hiring process. Leadership for example is a very important and challenging skill in the current market. It is a skill that should be taught in universities; however, curricula tend to teach mainly technical and hard skills without considering soft skills such as leadership. This results in students and graduates lacking general soft skills that are very important for communicating, understanding, and put their knowledge into use. Close collaboration across all levels of professional education and training must be prioritized, and innovative ways must be found to develop flexible and adaptable curricula that reflect the various challenges of on-the-job training by placing a stronger emphasis on courses that teach Data Science and other advanced technologies, as well as helping students acquire relevant soft skills to succeed in competitive business markets.

At this point, it is important to talk about the concept of Education 4.0, as it is a very helpful concept to develop both soft and hard skills needed for the future environment (Flores et al., 2020). Education 4.0 considers universities not only as places where research and education are conducted, but also as centers for creative innovation, practical problem solving, and social value creation (Anh et al., 2018). This concept enables the application of advances in information technology to update the efficiency of education and training so that teaching and learning activities can take place anytime, anywhere, as the idea of lifelong learning and continuous training of the existing workforce becomes important for manufacturing companies, service providers, and education-oriented institutions alike. In addition to these recommendations and approaches to skill development, it is also important to attract students in the STEM fields with the help and collaboration of governments and institutions. The idea in the society can be changed and STEM courses can become more attractive, which will help to increase the number of graduates with the expected skills as mentioned.

5.Conclusion

We believe that this paper can be a basis for companies and educational actors to understand the basic general competences needed and switch their focuses on the right skills, develop and acquire them (Whysall et al., 2019). In this case, we presented the most popular skills that are requested by companies who are facing I4.0. Even though the analysis is not industry specific, it gives general insights for companies and recruiters about the future requirements in human resources.

Decision makers based on the extracted skills, should focus on their organization to analyze their current level in each skill type (related to their area), how much they are planning to automize, what is the level of readiness etc.. (Whysall et al., 2019). With these observations, they can complete the required skill assessment and go with the skill development phase. As we highlighted in this paper, humans will be the core of any collaboration, automatization and digitalization, and humans will still be required for specific jobs since emotions and cognitive intelligence makes big changes when it comes to decision making. Therefore, most of the effort should be on the process of searching for improvements and support for humans. In the I4.0 era, there is a need to develop not only hard skills connected to technologies, but also soft skills, as the human asset is characterized by emotional logic, a characteristic that technologies could never acquire (Vysocky and Novak, 2016).

6.Future Research

Future research should focus on creating a matrix that would match each skill or subset of skills with an I4.0 technology or a subset of them. Once this is identified, researchers could move to the next step which is studying how skills, especially soft ones could be transmitted to workers 4.0.

7. Limitations

This research has its limitations. It relies on one scientific database and the analysis performed is qualitative.

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