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Industry 4.0

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The workforce transformation

Module: Advanced Industry 4.0

Assignment 2 – Essay

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INTRODUCTION

Industry 4.0, the next/current revolution of the manufacturing industry, is happening now and to fulfil the customer demand which has evolved since the Industry 3.0 revolution, changes are required: mass-customisation, modularity, productivity, real-time decision making, interconnected manufacturing processes, automation, and agility.

Industry 4.0 technologies deployment requires various resources (money, time, integration skills) which makes the evolution less accessible to small and medium-size companies as they can have fewer resources than large companies. But generally, the deployment can be successful only if the humans, the workforce at every level in the organisation structure, are included in the strategy of this change.

Beyond the technologies which are the tools and enablers of this revolution, there are other important aspects to consider. Indeed, tools are efficient only if they are used appropriately. Tools by themselves will not have a value-added for manufacturing companies. Adding or changing tools in a factory requires the willingness of workers to change their ways of working. The way of introducing the change, new equipment to workers and showing its benefits is fundamental. Change management is of massive importance for a successful Industry 4.0 adoption. Lean methodologies have been intensively used in the last decades but the Industry 4.0 revolution, with all the digitalised production systems that it entails, requires additional skills for managers and workers (Agolla, 2018).

In this paper, the cultural changes and skill set shifts that deploying Industry 4.0 technologies entail for the diverse levels of the organisation will be described. First, an explanation of the requirements from the management and leadership team and a description of potential strategies to support them in a successful industry 4.0 integration will be done. In the second part, the focus will be on the skills needed by production, engineering, and transversal functions teams for the adoption of industry 4.0 technology. The last part of this document will focus on new training methodologies and the competencies required by the future workforce.

“The ingenuity of human beings in today’s world has surpassed any human definitions of creativity, as human has transformed into super beings. Humans now possess great knowledge and how organisations will trade in such knowledge will make the difference in Smart Manufacturing and Industry 4.0 revolution.” (Agolla, 2018)

I. Management/Leadership Team involvement

a. The main blocker of Industry 4.0 deployment: technology resistance

Industry 4.0 is enabled by technologies in various forms from sensors, robots, Virtual Reality, etc. Workers can be reticent in using these new technologies for several reasons such as:

- Non-sensibilisation of new technologies and fear of not knowing how to use them
- Not seeing the value-added and benefits in using them
- Reticent to changes in general – wanted to keep the current ways of working
- Fear of being replaced by a machine and losing the job
- Feeling of being monitored and controlled.

Technology resistance is a major issue in companies today as they faced challenges regarding skills shifts. Especially in SMEs, some factories have the same employees for years with an incredible knowledge of the processes, production, machines, etc. These employees are not always receptive to changing the ways of working. The extreme would be to change the workforce and employ new workers with Industry 4.0 knowledge such as connectivity, automation, smart technologies, and data analytics but the gap in linking specific production knowledge of the company and industry 4.0 concepts would be challenging.

Several studies and research have been conducted to propose methodologies to support the technology acceptance by the workforce. Showing the benefits of the new technologies can be part of a successful deployment: *“economic benefits are made possible by reducing warehouse and maintenance costs, quality costs and consumption of raw materials and energy. Second, quality is improved by a higher customization of products and customer satisfaction, and by advanced and more stable processes. Moreover, wider data availability supports predictions and decision-making and accelerates all processes.”* (Molino, Cortese and Ghislieri, 2020). However, these benefits are advantages for the wider company and not the individual. The worker must see the benefit for him in his day-to-day tasks to agree and be on board with this change. Depending on the technologies it could be *“improved safety and environmental protection, more autonomy and independent decision-making, and the development of new skills”* (Molino, Cortese and Ghislieri, 2020). The management team has an important role to play in demonstrating these advantages to the workforce by making good use of communication: *“the role of leadership deserves special attention, because it represents one of the most important areas of intervention to support the technological transformation”* (Molino, Cortese and Ghislieri, 2021).

In the research paper of Van Dun and Kumar, an example is described for the adoption of a robot “Fabricator” using good communication: this fully automated robot replaces several machines previously operated by workers. The operators have been solicited at an early stage beforehand of the implementation in the factory. Training has been given *“The training enabled operators to work with the new machine, boosting the perceived ease of use”* (Van Dun and Kumar, 2021). Managers and directors were listening to workers before the change to reassure them that robots are not going to replace them. This led to successful adoption as workers knew the machines before the implementation and understood the value added to the business and themselves.

Many models are available in the literature which analyse the factors that can influence the acceptance of new technologies by the workers and offer some frameworks to facilitate the Industry 4.0 adoption.

b. Frameworks for a successful implementation of Industry 4.0 technologies

In this section, two different frameworks will be presented: the worker-centric design and evaluation framework developed by Kaasinen and the cultural web defined by Johnson.

The framework of Kaasinen is human/worker-centric, on the individual especially using the well-being factor of the operator: *“New work tools and related work practices should be designed so that they result in meaningful, motivating and engaging work tasks. Accordingly, the design outcomes should have a positive impact on work well-being and company benefits.”* (Kaasinen et al., 2019)



Figure 1: The worker-centric design and evaluation framework (Kaasinen et al., 2019)

Figure 1, here above, summarises this framework. The **antecedents** are the current situation of the worker before the implementation of any technology. Then, the **immediate implications** are the direct implications and parameters to consider. Indeed, *“Well-designed tools that are acceptable and safe to use, that provide high usability as well as positive user experience and that are ethically sound, will most likely have a positive impact on work well-being.”* (Kaasinen et al., 2019). The next box shows the **Impact** of a longer-term perspective always linked to well-being: job satisfaction, work engagement, and job motivation. The last box looks at the **company benefits**.

The second framework to be analysed in this document is the Cultural Web by Johnson. This framework is from a different perspective as it is used at the company level and not at the worker level as just described with the Kaasinen framework.

The Cultural Web looks at the global organisational culture of the company to map its status, goals, and where the company wants to be in the future. This mapping exercise helps to identify the gaps between the current culture versus the desired culture and to define a roadmap to move towards the end goal. This framework also enables the company to take a

step back and question the current processes, tools, and how works the company which can help to highlight some unknown issues that need to be addressed.

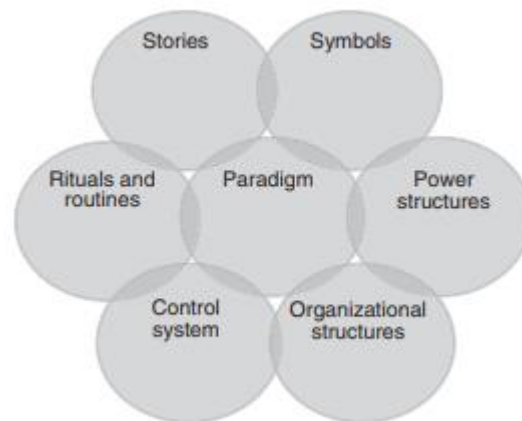


Figure 2: The cultural web (Sammur-Bonnicci, 2015)

As shown in Figure 2, the cultural web rests upon seven concepts:

- **Paradigm** – the core of the culture which is made of the 6 following elements
- **Stories** – what people say inside and outside the company and past events
- **Symbols** – the visual representation of the company
- **Power structures** – people who have the real influence in the company
- **Organisational structures** – organisational chart (flat, silo, hierarchical structure) and unwritten lines of power indicating whose inputs are most valued
- **Control system** – organisation control systems (Finance, Quality, Reward)
- **Rituals and routines** – daily behaviour of people, normal activities

The first methodology (worker-centric) is easier to implement and requires fewer resources. Moreover, this first methodology is supportive in showing the direct benefits of the change to the individual. However, for companies with underlying issues, this methodology might not be enough deeper for sustainable implementation. On the other hand, the cultural web methodology requires a lot of resources and might also require someone external to the company to do the study and analysis of the company culture to avoid biases, but this technique allows an in-depth analysis of the company and helps to refocus and redefine the foundations of the company.

c. Leadership 4.0

In this section, a description of several types of leadership will be done to understand which one is more adapted for Industry 4.0 adoption.

First, transactional leadership values order and structure, is a really organised technique, and does not promote creativity and innovation (STU Online, 2018). This leadership is not convenient for Industry 4.0 as it maintains the status quo and does not facilitate changes.

Secondly, transformational leadership “is defined as a leadership approach that causes change in individuals and social” (Langston University, 2020). Transformational leadership is more a motivational and inspirational type of leadership that focus on the development of the individual.

Figure 3 below summarises these two types of leadership:

Transactional Leadership	Transformational Leadership
Transactional leaders do not feel easy to discuss with employees about plans.	Transformational leaders ready to discuss with employees about plans before execution.
Leader set rewards and punishments for employees to accomplish the goal	Employees complete goal through superior principles and ethics
Motivates employees by tempting their self interest	Motivates employees by give priority to group interests first
Works surrounded by the organizational traditions	Works to transform the organizational traditions by implementing new thoughts
Management-by-exception: continue the status quo; pressure correct actions to recover performance.	Individualized reflection: Each behavior is intended for each person to convey kindness and support. Intellectual stimulation: support new and creative ideas to solve problems.

Figure 3: Differences between Transactional Leadership and Transformational Leadership (Salma, Darun and Yao, 2015)

Moving from a conventional business model to Industry 4.0 requires changes, good communication, and individual consideration. Based on the table above, Transformational leadership seems more adapted than Transactional leadership for the Industry 4.0 implementation.

However, Holst in his paper, defines a third type of leadership: Instrumental leadership: *“the application of leader expert knowledge on monitoring of the environment and of performance, and the implementation of strategic and tactical solutions”* (Antonakis and House, 2014). Based on his study, a combination of instrumental and transformational leadership would work best for industry 4.0 implementation: *“the instrumental leadership style may provide an early push in the transition, while the transformational style works better for the long term change”* (Holst, Van Dun and Wilderom, 2021).

In the next section, some examples of Industry 4.0 technologies will be presented and how these can be beneficial to the company and the individual.

II. The new workforce: operators, engineering, planning, and transversal functions (HR, Finance, Procurement, ...)

The operator within the Industry 4.0 is called Operator 4.0 defined as *“a smart and skilled operator who performs ‘work aided’ by machines if and as needed”*. The machines provide a sustainable relief of physical and mental stress and free the operators for doing more creative, thinking tasks. The next 2 parts will focus respectively on cognitive and physical skills where Industry 4.0 technologies can support the Operator 4.0.

a. Operators 4.0 – Cognitive skills

Cognitive automation can be defined as *“technical support to know what and how to assemble”* (Fast-Berglund et al., 2013).

The use of Augmented Reality/Virtual Reality (AR / VR) tool for activities such as training, visual inspection, and visual aid for production processes augments the worker and supports him in his daily activities.

Even if the worker does not know a process, he can complete his work using an AR tool. The tool will guide him in real-time all along the process and interact with him and through the sensors if something is not correct for example. Everything is happening in the real space, field of view of the operator: visuals are superposed on the actual elements on the production line of the factory and not on a virtual screen. It can be via the use of glasses for example or a projector (Paelke, 2014). Moreover, AR tools are hand-free systems. From the company's point of view, this is a great benefit as it allows to have a flexible and modular workforce.

As seen in the first section of the document, this type of tool might be frightened to be used by some workers as they do not know how to use it but by doing appropriate training and communicating properly all the benefits (stress relief, etc.) to the worker, the implementation could be smoother. An approach of introducing the tool to the operators beforehand and linking the developer of the AR applications with the operators would allow an easier adoption on the operators' side and a creation of much-adapted applications as operators can communicate to the developers how they work, their needs, processes, issues, etc. (Paelke, 2014).

The second blocker could be the skills needed to create the applications as it is customised for each factory layout, there is a requirement for an AR/VR specialist in the company or to pay an external to develop and maintain the applications. Indeed, the accuracy of the process and the well-representation of the reality in visuals are fundamentals.

Another application of AR/VR could be remote maintenance. If an operator on the production line encounters an issue, via mixed reality headset such as the Hololens, a maintenance operator in any location around the world can visualise the issue and guide in real-time the operator to resolve it in the factory (Masoni et al., 2017).

A second technology that supports workers is machine vision systems. Using camera(s) and image processing, this system can be used for various applications such as quality controls, defects detection, metrology measurement, process monitoring, counting parts, etc. (Pierleoni et al., 2020).

This system eliminates "no-brain" tasks from the operator who can use his skills for more added-value activities and avoid human errors.

Vision systems could be more powerful when integrated with other machines. For example, based on the result of the image processing, data can be sent to robots or other machines to do a specific action.

The monitoring of tool wear can be another use case for machine vision. That could have an important impact on the reduction of scrap and machine tool failures (Hou, Sun and Huang, 2018).

Machine vision systems are not replacing the operators but supporting them in understanding and decision-making as the system provides the data to support their knowledge: *"The scanned information with the help of this technology is analysed to maximise the performance, which is historically based exclusively on human evaluation."* (Javaid et al., 2022)

b. Operators 4.0 – Physical skills and well-being

Several Industry 4.0 technologies (ergonomic) improve the physical skills of the operator. For example, the Exoskeleton is: *“a kinematic chain in close contact with the human body”* (Munoz, 2017).

The exoskeleton has 2 functionalities: body protection and support (passive) and providing additional strength (active). A use case could be when an operator is doing a long overhead operation to support his arms. This improves the physical health of the worker and mental health as well.

This technology is probably easier to be adopted by an operator as he can see the immediate impact in his daily activities and the technology is easy to use.

With the ageing workforce, – the percentage of seniors (65+) is forecasted to grow by 10% in Europe (Calzavara et al., 2019) – the exoskeleton is a great technology to support elderly operators as they have less physical strength but are still valuable in the company as per the knowledge they have accumulated over the years.

A second example is the use of collaborative robots. These industrial robots are great to work alongside humans and safe to use in proximity to humans. Collaborative robots can support the worker in doing repetitive, using hazardous materials, and physically tiring tasks (heavy lifting, etc.). Even if the robots are safe to use with humans, some workers could be reticent and scared of the robots. By doing appropriate training these fears can be appeased.

They are easy to use as operators can program them by moving the robots and saving the positions to perform the tasks and few programming knowledge is needed compared to non-collaborative robots. The use of collaborative robots increases the job satisfaction of the workers by removing tedious and non-ergonomic tasks (Romero et al., 2016).

Another example is the use of wearable trackers. The use of various sensors to monitor several health indicators such as the heart rate of the worker in real-time can be useful to alert workers and managers when something might go wrong, recommend taking breaks based on the worker's condition, monitor fatigue, etc. It is not only used by the automation system: *“the worker him/herself also gets empowering feedback of his/her competence and performance”* (Kaasinen et al., 2020). The downside of using these technologies is the fear of being monitored and controlled continuously by managers. A lot of analysis could be done with all the data collected such as productivity comparison of individuals which could be quite controversial. To overcome this, the workers need to be informed ahead of the deployment: *“Doubts towards worker monitoring, highlighting that solutions need to be designed in close collaboration with workers”* (Kaasinen et al., 2020)

Data confidentiality and data protection is another important point to consider as storing and using data from individuals should be well-protected against cyber-attack and the user's agreement should be requested to each individual beforehand. This point is sensitive as if the operator does not want personal data to be collected the use of these technologies will not be possible. A lot of work from management is needed to explain the positive impacts of this technologies for them, clarity and transparency about the data usage and cybersecurity training.

c. Other teams and unify company

“Engineers are required to acquire skills, knowledge and abilities about state-of-the-art software architectures, modelling and programming techniques [4]. In addition, statistical methods and data mining techniques are key capabilities for future production engineers”
(Agolla, 2018)

The industry 4.0 technologies are not impacting the operators only. These technologies change the ways of working of everyone in the company in different ways. Digital skills are also required in other teams such as engineering, procurement, planning, etc. as in the Industry 4.0 dream everyone is using the same software and platform and everything is interconnected. That means that HR, Planning, Maintenance, etc. would all need to switch from their old tools to the new integrated tool. As seen in the previous section, some people might be resistant especially if they are using their tools for years and do not understand the benefits of the new ones as well as fearing learning something new. One example regarding the benefit for Maintenance Team has been described in [II.a](#). The planning team can be represented in the middle of an organisation as they need information from customers' orders, procurement (raw material availability), workers' availability, tools, and machines availability (downtime due to maintenance...). The use of a centralised platform (including information from production, procurement, sales, and maintenance...) to support their planning activities could be a great asset and save time in their daily jobs.

We could assume that globally white collars are genuinely more confident with digital tools than operators. This might be correct in the past but today with the surrounding of many technologies in personal life too (chatbots, smartphones, etc.), the gap does not probably exist anymore.

The use of knowledge-sharing platforms between the teams such as Slack is key to improve communication, facilitate continuous learning and remove the silo-working element: *“there are clear needs for knowledge sharing and adaptive learning solutions that would support personalized competence development and learning while working. An easily accessible platform for knowledge sharing could evolve to a forum where good work practices and ways to solve problems are shared not only within the work community, but also with machine providers and other stakeholders”* (Kaasinen et al., 2020).

Channels can be created based on the subject/knowledge to allow people to only subscribe to the topics they are interested in developing themselves or sharing knowledge. This concept is called Community of Practice (CoP). By using technologies such as Slack, it would be virtual gathering but also allow constant connection to each one in the group without location limitation. These CoPs can be organised in person meeting to foster their relationships. The strength of this group is the team effort and years of experience and knowledge accumulated by all. Members of a CoP have different backgrounds and experiences that enrich the group as a whole: *“Each member of the CoP has the potential to bring a unique skill set and contribute to a greater body of knowledge that is available indefinitely and can be called upon even when they leave the community”* (Langley, Patel and Houghton, 2017).

Using these technologies will increase the cohesion in the company, sharing knowledge and rotational job to understand each other activities and points of view is also a way to make people aware of what are the challenges of each other's and how they can support each other.

III. Expectations of the future workforce and adapted training

a. Expectations

With automation, manual workers will decrease over time. The skills will shift towards more intellectual activities: *“Specialist knowledge, self-management and creativity are estimated properties to increase for employee demand than ever, contributing to lifelong learning through continuous professional development.”* (Ekren and Kumar, 2020). The operator will become a Maker 1.0 as per Taylor et al.: *“we foresee the operator as a maker, a person who works alongside the automated production system but in a creative role rather than simply monitoring non-discretionary work-flow processes. The act of producing may be highly automated, but both it and the products are open to innovative activity through the worker as maker”* (Taylor et al., 2018)

The companies must invest in their workers to support them in their development towards new technologies for a smoother industry 4.0 adoption and implementation in the factories. Everyone (the individual and the company) is responsible for the lifelong learning and development of each. Companies should have a better understanding of what is required and be able to advise and support the worker. The worker has then his responsibility to learn and develop himself for his own future. (Agolla, 2018)

The ideal skills of the new workforce would be: *“a mix of cognitive, intrapersonal, and interpersonal attributes such as collaboration and teamwork, creativity and imagination, critical thinking, and problem solving”* (Ekren and Kumar, 2020) with the most required being *“Analytical thinking and innovation, active learning, creativity”* (Ekren and Kumar, 2020). On the technical side, all skills related to Industry 4.0 are also important such as connectivity, Internet of Things (IoT), data analysis, data visualisation, and programming.

The pace of technological evolution being extremely fast, learning in university the use of technologies might not be a good strategy as the learnt technologies might be out of date after the graduation of the individual. In that case, it would be difficult for the new graduate to sell his capabilities. Universities should focus on “learning to learn” or “learning to think” to give to students this appeal to develop and learn new skills continuously (Ekren and Kumar, 2020).

In the next 2 parts, some new methodologies of learning will be discussed.

b. Makerspace and Learning Factory

Makerspace or Learning Factory are new concepts to design, create, try, and learn new skills such as Industry 4.0 capabilities. These spaces are designed in a way to support collaboration between people from various backgrounds, encourage the learners to be proactive in developing, and learning new skills, go outside the box, and be creative and innovative. Indeed, Dos Santos and Benneworth in their paper describe it as: *“a place where students can share their projects, can innovate using rapid prototyping equipment, use low and high technology that serves as a starting point for students to launch start-ups, get advice on how to place a product in the market, and relate to potential lenders.”* (Dos Santos and Benneworth, 2019). They are similar to a laboratory where they can experiment: *“The aim is to modernize the learning process and bring it closer to industrial practice”* (Elbestawi et al., 2018).

The success of this new test-bed area is dependent on the way it is designed. The more offerings of hands-on components determined his value and power in developing the learners.

c. Education 4.0

The education system which accommodates Industry 4.0 technologies can be named Education 4.0: *“learning technique is believed to enhance learners’ ability to apply the new technology which will empower them to produce innovations and creativities according to the changes in their societies”* (Bongomin et al., 2020).

J. Miranda in his research paper describes Education 4.0 in 4 components: Competencies, Learning Methods, Information and Communication Technologies, and Infrastructure. The diagram below explains what is in each component (Miranda et al., 2021):

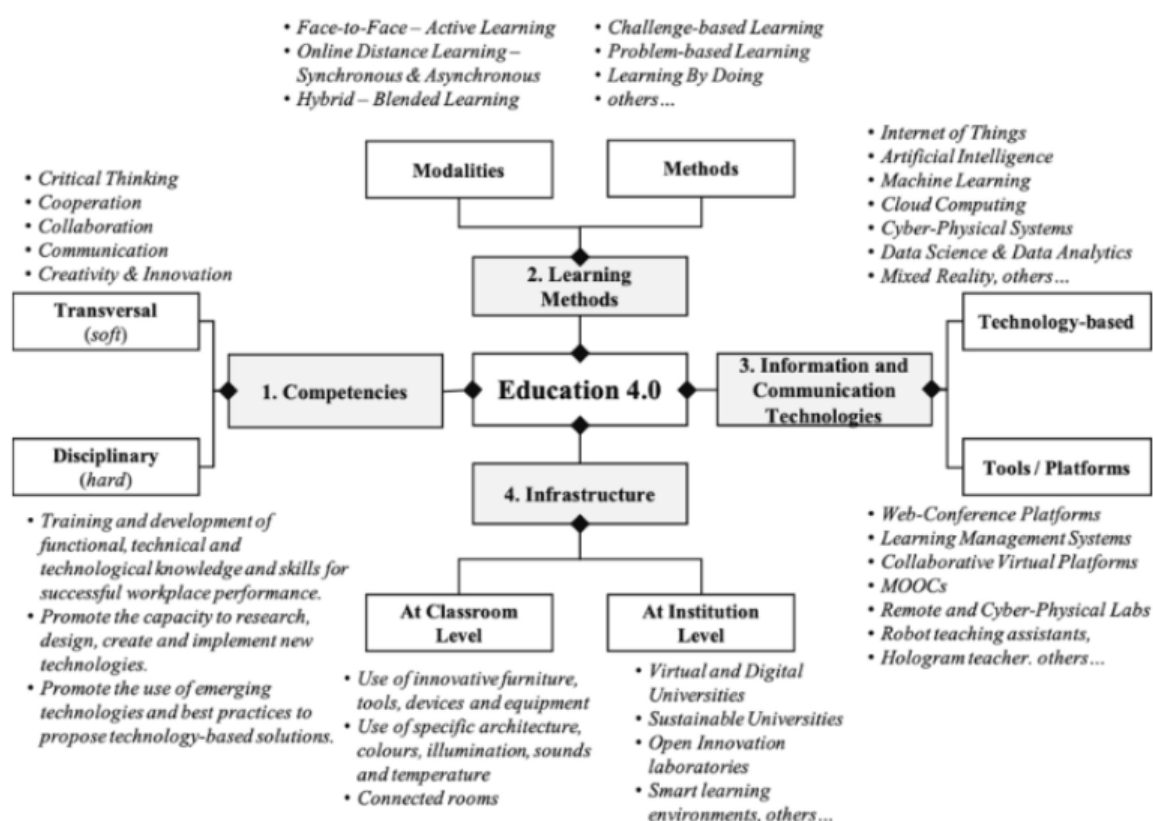


Figure 4: 4 components of Education 4.0 (Miranda et al., 2021)

This new education system leverages the digital world, as in Industry 4.0, especially with the multiplication of the online learning platforms (MOOCs). This kind of platforms offers a lot of resources for those who want to learn new things. That could create a more diverse skill set of the workforce. Workers will not be classified anymore as per what their university diploma specifies: *“Another crucial issue in building the skills of industry 4.0 is the need for diversifying education and credentialing systems”* (Bongomin et al., 2020).

Ramirez-Montoya defines what would be the Education 4.0 teacher: *“An Education 4.0 teacher must have the same competencies demanded of students: digital literacy, critical thinking, and problem-solving, a fact that is of great interest to employers, who are the main stakeholders*

in education” (Ramírez-Montoya et al., 2021). Indeed, teachers must change, and adapt their module contents based on the evolution in Industry but that is not enough as they must also develop their skills in these areas to be more knowledgeable about the subject they teach. Teachers have a lot of influence on their students, a passionate teacher can make his subject much more interesting to students and motivate them in learning more. Teaching methodologies need to evolve to be in phase with the new generation, which is more digital and lives in an immediate, interactive world.

CONCLUSION

“According to Schwab, the Fourth Industrial Revolution differs from the previous ones for three reasons: (1) velocity, since it is evolving at an exponential rather than a linear pace; (2) scope, as it is disrupting almost all industrial sector; and (3) system impact, because it is transforming governance, management and production.” (Molino, Cortese and Ghislieri, 2021)

Digitalisation is impacting almost everyone today, especially in the manufacturing industry with the Industry 4.0 revolution. This change affects the employees, at every level of the organisation. The skill set shift is important. The current workforce must train themselves throughout the implementation of technologies in the factories and learn to be more in a proactive and continuous learning attitude. For the new/future workforce the university and schools must adjust the syllabus and contents to support the students in having the required skill set which is not only technical and digital literacy capabilities but also interpersonal skills such as critical thinking, creativity, communication, active learning, and innovation.

Leadership and management teams play an important role in promoting and communicating the benefits of the changes to make successful the adoption of these new technologies. Today, workers need to be more empowered and included in the strategy to be motivated and feel part of the company. By promoting and working on having a united team as well as being transparent about the strategy and changes to come, the managers facilitate and make the implementation of Industry 4.0 technologies smoother: *“a strong link among all the hierarchical levels generates solidarity among all the organisational actors to achieve strategic and performance objectives”* (Robert, Giuliani and Gurau, 2020).

Worker-centric approach, understanding of the situation of each one in the company and their needs are fundamental to offer tools and machines that benefit everyone, i.e., not only the company but also the individual. If the worker can see the advantage at his level to use this new tool, he will not resist the change but adhere to it and help with its implementation.

*“The Industry 4.0 adoption was supported by **managers’ clear vision** and serious attention for **people’s sentiment**, supporting innovation through **employee training** and their opportunity to **voice opinions**. This enabled employees to overcome any fears of job loss and embrace the Industry 4.0 adoption opportunities.”* (Van Dun and Kumar, 2021)

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