INDUSTRY 4.0: REQUIRED PERSONNEL COMPETENCES

Panos Fitsilis[1], Paraskevi Tsoutsa [1,2], Vassilis Gerogiannis[1]
Faculty of Business and Economics, University of Applied Sciences of Thessaly, Greece[1]
Department of Mathematics, University of Patras, Greece[2]

pfitsilis@gmail.com, tsoutsa@teilar.gr, gerogian@teilar.gr

Abstract: *The rise of Industry 4.0 and of smart factories along with all enabling technologies such as cloud computing, Internet of Things, multi agent systems, cyber physical systems, artificial intelligence, etc. will transform current factory workers to knowledge workers. Hard work and routine tasks will be executed by machines or robots, while tasks requiring experience, intuition, creativity or decisions making based on uncertainty will still reside to humans. This constitutes a huge shift on the required competences. Further, this change is transforming manufacturing to a software intense business, where software development and operation is a core part of the manufacturing process, but as well as of the products being manufactured either as a standalone component or as a part of a larger product or service. The need is prominent, since we need urgently to study the knowledge and competences needed for manufacturing personnel of the near future. In this paper, we present an initial competence model where will outline the knowledge dimensions and skills needed for Industry 4.0. This model can be used to create training proposal individuals or for assessing the knowledge gaps existing in an enterprise. The identified skills are classified as technical, behavioral and contextual.*

Keywords: IoT, Competence models, DevOps

1. Introduction

Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies. While Industry 3.0 focused on the automation of specific business processes, Industry 4.0 focused on the digital transformation of enterprises. This implies end-to-end digitization of all physical assets and the creation of a new digital ecosystems including value chain partners [1]. Generating, analyzing and communicating data seamlessly underpins the gains promised by Industry 4.0, which networks a wide range of new technologies to create value. In the context of Industry 4.0, the new technological systems will be linked with organizational processes to transform industries and this will enable the real time connection between humans, machines and smart objects.

Industry 4.0 is an application area, it can be considered as a sub-category of the Internet of Things (IoT) technologies and in the literature it is commonly referred as well as "Smart Manufacturing", "Smart Industry", "Smart Factory", etc. Further, Industry 4.0 concept incorporates a number of key technologies such as Big Data/Analytics, advanced human-machine interfaces, smart sensors and actuators, robotics, big data analytics, artificial intelligence, security authentication, cloud computing, location tracking technologies, 3D printing, augmented reality and wearables, etc. It constitutes according to many scholars and practitioners the 4th industrial revolution [2], [3]. It should be noted that it is not limited to automation of a single production facility but it refers to the whole production chain, including the supply chain, material sourcing, warehousing, production and delivery [4].

According to Burke et al [5]. Industry 4.0 factories are:

1. Connected. Data are flowing from production plane, between various subsystems or departments or from the supply chain.
2. Optimized. Running algorithms are optimizing every aspect of operation with minimum human intervention.
3. Transparent. Extensive use of metrics allow easier control of operation and at the same time transparency in order processing within the supply chain.
4. Proactive either in quality aspects, or in replenishing the inventory of in preventive maintenance,
5. Agile. This quality enables a smart factory to implement schedule and product changes fast and with minimal intervention.

However, Industry 4.0 is not only technology and of the transformation of the production line. It includes as well the digital transformation of the whole business. This implies that we have to rethink a) the digitization and integration of vertical and horizontal value chains and b) of the business model in general by optimizing the customer interaction and access. This is an important shift from a linear, sequential supply chain operation to an interconnected, open system, known as the digital supply network that will lay the foundation for how companies compete in the future. This applies as well to SME manufacturers.

Further, according to market reports, the Industry 4.0 market including industrial robotics installation, cyber security, IoT, 3D printing, etc., was valued at 66.67 Billion USD in 2016 and is expected to reach 152.31 Billion by 2022 USD. This indicates an annual growth of 14.72% in the next five years. The increasing adoption of the industrial internet and increased focus on efficiency and cost of production are the major drivers for the Industry 4.0 market [6].

Similar trends are reported to "EU Skills Panorama 2014" [7]. According to Eurostat data, in 2013, over 32 million employees were working at the manufacturing sector across the EU. Even though, employment across the manufacturing sector as a whole in EU is expected to decrease by 4% up to 2025, employment in the high-technology manufacturing sectors is expected to create more than 2 million jobs.

The implementation of Industry 4.0 is expected to face a number of challenges. According to Pricewaterhousecoopers survey [1] the most important challenges to be faced are:

1. Lack of digital culture and training (50% of the respondents)
2. Lack of a clear digital operations vision and support / leadership from top management (40%)
3. Unclear economic benefit and digital investments (38%).

It should be noted that this challenge, to build a digital culture and the properly train the personnel, was equally applicable even for companies perceived as technologically advanced and as well for companies across various industry sectors. This is something to be expected, since Industry 4.0 implementation has severe implications on the organization structure of an enterprise, on the

way it is operating and on the delivery models applied. Even though training, or re-training, the workforce is one of the biggest challenge to overcome with Industry 4.0, this topic has not received a lot of attention neither at the VET level nor at reshaping the curriculum offered at HEI's level.

In this paper, we attempt to address this problem by proposing a competence framework that is not based on specific job profiles but rather on the industry requirements. The remaining of the paper is structured as follows. In section 2, we are presenting briefly the related studies giving emphasis on specific educational approaches or curriculums. We do not present systematically a literature review of the domain, but only studies that are considered applicable. In section 3, we present our competence framework at a higher level, and in section 4 we present the conclusions and future work.

2. Related Studies

In the study of Hartmann and Bovenschulte [8], a methodology for skills needs prognosis for Industry 4.0, based on technology roadmaps, is presented. This methodology is conceptually defining the steps needs and provides the technology roadmaps, on how to identify the skills needed in the case of Industry 4.0. It provides a description of the general landscape, foresight, skills needs analysis, and the implementation of educational structures, and programmes that are related to the development phases of emerging technologies. The outcome of this work highlights firstly that in the case of Industry 4.0 there is no 'technological determinism', implying that potentially similar technologies may lead to different skills needs, depending on the organizational environments. Secondly, there is need to address different skills needs according to the specific Industry 4.0 'biotopes', implying different workforce segments in different sectors using different subsets of the technologies under consideration.

These findings are in line with Boston Group Consulting study (BGC) [9] and other studies [10], [11]. In BGC study for analyzing the evolution and the impact of the introduction of Industry 4.0 to the labor market they have studied ten different cases in order to prove that not all cases require similar skills. For example, the introduction of "big data driven quality control", where a company uses historical and current quality control data are analyzed for pinpointing the causes of failures, implies that the demand for data scientists will be increased. Similarly, the transformation of supply networks to smart supply networks will lead to lower demand in operators for planning and in higher demand for supply chain coordinators. In the same report it is stated that the introduction of Industry 4.0 will reshape the demand for a number of professions. For example demand for R&D and human interface design, IT and data integration, production of robotics and automation, logistics, sales and services will increase, while demand for production and quality control professions will decrease. However, change in technical skills required will not be the only change. Personnel need to adapt to new forms of organizational structures regarding processes and personnel issues and with the new human role in production processes.

Further, the digital transformation of enterprises that is implied from Industry 4.0 initiative, requires new delivery approaches for software development and deployment. These approaches are Agile development, Lean Product Management, Site Reliability Engineering, DevOps, most of the requiring an updated training response [12]. As such training and educators should consider including in the IT software curricula:

- Dynamic infrastructure and operations. This implies a change from physical administration controlled infrastructures to virtual, cloud infrastructures controlled by software
- Continuous delivery. Software teams produce software in short software life cycle, ensuring that the software can be reliably released within short time intervals. This requires the existence of a simple and repeatable deployment process.
- Product management. A shift from deliverable-focused project management to outcome-focused product management.
- Resource and execution management. This implies a shift from project management approaches to techniques and theories influenced by Operations Management and Industrial Engineering.
- Organization and culture. From inattention to culture, to recognition of culture's central role in digital product delivery effectiveness

These changes in the job market will affect dramatically the job market, more specifically the skills in demand and the way companies are recruiting their personnel. World Economic Forum [13] suggests several major changes are needed on how business views and manages their employees, both immediately and in the longer term. Further, in the report is mentioned that there will be a shift to the required skills in 2020. These skills are complex problem solving, to critical thinking, creativity, people management, coordination, emotional intelligence, judgement and decision-making, service orientation, negotiation and cognitive flexibility.

The fact that the skills needed for Industry 4.0 are numerous and diverse has been recognized in various studies [14], [15]. Leinweber in his study clustered the identified competencies into four main categories. These categories are:

- Technical competence such as state-of-the-art knowledge, process understanding, technical skills, etc.
- Methodological competencies including creativity, entrepreneurial thinking, problem solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation.
- Social competencies such as intercultural skills, language skills, communication skills, networking skills, ability to work in a team, ability to be compromising and cooperative, ability to transfer knowledge and leadership skills.
- Personal competencies that includes flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset and compliance

However, the above studies are only indicative since standardizing ICT skills, for example at the European level is a major objective of the European Commission, of The European Committee for Standardization (CEN), [16], Skills Framework for the Information Age (SFIA) Foundation [17], etc. It is important to mention the European e-Competence Framework (e-CF) was created by a technical expert group from European HR and ICT businesses in the context of the CEN Workshop ICT Skills of CEN.

e-CF has become European standard and it is not based on job profiles but rather on competences. Its purpose is to define in an adaptable and flexible way e-Competences so it can be customized to satisfy requirements stemming from different ICT businesses and stakeholders. e-CF defines 40 competences that are classified according to five main ICT business areas (plan, build, run, enable, manage). For example, among these 40 competences and for the business are of planning the following competences are included: IS and Business Strategy Alignment, Service Level Management, Business Plan Development, Product/Service Planning, Architectural Design, Application Design, Technology Trend Monitoring, Sustainable Development and Innovating [16].

3. Our proposed framework

According to the discussion in the previous section an educational model for Industry 4.0 should take into account the following facts:

- there is no 'technological determinism',
- there is need to address different skills needs according to the specific Industry 4.0 'biotopes',
- there are different workforce segments,
- there are different sectors using different subsets of the technologies under consideration,
- there are different product lifecycles according to which different development and operation processes need to be supported.

As such a framework for assessing the training needs or the readiness of an enterprise should take into account all the above aspects and therefore it should be multidimensional. We are proposing to employ six different dimensions to define the educational needs namely *technology*, *industry sector*, *software lifecycles*, *transversal skills*, *proficiency*, and *job profiles*. By combining factors from these five dimensions should be able to provide a set of skills either at the individual level or at the enterprise level.

In Figure 1 we present our proposed approach where it is indicated that by combining these six different facets we can produce balance training proposals for individuals or for enterprises. These six dimensions have to be analyzed for producing the training proposals are briefly analyzed below.

Technology: According to various studies and reports there are nine technological areas that are driving developments in Industry 4.0 initiatives. These key technologies are: a) Big data and analytics; b) Autonomous robots; c) Simulation; d) Horizontal and vertical system integration; e) The industrial Internet of Things; f) Cybersecurity; g) The cloud; h) Additive manufacturing; i) Augmented reality. Some may argue on the above list but this list may be adapted according to specific needs.

Industry sector: Obviously each industry sector has different training needs since different production processes are employed. These process may be management related (Business Planning and Logistics, Manufacturing Operations and Control, Automation and Machine Control, etc.) or production related (product design, engineering, etc.) [19]. Boston Group Consulting report [9] defines 23 industry sectors that are directly affected by Industry 4.0 initiatives. (eg. aerospace and defense, automotive, machinery, medical products). For each of those industry sectors an analytical list of core business processes needs to be defined. As such, this category refers to the contextual skills that are related to specific production processes, standards, guidelines, organization structured that are specific to an industry sector.

Job profile: There are numerous job profiles classifications [9], [20]. According to these classifications job profiles refer to specific roles within Industry 4.0 enterprises such as: logistics, sales, customer support, administration and management, maintenance, production planning, etc. Special emphasis has to be given to IT job profiles e.g. informatics specialist, robot programmer, software engineer, cyber security expert. Each of those job profiles relates to specific training requirements.

Software development and production lifecycle: Software is the key enabler of Industry 4.0 initiatives. Most of the new Industry 4.0 jobs profiles are related with the development and operation of software systems. The proposed approach if similar with the one proposed at e-CF framework that defines five concreate areas (plan, build, run, enable and manage). However, since the development of Industry 4.0 system is a complex endeavor, we need to enhance this approach with two major trends: a) the "agile infrastructure" that sprang from applying agile and lean approaches to operations work and b) from the collaboration between development and operations staff throughout all stages of the development lifecycle when creating and operating a service. As result, different skills are needed including business analysis, software development and testing, quality assurance but as well system operation skills such as database and network administration, web site management, security, source control (e.g. Git), continuous integration (e.g. Jenkins), infrastructure automation (e.g. Puppet), deployment automation & orchestration (e.g. Jenkins), service orchestration (e.g. Kubernetes), cloud (e.g. AWS), and on testing automation.

Transversal skills that refer to "Skills that are typically considered as not specifically related to a particular job, task, academic discipline or area of knowledge and that can be used in a wide variety of situations and work settings (for example, organizational skills)" [18].

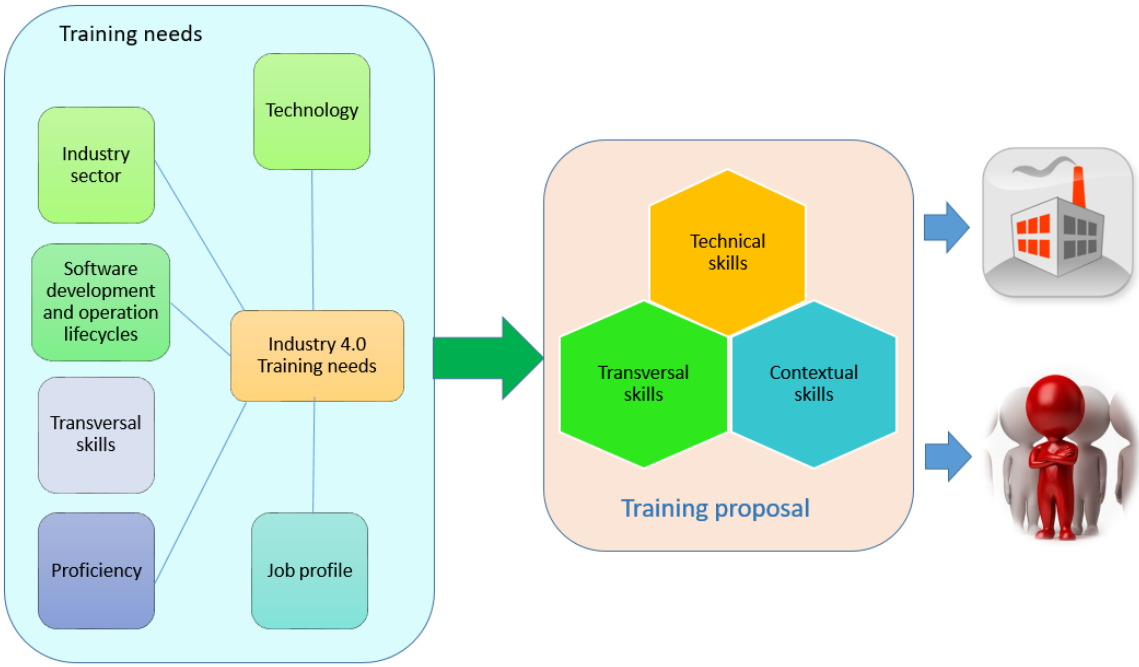

Fig. 1 *Industry 4.0 competence framework*

This includes a) personal competencies that can be understood as the ability to act in a reflective and autonomous way, etc. b) social/interpersonal competencies that refers to the ability of employees to communicate, cooperate and to establish social connections and structures with other individuals and teams, to build and maintain maintaining networks of experts, to be able to cooperate in ad-hoc fashion and c) action-related competencies that refers to the ability to take individual or socially constructed ideas into action [19] and d) methodological competencies such as creativity, entrepreneurial thinking, problem solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation [15].

Proficiency: Similarly to e-CF or SFIA our model is based on skills proficiency levels. For example we are proposing the adoption of five levels, where level 1 is the lowest and level 5 is the highest. More specifically, professionals at *level 1* should be able to follow or to understand a subject area, at *level 2* to apply in a professional manner a techniques of method, at *level 3* to design solutions or solve complex problems of the subject area, at *level 4* to lead teams of professionals and/or offer consultancy on the subject area and finally at *level 5* to research or to develop new technology on the subject area.

The above presented six dimensions can be combining for creating training proposal for individual professionals or for assessing the knowledge – skills gaps of enterprises.

4. Conclusions

In the first part of this paper we have provided, a comprehensive list for skills and competences needed for the introduction of Industry 4.0 where it was proved that the new skills landscape – ecosystem is complex and diverse since there is no 'technological determinism', there are different workforce segments and different production lifecycles. In order to answer to this need we have proposed a multi-dimensional where we propose to use a conceptual grid to address different skills needs in different workforce segments in different sectors depending on different subsets of the technologies. The proposed competence framework consists of six dimensions that need to be combined in order to produce the training needs for each specific case or to calculate the skill coverage when the readiness of enterprises for introducing Industry 4.0 technologies is assessed. Namely, these dimensions are: proficiency, technology, industry sector, product lifecycles, job profile and transversal skills. The outcome of this assessment will be a set of skills needed. These skills are categorized in three categories: technological, traversal and contextual.

Future work includes to further elaborate the proposed framework and to develop a tool that could be used for the assessment of the maturity of SMEs, especially when industry 4.0 technologies need to be introduced.

5. References

[1] Pricewaterhousecoopers (2016), Global Industry 4.0 Survey. Available at https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[2] Vogel-Heuser, B., & Hess, D. (2016). Guest editorial industry 4.0–prerequisites and visions. IEEE Transactions on Automation Science and Engineering, 13(2), 411-413.

[3] Data, B. (2011). Let ' s start with the definition of Industry 4.0. What does it mean ? Available at http://www.opendatasrl.it/index.php/en/

[4] SAP (2017), Introduction to Industrie 4.0 with SAP Connected ManufacturingVersion, SAP AG.

[5] Burke, R, Mussomeli, A., Laaper, S., Hartigan, M. Brenna, S. (2017). The smart factory. Available at https://www2.deloitte.com/insights/us/en/focus/industry-4-0/smart-factory-connected-manufacturing.html

[6] Marketsandmarkets.com (2017). Industry 4.0 Market by Technology (Industrial Robotics, Cyber Security, Internet of Things, 3D Printing, Advanced Human-Machine Interface, Big Data, Augmented Reality & Virtual Reality, Artificial Intelligence), Vertical, Region - Global Forecast to 2022, marketsandmarkets.com

[7] European Commission (2014). EU Skills Panorama. Advanced manufacturing Analytical Highlight, ICF GHK and Cedefop.

[8] Hartmann, E. & Bovenschulte, M. (2013): Skills Needs Analysis for "Industry 4.0" based on Roadmaps for Smart Systems. In: SKOLKOVO Moscow School of Management & International Labour Organization (ed.) (2013): Using Technology Foresights for Identifying Future Skills Needs. Global Workshop Proceedings, Moscow; p. 24-36

[9] Boston Consulting Group (2015), Man and Machine in Industry 4.0: How Will Technology Transform the Industrial Workforce Through 2025?. Available at http://englishbulletin.adapt.it/wp-content/uploads/2015/10/BCG_Man_and_Machine_in_Industry_4_0_Sep_2015_tcm80-197250.pdf

[10] Prinz, C., Morlock, F., Freith, S., Kreggenfeld, N., Kreimeier, D., & Kuhlenkötter, B. (2016). Learning Factory modules for smart factories in Industrie 4.0. Procedia CIRP, 54, 113-118.

[11] Gebhardt, J., Grimm, A., & Neugebauer, L. M. (2015). Developments 4.0-Prospects on future requirements and impacts on work and vocational education. Journal of Technical Education (JOTED), Jg, 3, 117-133.

[12] Betz, Charles. (2016). Renewing the IT Curriculum: Responding to Agile, DevOps, and Digital Transformation.

[13] World Economic Forum (2016), The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. Available at http://reports.weforum.org/future-of-jobs-2016/

[14] Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. Procedia CIRP, 54, 1-6.

[15] Leinweber S. Etappe 3: Kompetenzmanagement. In: Meifert MT, editor. Strategische Personalentwicklung - Ein Programm in acht Etappen. 3rd ed. Wiesbaden: Springer Fachmedien; 2013. p. 145–178

[16] European e-Competence Framework 3.0 (2014). A common European Framework for ICT Professionals in all industry sectors. European Commission. Available at http://ecompetences.eu/wp-content/uploads/2014/02/European-e-Competence-Framework-3.0_CEN_CWA_16234-1_2014.pdf

[17] SFIA Foundation, 2005, Framework Reference SFIA version 3: Skill definitions in categories, subcategories, and skills, http://www.sfia.org.uk/cgi-bin/wms.pl/932

[18] International Bureau of Education (2013). IBE Glossary of Curriculum Terminology. UNESCO International Bureau of Education.

[19] Erol, S., Jäger, A., Hold, P., Ott, K., & Sihn, W. (2016). Tangible Industry 4.0: a scenario-based approach to learning for the future of production. Procedia CIRP, 54, 13-18.

[20] Prifti, L., Knigge, M., Kienegger, H., & Krcmar, H. (2017). A Competency Model for" Industrie 4.0" Employees.