

Preparing for Education 4.0: Skills Facing Economic, Social and Environmental Challenge

Maria do Rosário Cabrita, Hossein Safari, and Maria del Pilar Muñoz Dueñas

Abstract—Increased digitation, automation, intelligent processes and global interconnectivity, are just some of the drivers reshaping how we think, we work, we learn, we organize in society. These drivers will entirely change the way we live and work, impacting directly the way we build education system for today's students. Education 4.0 emerges as a response to the challenges of Industry 4.0 that focuses on the intensive use of cyber-physical solutions and internet-based technologies across our lives. The very driver of education for the future should be aligned to these exponential technologies, not forgetting a social and environmental view in the refreshing curricula. Rapid technological breakthroughs are leading changes in our social, economic, ecological, and cultural lives, causing a great variety of challenges in the education system. Future skilled workers depend very much on the quality of education system, which is itself dependent upon a serious and responsible debate involving education, industry leaders and public politics. The literature reveals a lack of studies on this topic. This paper focuses on exploring skills in today's students need to seize opportunities and find solutions in the context of Industry 4.0. The study emphasizes the need for a full-scale transformation in technical, learning and citizen system.

Index Terms—Education 4.0, economic, social and environmental challenges, industry 4.0, skills and competencies.

I. INTRODUCTION

Progress in digital technologies is changing the way we think, the way we work, the way we commute, and at the organizational level, the way we design, produce, commercialize and generate value from products and services. This new paradigm brings with it enormous possibilities, new solutions to global challenges, and employment opportunities for jobs that have yet to be invented [1].

At the same time, it consolidates a potential threat of technological unemployment. Combined with environmental changes and population growth, we have never lived a time of greater promise, or greater peril [2]. To adapt to these transformations, people must have the skills required to work with the new technology, and with one another, and also to adopt a new mind set.

This new industrial paradigm will demand for new skills and competencies. Literature review estimates that the growing complexity of jobs as a result of digitalization and the consequent growing demand for higher skilled people would necessarily lead towards an increase in the importance

of continuous learning, training and education. To take advantage of the set of opportunities brought by advanced technology, we need a similar revolution in education. The competencies and skills of students should reflect the challenges of the society. Education 4.0 emerges as a response to Industry 4.0 in order to encourage the development of a school of thought committed to prepare qualified, trained and skilled people who are ready for a highly globalized world and a digital-driven society.

Literature examines Industry 4.0 predominantly from a technical perspective, whereas only few articles consider aspects concerning to social and environmental perspective. Education system must prepare students for jobs that have not yet been created, technologies that have not yet been invented and problems that we don't yet know will arise [3]. This work intends to examine: i) how education system should evolve to accommodate a digital-driven society; ii) What kind of skills can be provided in educational institutions that will be most useful to adapt, shape and harness the potential of this big transformation. The rest of the paper is structured as follows: in Section II we provide a brief introduction of Industry 4.0, emphasizing its main drivers and requirements to face digital transformation; in Section III we describe Education 4.0, pointing out the *curricula* required to face Industry 4.0 challenges, the methods of teaching and learning, learning environment and assessment; Section IV examines what skills in today's students/learners need to face economic, social and environmental challenges; Section V concludes that changes in educational profile calls for a renewed education system involving society as a whole.

II. INDUSTRY 4.0: DEFINITION, CONCEPT, DRIVERS AND REQUIREMENTS

A. Definition and Concept

Industry 4.0 is a high-tech strategic initiative, first mentioned in 2011 in Germany as a proposal for exploring the potentials of new technologies and concepts such: i) the massive use of networked systems and Internet of Things (IoT); ii) the creation of smart products and services, including the idea of smart factory that “context-aware assists people and machines in execution of their tasks” [4], and; iii) the use of Cyber-Physical-Systems (CPS) that “accomplish their tasks based on information coming from physical and virtual world” [5]. The focus of Industry 4.0 is to create smart products, procedures and processes, a manufacturing approach characterized by small decentralized and digitalized production networks that act without human intervention and autonomously control their operations depending on their environment changes and requirements [6].

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Despite the interest in the topic for both academics and practitioners, a generally accepted definition of Industry 4.0 has not been published so far, being the meaning of the term still more blurry than concrete. The Industry 4.0 concept is seen as a fundamentally new approach that brings together the digital and physical worlds that aims at strengthening industrial competitiveness. Currently, Industry 4.0 is a collective term for combining different technologies that come together and bring different areas together [7].

B. Main Drivers and Requirements

Literature review [8]-[10] states that Industry 4.0 has been driven by four disruptive drivers: the rise in data volumes, computational power, and connectivity; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces, and; improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing. Other authors [11], [12], focusing on a human-centric and environmental perspective, study the implications concerning the potential use of different technologies in the social and environment context. To successfully embrace the Industry 4.0 challenges, in a social and environmentally sustainable way, it is vital to accompany technological transformations with education and ecological training programs. Table I shows the main drivers and requirements to face digital transformation in the context of Industry 4.0.

TABLE I: MAIN DRIVERS AND REQUIREMENTS IN THE INDUSTRY 4.0 CONTEXT

Main Drivers in the Industry 4.0 Context	Main requirements to face digital transformation
<u>Economic</u>	
Interoperability	Work organization
IoT (Internet of Things)	Culture of collaboration
Digitization	Skilled workers
Automation of tasks	Data analytics
Service-orientation	New business models
Connectivity	Know-how protections
Computation	Legal frameworks
Cloud/Big data	Communication
Real-time capability	Networks
Smart products/processes	Strategic vision
<u>Social</u>	
Immigration	Technical skills integrating different cultures
Demography	New socio-technical system
Urbanization	Human-machine interaction
Smart cities	Governance
Inequality	
<u>Environmental</u>	
Energy consumption	Smart energy systems
Environmental impact	Environmental mind sets
Lack of resources	Efficient processes
	Recycling

Demography is changing, namely in Europe which brings additional challenges. Immigration phenomenon may partially mitigate the effect of the movement of ageing workers in developed countries. However, it requires an integration of different cultures and various technical skills in new socio-technical system. Smart technologies can be

harnessed to both enhance urbanization and reduce environmental impact. Industry 4.0 is expected to facilitate a mixed urban development, bringing the factories back to towns, close to the residential areas, promoting the concept of “city of short distances”, with impact on the adoption of environmentally-friendly integrated “urban production” [13]. This will engage governments, citizens, visitors and businesses in an intelligent ecosystem.

Industry 4.0 is also coping with the urgency of producing within environmental constraints in order to be geared towards sustainability. The main environmental pressure that digital technologies are suffering is related to the adoption of low-carbon energy systems [14].

Environmental concerns will benefit from Industry 4.0 technologies, especially from Artificial Intelligence (AI) and Internet of Things (IoT), by enhancing urban transportation, waste and water management, renewable energy, smart grids, urban farming with real impact in climate issues.

These new opportunities will demand for workers which are high skilled, innovative, resilient and dynamic with preference for those with high IT competence as well as practical abilities with good understanding management and engineering aspects [15].

III. EDUCATION 4.0: TRENDS AND OPPORTUNITIES

As work organization and environment are transformed by the drivers described above, employees’ skills will be required to change dramatically. While business models and processes become more agile and data-based, new skills and qualifications are needed. Education institutions play a key role in shaping a new society, however, most today’s education systems are based on models designed to output a workforce for jobs that no longer exist, being insufficient to meet the challenges ahead. We need to reinvent our education systems, preparing people with skills and knowledge to design and invent solutions to our most pressing problems (e.g population growth, growing inequality, population ageing, climate change, among others) and reimagine society to face Industry 4.0 challenges. The purpose of Education 4.0 is about learning how to thrive in a transforming world. In this sense, creativity, imagination, innovation, critical thinking to solve complex and abstract problems become civically engaged in education concerns.

A. Education Trends and Opportunities

Some authors [16]-[18] explore the trends of Education 4.0 and advance a vision for the future of education, from schools to lifelong learning, student-centric while built around individual, where the major learning responsibilities will shift from the instructors to the learners. Learning together and from each other, peers become very significant in the learning process, while teachers assume the role of facilitators. However, Education 4.0 requires shifting not only technical/soft skills but also learning/teaching methods, learning environment, and learning assessment as shown in Table II.

B. Technical/Soft Skills

The competencies and skills of learners should reflect the challenges of the society as well as the requirements of the

employers. IT systems know-how are required to ensure the connection between the digital and physical side of the company's operations. In addition to professional IT competencies (expert systems, data analysis, databases, etc), and other technical disciplines, to embrace Industry 4.0, soft skills such as creativity and design, critical thinking, problem solving, intercultural skills, social competences and team work ability are also required. Data interpretation will be crucial to make inferences based on logic and trends from given sets of data. It is also expected more collaboration of learners on designing and updating *curricula*. Although we have no idea what jobs people will do in the future, we do know at least that most of them will be based on science, technology, engineering and mathematics (STEM).

C. Methods of Learning and Teaching

Due to the great opportunities of remote tools, learning can take place anywhere and anytime and can be personalized. Education 4.0 empowers learners to structure their learning paths. It means that learners may personalize his(her) learning experience, where the learner has complete flexibility to design his(her)own future and has the freedom to approach and achieve personal goals by choice. With the rise of wearable technology personalized learning becomes both approachable and dynamic. Besides, learners can decide how they want to learn being creative on their learning approach - BYOD (Bring Your Own Device). Learning will be mostly experiential and lifelong demanding collaboration skills. Learners will be more involved in hands-on learning through collaborative projects, internship and international cooperation, which requires intercultural and networking skills. In such scenario, teachers assume the role of facilitators who will guide the learners through their learning process. Besides that, mixed reality further improves the collaboration among learners, teachers and external parties offering the opportunity to work remotely together. Blended learning stimulates learners to choose a more personalized method of learning.

D. Learning Environment

Classroom layout will be designed to enable both individual and collaborative workspaces, instead of traditional seating arrangement [18], [19]. The importance of ergonomics should be considered when thinking the architecture of learning spaces. Learners in a classroom should feel as comfortable as they are at home and furniture in the same learning space may allow them to work in different areas depending on the project they are involved. Gamification is becoming a powerful tool to be more interactive and engaged to learning process [20]. Virtual, augmented reality and mixed reality will be one of the most important trends allowing learners go back in time, interact with objects or human beings no longer existing.

E. Learning Assessment

As we cannot expect to conform the same educational model for everyone, learners' assignments in the form of constructed or selected responses only are no longer effective. While learning will be more experiential, Education 4.0 calls for methods for certifying the skills learned on the job. It is expected that learners' assessment will occur during the learning process while applying the knowledge to their

projects. Considering the online environment, alternative assessment tools should be implemented to accommodate multiple learning options. Some tools like Mobile learning (MLearning), E-learning, Massive Open Online Course (MOOC) are a new concept of learning and assessing via online [21].

TABLE II: EDUCATION TRENDS

Learning context	Trends
Technical/Soft Skills	IT systems know-how
	Data analysis
	Creativity
	Critical thinking
	Problem solving
	Intercultural and social skills
	Team working abilities
	Participative <i>Curricula</i> design
	STEM education
Methods of learning and teaching	Focus on personalized teaching
	Creative learning approach (BYOD)
	Hand-on learning
	Virtual, Augmented, and mixed reality
Learning Environment	Blended learning
	Collaborative work environment
	Cozy spaces
	Adaptable furniture
Learning Assessment	Gamification
	On the job certification of learning
	On line assessment tools (MLearning; MOOC)

Education 4.0 is a technology-implemented upskilling in the teaching and learning process, opening huge opportunities for the economy and society. Jobs of the future will be those that machines cannot do, and education is at the heart to preparing the present and future generations to thrive. The future is learning, unlearn and relearn where Education 4.0 has a vital role.

IV. PREPARING SKILLS FOR INDUSTRY 4.0 CHALLENGES

It is very important to understand what changes will bring Industry 4.0, what new tasks the workers will have to develop and what additional skills would be required. We have explored the main drivers of Industry 4.0 and we are aware that the tools, machines and technologies to be used will be different from those used at present. With the change in work environment and tools to be used, the skills required will also change [22]. Learners will need both broad and specialized knowledge about maths, engineering, management and science. Global problems require global solutions and thinking across disciplines will be crucial to face ongoing transformations on the economic, social and environmental landscape of Industry 4.0.

A. Skills Facing Economic Challenges

New jobs will appear as products, services, processes or new business models emerge. A new set of mixed skills to perform in the increasingly dynamic and complex world, will be required [23]. On-going globalization will require intercultural, language and networking skills. Automation, digitization and the rise in data volumes will require workers

with a new set of skills which are focussed on collaboration, data analytics and computer proficiency. Table III lists some economic challenges and skills required to face them.

TABLE III: SKILLS REQUIRED TO FACE ECONOMIC CHALLENGES

Economic Challenges	Skills Required
On-going globalization	Intercultural Skills Language skills Networking skills
On-going automation and digitization	Digital proficiency New technical skills Problem solving
Increased need of innovation	Creativity Entrepreneurial thinking Research skills Process understanding Problem solving Work under pressure
Rise in data volumes	Data analytics Decision making
Higher service orientation	Communication Skills Networking skills Conflict solving Commitment Conflict solving

B. Skills Facing Social Challenges

Demographic change is one of the most influencing social challenges, potentially impacting on work environment. The implications of an aging workforce are the possibility that large scale retirements may lead to an unrecoverable loss of knowledge. It is expected a growing complexity in many job profiles, along with an increasing need for cross-functional work organization. There is a consensus that technology is a facilitator or driver of most of the new work behaviors and opportunities that will appear in the future. Table IV comprises some social challenges and skills required to deal with the new paradigm.

TABLE IV: SKILLS REQUIRED TO FACE SOCIAL CHALLENGES

Social Challenges	Skills Required
Demographic changes	Ability to transfer knowledge (retaining the knowledge from older employees)
Increasing virtual work	Digital proficiency Media skills Technology skills
Growing complexity of processes	Technical skills Process understanding Motivation to learn Ambiguity tolerance Analytical skills

C. Skills Facing Environmental Challenges

Education 4.0 should also address some of the most pressing challenges of our days: global climate change, ecosystem degradation and the depletion of natural resources. A “go-green” mentality from prior scholarship, involving pedagogical practices and new curriculum theories, is urgent to implement in order to motivate human engagement and

action in resolving environmental problems [24]. Table V attempts to define some necessary skills to face environmental challenges.

TABLE V: SKILLS REQUIRED TO FACE ENVIRONMENTAL CHALLENGES

Environmental Challenges	Skills Required
On-going climate change	Go-green movement “Sustainable” mindset Motivation to protect planet
Ecosystem degradation	Sustainability concerns Creativity to develop sustainable solutions
Depletion of natural resources	Energy efficiency systems Socio-ecology skills

V. CONCLUSIONS

Inspired on the Industry 4.0 challenges, Education 4.0 emerges as a response to align human and technology searching for new possibilities. In this sense the term “education 4.0” means preparing people for the needs of Industry 4.0. Focused on the learner supported by technology, Education 4.0 is a system that involves and benefits multiple stakeholders (not only education institutions and students, but also enterprises, policy makers and representative bodies) with great impact in society. There is a consensus that technology is a facilitator or driver of most of the new work behaviours and opportunities will appear in the future.

While further research is needed, the analysis conducted so far, provides some perspectives with respect to education for Industry 4.0. New technological solutions will lead to an unprecedented transformation of our ecosystem. Education policies aimed at addressing the demand for new Industry 4.0 skills, should focus on not only technical skills (e.g. digital proficiency, data analytics, engineering, management, mathematical knowledge, language, intercultural skills, etc) but also on soft skills (e.g. networking, problem solving, conflict solving, sustainable mindset, process understanding, socio-ecology skills, etc).

The change in education system calls for a renewed education and training policy agenda as a critical approach to developing a more sustainable society.

CONFLICT OF INTEREST

The authors declare no conflict of interest

AUTHOR CONTRIBUTIONS

MRC conducted the research and wrote the paper; HS and MPMD organized the literature review; all authors had approved the final version.

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REFERENCES

- [1] V. Banwari, "Fourth industrial revolution: Role of education and government," *International Journal of Research in Engineering*, vol. 8, no. 12, pp. 47-51, December 2018.
- [2] R. Drath and A. Horch, "Industrie 4.0: Hit or hype?" *IEEE Industrial Electronics Magazine*, vol. 8, no. 2, pp. 56-58, June 2014.
- [3] A. Shahroom and N. Hussin, "Industrial revolution 4.0 and education," *International Journal of Academic Research in Business and Social Sciences*, vol. 8, no. 9, pp. 314-319, September 2018.
- [4] H. Kagermann, W. Wahlster, and J. Helbig, *Final Report of the Industrie 4.0 Working Group*, Acatech — National Academy of Science and Engineering, München, April 2013.
- [5] F. Almada-Lobo, "Industry 4.0: A challenge of competition," *Journal of Innovation Management*, vol. 3, pp. 6-21, May 2018.
- [6] S. Erol, A. Jäger, P. Hold, K. Ott, and W. Sihn, "Tangible industry 4.0: A scenario-based approach to learning for the future of production," *Procedia CIRP* 54, pp. 13-18, June 2016.
- [7] D. Paulus-Rohmer, H. Schatton, and T. Bauernhansl, "Ecosystems, strategy and business models in the age of digitization — How the manufacturing industry is going to change its logic," *Procedia CIRP* 57, pp. 8-13, 2016.
- [8] B. Slusarczyk, "Industry 4.0: How are we ready?" *Polish Journal of Management Studies* vol. 17, no. 1, pp. 232-248, June 2018.
- [9] K. Schwab, *World Economic Forum*, 2016.
- [10] S. Choi, G. Kang, C. Jun, J. Lee, and S. Han, "Cyber-physical systems: A case study of development for manufacturing industry," *International Journal of Computer Applications in Technology*, vol. 55, no. 4, pp. 289-297, August 2017.
- [11] D. Romero, J. Stahre, T. Wuest, O. Noran, P. Bernus, A. Fast-Berglund, and D. Gorecky, "Towards an operator 4.0 typology: A human-centric perspective on the fourth industrial revolution technologies," in *Proc. CIE46*, 2016, pp. 29-31, Tianjin / China.
- [12] D. Kiel, J. Müller, C. Arnold, and K. I. Voigt, "Sustainable industrial value creation: Benefits and challenges of industry 4.0," Presented at the XXVIII ISPIM Innovation Conference – Composing the Innovation Symphony, Austria, Vienna on 18-21, June 2017.
- [13] M. Gabriel and E. Pessel, "Industry 4.0 and sustainability impacts: Critical discussion of sustainability aspects with a special focus on future of work and ecological consequences," *Annals of Faculty Engineering Hunedoara – International Journal of Engineering*, vol. 1, no. 16, pp. 131-136, 2016.
- [14] C. Herrmann, C. Schmidt, D. Kurler, S. Blume, and S. Thiede, "Sustainability in manufacturing and factories of the future," *International Journal of Precision Engineering and Manufacturing - Green Technology*, vol. 1, no. 4, pp. 283-292, March 2014.
- [15] G. Sogari, T. Pucci, B. Aquilani, and L. Zanni, "Millennial generation and environmental sustainability: The role of social media in the consumer purchasing behaviour for wine," *Sustainability*, vol. 9, no. 10, October 2017.
- [16] K. Umachandran and D. Ferdinand-James, "Affordances of data science in agriculture, manufacturing, and education," in *Privacy and Security Policies in Big Data*, S. Tamane, Ed. USA: IGI Global, November 2017.
- [17] S. M. Sackey, A. Bester, and D. Adams, "Industry 4.0 learning factory didactic design parameters for industrial engineering education in South Africa," *South African Journal of Industrial Engineering*, vol. 28, no. 1, pp. 114-124, May 2017.
- [18] European commission, high-tech leadership skills for Europe. (2017). [Online]. p. 132. Available: http://eskills-scale.eu/fileadmin/eskills_scale/all_final_deliverables/scale_e-leadership_agenda_final.pdf
- [19] L. Levano-Francia, S. Sanchez, P. Guillén-Aparicio, S. Tello-Cabello, N. Herrera-Paico, and Z. Collantes-Inga, "Digital competences and education," *Propósitos y Representaciones*, vol. 7, no. 2, pp. 569-588, 2019.
- [20] C. Iordache, I. Mariën, and D. Baelden, "Developing digital skills and competences: A quick-scan analysis of 13 digital literacy models," *Italian Journal of Sociology of Education*, vol. 9, no.1, pp. 6-30, 2017.
- [21] P. Edwards and P. Ramirez, "When should workers embrace or resist new technology?" *New Technology, Work and Employment*, vol. 31, no. 2, pp. 99-113, 2016.
- [22] Acer for education. [Online]. Available: <https://eu-acerforeducation.acer.com/category/education-trends/>
- [23] S. Carretero, R. Vourikari, and Y. Punie, "The digital competence framework for citizens Luxembourg," *Publications Office of the European Union*, 2017.
- [24] S. Ramli, M. Rasul, and H. Affandi, "Sustainable development: Needs of green skills in the Fourth Industrial Revolution (4IR)," *International Journal of Academic Research in Business and Social Sciences*, vol. 8, no. 9, pp. 1082-1095, September 2018.

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