

## FUTURE-ORIENTED DIGITAL SKILLS FOR PROCESS DESIGN AND AUTOMATION

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**Abstract:** *The digital transformation in both the social and business fields requires the development of new skills related to the use and implementation of contemporary IT technologies, which provide the basis for Industry 4.0. One of the main concepts of these changes is the automation and robotization of business processes. The design, implementation and use of solutions in this field require appropriate skills. Therefore, it is necessary to identify gaps in digital skills and reduce them with adequate training and development. The main objective of the paper is to identify both current gaps and future needs for digital design skills to support and understand the automation of business processes. A survey was carried out in manufacturing companies from six European countries. Its results have enabled us to create a future-oriented digital design competence framework that addresses the requirements of process design and automation in the Factory of the Future.*

**Keywords:** *Industry 4.0, Factory of the Future, digital skills, process design, automation.*

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## INTRODUCTION

In the contemporary digitalization and robotics world, industries are facing new challenges. The growth of disruptive technologies and, as its consequence, the rise of Industry 4.0 and smart factories will change the traditional role of factory workers. The innovative technologies (artificial intelligence, robotics, automation, big data analytics, cloud computing, Internet of Things, 3D printing), intelligent production system and knowledge workers create a backbone of the "Factory of the Future" (FoF). Unfortunately, availability of adequate digital skills seems to be a challenging issue for the development of FoF.

According to the World Economic Forum (2017, 2020), due to the rapid evolution of the labour market, most people who rely on a single skillset or narrow expertise are unlikely to keep long-term jobs in the digital economy. Moreover, in the next few years newcomers will require new digital, social, emotional, personal development and learning skills. These skills will enable the next generation of employees to achieve the FoF's objectives and meet new demands of the labour market. Digital skills are considered by many researchers (European Parliament, 2018; Ozkan & Ozen, 2020; van Laar et al. 2020) as one of the strategic pillars and drivers of this transition. It is clear that the deficit of appropriate digital competences, both among the management and employees, causes difficulties for enterprises in implementing digital solutions (McGuinness & Ortiz, 2016; Sari et al., 2020). The European Commission (EC) points out that 15% of EU employers declared a significant digital skills shortage among their employees. This is highly problematic in the context of an increasing automation of processes and digitisation of different areas of our life, according to the EC's experts (Curtarelli et al., 2017). The results of the ongoing analysis and experts' opinions give a clear indication of the need to identify and close the existing digital skills gap in the context of Industry 4.0 challenges. We understand the skills gap as a phenomenon in which the skill level of employees is insufficient to meet the demands of the current job (McGuinness & Ortiz, 2016). That gap may also occur for newcomers, thus reflecting a mismatch between the education system and labour market needs.

Digitalisation and its challenges also affect the education sector. According to the European Strategy for Universities (European Commission, 2022), higher education in Europe needs to address and adapt to variable and ongoing conditions related to climate change, digital and technologies in all activities sectors, demographic change, the COVID-19 pandemic, big crisis situations like war or other not identified yet (Feijao et al., 2021). Students and staff across the EU need to be equipped with the green and digital skills of the future, and the innovative and technological potential of universities needs to be harnessed to address related societal and industry challenges (European Commission, 2022).

As an effect of a digital transformation employment is shifting away from low-skilled jobs and from tasks with a higher routine content, which are easier to automate (Morandini et al., 2020). Whereas tasks requiring experience, intuition, creativity, or the ability to make decisions in the face of uncertainty will remain in the hands of people. Pontes et al. (2021) show that the development of Industry 4.0 fosters several trends (Connectivity, Lower Energy Use, Artificial Intelligence, Big Data and Value of Data) resulting from digitalisation. Sobczak (2021) and Bejaković and Mrnjavac (2020) point out that in addition to technical competence, new technologies including Robotic Process Automation (RPA) also require the development of analytical and cognitive skills. According to a study by Schlegel & Krause (2021), today's

companies looking for RPA professionals expect them to have not only the ability to use certain tools but also domain specific knowledge (business process management, human resources). Employees competence is also seen as a critical factor for the efficiency of Industry 4.0. According to Kumar & Kumar (2019), complexity of an information of FoF production systems makes the cognitive skills of employees and their domain-specific skills, equally important. Digital transformation entails changes in both hard (simulation, programming, machine learning) and soft skills (leadership, teamwork, problem solving). Thus, they should be perceived as a complimentary skill set required by FoF.

Therefore, a need can be observed to develop a digital skills framework that can support serve educators, policy makers, and employers to eliminate a digital competencies gap. Most of existing frameworks are focused on general digital competences (DigComp) and a few consider requirements of Industry 4.0 (Hecklau et al., 2017; Flores et al., 2020; Hernandez-de-Menendez et al., 2020; Oberländer et al., 2020). However, there is a distinct shortage of frameworks that address FoF-specific technologies and fields.

The recommendations of the ongoing debate on the digital transformation challenges stressed the necessity for a deeper understanding of a phenomena. Ras et al. (2017) highlight the need to shape new digital competencies and create a new generation of Industry 4.0 leaders. Margherita and Braccini (2021) point out that while the technical aspects of smart factories are quite widely researched, few studies address the competencies required to manage them. Moreover, existing modes of education may not keep up with employers' demand for digital skills (Feijao et al., 2021). As a result, this leads to inconsistencies between market needs and the education curricula of the future FoF workforce. A variety of studies suggest the necessity of taking initiatives to identify and reduce digital competency gaps. It is indicated that this is one of the main success factors for digital transformation and FoF development (Ras et al., 2017; Florea, 2019; Bejaković and Mrnjavac, 2020).

The literature review findings suggest the following significant research problems: the identification of new digital design competencies, revision of existing frameworks representing the requirements of FoF. There are two main research gaps. First, there are only limited empirical study on the digital competency frameworks for manufacturing industry. Second, there are no empirical study on digital competency supporting process design and automation in the context of Factory of the Future requirements. In the context of the long-running debate on the digital transformation, the following questions arise:

1. What transversal digital competencies supporting process design and automation are required by Factory of the Future employees?
2. What digital skills are required to meet the challenges of process design and automation in a Factory of the Future?

Following this, the main objective of this article is to identify areas of digital skills to support process design and automation in the context of the needs of the Factory of the Future. A general set of digital skills was identified through a literature review. This was the basis for the development of a set of competencies reviewed by representatives of manufacturing companies from six European countries through a survey. The study focuses on the diagnosis of digital transversal competences and digital skills fostering process design and automation from a perspective of a manufacturing sector. The paper also considers the existing digital competency requirements of contemporary enterprises - potential FoF stakeholders which was an additional rationale for proposing a future-oriented digital design competency framework.

The remainder of the paper consists of the following sections: first part reviews the literature on the issues relating to digital competences relating to Industry 4.0 and Factories of the Future and proposed a set of generic set of digital skills and competences Then, the methodology section identifies the relevant research process and methods, and describes the tools and techniques for data acquisition and collection. The empirical data analysis is described in the results section. The literature review and empirical research results served as the basis for the formulation of the future-oriented framework of digital skills supporting process design and automation are included in the following section. Finally, paper summarizes the findings and research contribution and implications for the future research.

## **DIGITAL DESIGN AND PROCESS AUTOMATION SKILLS IN FACTORY OF THE FUTURE**

Today's companies are facing new market challenges driven by, among others, high demand for personalized products, shorter product lifecycle and need to increased productivity, efficiency and energy savings. To cope with these challenges, a wide range of advanced Industry 4.0 technologies (among others: Internet of Things, big data analytics, artificial intelligence, augmented reality systems) have been adopted to improve the capability and effectiveness of manufacturing processes. As a consequence of the changing circumstances, there is need to develop an intelligent, smart manufacturing and cybernetic-physical systems (CPS) as the foundation of Industry 4.0 (Yao et al., 2017). It merges the physical and the virtual worlds in industrial production. Industry 4.0 brings together information technology and factory automation. The new approach to a manufacturing system includes smart design, smart machining, smart monitoring, smart control, smart scheduling (Kumar & Kumar, 2019). This creates opportunities for new ways to automate mundane rules-based business processes using Robotic Process Automation (RPA) tools on information acquired from smart devices (Madakam, Holmukhe & Jaiswal, 2019). Moreover, the joint use of RPA and artificial intelligence, business process management, or natural language processing enables the automation of more complex processes (Kedziora & Kiviranta, 2018; Siderska, 2020). Further, the integration of RPA and cognitive, deep learning results in increased potential and efficiency of process automation (Anagnoste, 2018).

These new and emerging technologies constitute a future-oriented production ecosystem called "Factory of the Future" (FoF). Generally, the term Factory of the Future could be perceived as synonymous with the forthcoming era of digitalisation of industry (DIGIFoF, 2019). The European Commission defines Factories of the Future as a future-oriented manufacturing companies embracing Industry 4.0 opportunities to their full extent. FoF can be considered as an ongoing interconnection in manufacturing systems driven by technology, sustainability, optimization and the need to meet customer demands (Biegler et al., 2018). Lee et al. (2015) conclude that the way to build FoF is to integrate CPS with innovative production, logistics and services practices.

Some scholars argue that a digital transition offers the opportunity to meet not only business objectives (Thames and & Schaefer, 2017; Kedziora et al., 2021) but also enables enhanced human learning through intelligent assistance systems (Müller, Kiel & Voigt, 2018) and helps to face with the challenges of the circular economy and socio-economic sustain development

(Sarc et al., 2019). Since the “digital shift” makes production processes more demanding and complex, the technological development and the implementation of FoF should be considered as a long-term strategic project aimed at: creating smart, closed processes in manufacturing and, and altering the entire value-added chain in manufacturing (Spöttl & Windelband, 2021). KPMG report (2016) suggests that Industry 4.0 is now more of a certain idea than a material entity. At the same time, they draw attention to one fundamental and already topical issue. Industry 4.0 requires products (industry and management software), processes and devices (e.g. Ethernet, sensors, robotics). In turn, FoF equipment requires specialists in ICT and automation technology.

The key challenge of a new digital manufacturing paradigm is the upskilling and reskilling needs required by FoF (KPMG, 2016; Pontes et al., 2021). On the one hand the Industry 4.0 paradigm causes changes in the competences set of FoF's employees while on the other hand creates new jobs. According to recent research (World Economic Forum, 2020) 133 million new jobs will be created over the period 2018-2022. Pouliakas (2018) suggests that around 14% of jobs in the European Union are at high risk of automation. In the medium term, 35 - 40% of workplaces are expected to change in terms of the qualification requirements of employees. This issue is also highlighted by Spöttl & Windelband (2021). They argue that the idea of Industry 4.0 addresses issues related to interdependence of technological and social intelligence as well as the issue of the training and professional development and work design. Development of the required competences and skills plays a significant part in shaping a new ecosystem of FoF, which should not be marginalized. This poses a significant challenge for institutional and national systems of a future oriented competence development (Florea, 2019).

Factory of the Future requires tailored and domain-specific competencies and skills, such as data analytics, IT, software, and human-machine interaction know-how (Müller, Kiel & Voigt, 2018). The leading role of cybernetic-physical systems in FoF requires interdisciplinary and collective competences. Moreover, it calls for the integration of knowledge and skills from the fields of machinery manufacturing, electronics and information-communication technologies (Spöttl & Windelband, 2021). Veile et al. (2020) also argue that future employees of FoF require skills and competencies, such as Information and Communication Technology (ICT) know-how, interdisciplinary competencies and special personality traits. KPMG also suggests that the specificity of FoF requires the integration of different skill sets. Their proposed profile combines three skills areas: theory and expertise (material and production skills, process skills, electrical engineering, software, information and ICT), hardware (mechanical and plant engineering, automation technology, mechatronics, microsystem technology, electronics, IT infrastructure and security) and software (documentation, integration, process mapping, maintenance, trainings and continues professional development).

Leading role of process automation in FoF (KPMG, 2016; Madakam, Holmukhe & Jaiswal, 2019) will have significant consequences on people's professional development (Hirschi, 2018; Pouliakas, 2018). As already emphasised, manual tasks, routine activities and low-skilled jobs will be severely reduced (Morandini et al., 2020). Addressing these challenges requires FoF specific knowledge and skills. Essential technical skills related to RPA include knowledge of this technology, software testing and development, understanding of process design principles (Anagnoste, 2018). Therefore, the digital competence framework referring to FoF requirements should take into account the ability to use specific digital tools and knowledge specific to FoF key development areas (Schlegel & Krause, 2021).

In addition to competences of a technical nature, attention is drawn to the role in digital transformation of 'soft' competences providing, inter alia, creative approaches to analysis and problem solving, communication and networking skills (Hecklau et al., 2017; Flores et al., 2020; Hernandez-de-Menendez et al., 2020; Oberländer et al., 2020). This is very strongly emphasised in the context of implementing RPA solutions. Sobczak (2021) shows the very significant role of organisational, cultural and competence aspects as success factors, not just technological ones. Algorithmic and process thinking skills will play a key role, as well as soft skills not usually associated with RPA. The similar findings were presented by Bejaković and Mrnjavac (2020). The skills and competencies of the team, as well as the culture, ethics and behaviour of people in the organisation, determine the outcome of RPA implementation (Kedziora & Penttinen, 2021; Pramod, 2022). Anagnoste (2018) pointed out that among the non-technical competencies, leadership, communication, team working and problem-solving skills, new technology awareness play an important role in process design and its further automation.

The materialisation of the FoF concept entails very extensive changes in the traditional competence structures of employees. Both the type of technical skills and their relationship with soft skills are changing compared to the traditionally structured and non-smart enterprise. Moreover, digital skills gap is crucial challenge of a digital transformation. The gap is a result of the existing structure of the labour market and incomplete identification of FoF needs. This has led to a number of frameworks and maps aimed at developing digital competences and supporting the education and training sector, policy makers and FoF employers and employees in this regard.

## COMPETENCY AND DIGITAL SKILLS FRAMEWORKS

The competences and skills required by the Factories of the Future are becoming the determinants of new frameworks and a recommendation made to different sectors of industry, government and academia. Competence models represent the expected social and economic changes and therefore the need for new competences. However, as was discussed in the preceding part, there is a clear need to consider three fundamental skills and competencies: transversal, business and technical. A competency model is a compilation of competencies that, when put together can determine effective performance in a particular job environment. This lists may include different detail levels and also describe relationships between the competencies. Throughout the years, many competency models and frameworks have been developed, including those related to digital skills and competency. The review of digital competency and skills frameworks aims to identify their structure and a core set of digital competencies. Moreover, this has been used to develop a proposal of the future-oriented competency framework reflecting digital design and process automation skills required by FoF.

The Digital Competence Framework for Citizens (DigComp 2.1) covers five key areas of digital competence. These are information and data literacy, communication and collaboration, digital content creation, safety, problem solving (Carretero et al., 2017). DigComp framework provides only general guidance for the development of digital competences of EU citizens. However, it does not refer to specialised competences and skills. Nevertheless, the

comprehensiveness and a certain universality of this approach makes it applicable to the identification of basic and transversal digital competences supporting development of FoF.

Oberländer et al. (2020) identified 25 dimensions of digital competences. This research focuses only on white-collar workers with office jobs in Germany and, as the authors themselves point out, cannot be generalised and transferred to other regions and professional groups. Results of the literature studies done by Hecklau et al. (2017) and Flores et al. (2020) identified digital competences needed by Industry 4.0. Smart Factory competence framework proposed by Hecklau et al. (2017) distinguishes four competence areas, i.e. social, methodological, domain-related and personal competencies. Flores et al. (2020), in turn, recognised five sets of competences required by employees in Industry 4.0: soft, hard, cognitive, emotional intelligence, digital. They indicate that the most demanded skills of the digital workforce include programming, cybersecurity, digital networks, cloud computing, databases, web development and also the management of Industry 4.0 technologies. Further research led by Shet & Pereira (2021) focused on managerial competencies for Industry 4.0. They identified 14 groups of managerial competencies for Industry 4.0, including design thinking, problem solving & decision-making, digital intelligence & modelling, robotic process automation. The framework for Industry 4.0 proposed by Shet & Pereira (2021) indicates the need for their comprehensive consideration due to the specificity of FoF competence requirements. As with previous scholars, they do not refer to specialised skills for process design and automation.

On the other hand, report the “Industry 4.0 implications for higher education institutions. State-of-maturity and competence needs” (2019) distinguished two categories of competences supporting the development of Industry 4.0, i.e., discipline-specific competencies and knowledge as well as transferable skills. This framework focuses more on a professional competency that support design than previous works (Hecklau et al., 2017; Flores et al., 2020; Shet & Pereira, 2021). The authors of this study (Universities of the Future, 2019) proposes to classify competences into three categories: technical and engineering, design and innovation, business and management. The development of the technical competences assigned to the first two categories is based, among other things, on the acquisition of skills and knowledge in the field of big data analysis, Artificial Intelligence (AI), robotics, automation advanced simulation and virtual plant modelling, tech-enabled product and service design, human-robot interaction, programming, cyber-physical system development (Universities of the Future, 2019). The main limitations of the research and consequently the framework itself, is the number of respondents (20 respondents) and country representation (Finland, Poland and Portugal).

Unfortunately, presented in the literature frameworks are mostly focused on rather broad digital competences. There is also a lack of a consistent approach to the classification of digital competences among the models analysed. Moreover, these frameworks do not identify skills related to the key area for FoF that is design and automation. The proposed skill sets presented in the literature does not address the needs of the manufacturing sector essential for the development of Factory of the Future.

Considering the limitations identified, we have attempted to develop a set of key digital skills related to process design and automation for the manufacturing sector and FoF. Table 1 shows a proposition of a generic set of digital skills and competences for the Factory of the Future. With regard to the purpose of the study, competences related to process design in the broadest sense were identified. They include design skills understood as the ability to

intentionally create a plan or specification for the construction of an object/a service/a system/for the implementation of an activity or process. The scope of these skills involves e.g.: product design, service design, user interaction design, information system design, factory design, production process design, business process design, etc. (DIGIFoF, 2019).

**Table 1.** Competency framework for Factory of the Future – process design context (Carretero et al., 2017; Shet and Pereira, 2021; Universities of the Future, 2019; DIGIFoF, 2019; Flores et al., 2020; Kunrath et al., 2020).

Transversal competencies and skills	Design competencies and skills	
	Business	Engineering
Information and data literacy	Technology awareness	Big data analysis
Communication	Business analysis	Simulations and virtual plant modelling
Collaboration and networking	Systems analysis	Digital intelligence & modelling
Digital content creation	Process understanding	Cybersecurity/Data security
Safety, data protection	Design thinking	Programming and coding
Problem solving	Anticipatory thinking	Robotic process automation
Teamwork	Cognitive analysis	Process mining
Netiquette	Knowledge management	Cloud computing

Among the competences supporting FoF, we can therefore distinguish their two main groups: transversal and professional (expert/discipline-specific). The first group includes social, methodological and personal competences. According to Fray et al. (2014), they are crucial in shaping young people's career maturity, particularly in terms of perceptions of discipline-specific competency development trainings. Moreover, transversal competences facilitating the transition from professional trainings into employment. It is also worth emphasising that the competences in this group reflect the Digital Competence framework, which provides a reference model to support EU policy-making in this area (Carretero et al., 2017).

Design-specific competences, on the other hand, refer to professional skills and knowledge acquired through formal/vocational education. Among them we can distinguish key competences for the following two areas: business and engineering (Universities of the Future, 2019). They relate to planning, organisation, management, prototyping, testing, implementation and production, among others. These competences are seen as crucial especially for manufacturing sector and industrial processes. (Universities of the Future, 2019; Flores et al., 2020; Kunrath et al., 2020).

## RESEARCH METHODOLOGY

The literature review presented in the preceding parts of the paper allow to identify the competency demands of FoF and their role in process design and automation. As was already discussed, a key success factor for the implementation of the idea and development of FoF is the proper background of employees. Therefore, the primary purpose of our study is to identify the key digital skills and competences supporting a development of FoF in the field of design,



automation of processes. Results have been used to develop a framework of future-oriented digital design competency. It represents a perspective of a manufacturing sector.

## Research Design and Tool

Considering the nature of the research problem, an exploratory and descriptive methods was adopted. The choice of this approach allowed for a better understanding of the research problem and its refinement. Exploratory research enables the discovery of new insights and to see what is happening. Rahi (2017) underlines that it attempts to ask questions and evaluate phenomenon in a new light. The use of the descriptive method in the research has provided information on the current state of the phenomenon. In this research, the results of a quantitative study have been used to identify the key digital skills and competency in the field of design, automation of processes from manufacturing sector perspective. Creswell & Creswell (2018) suggest that survey designs helps to answer three types of questions: descriptive questions; questions about the relationships between, and questions about predictive relationships between variables over time. A survey design provides a quantitative description of opinions of a population by studying a sample of it. Moreover, a quantitative research has the advantage of being an objective representation of reality (Creswell & Creswell, 2018).

The quantitative research consisted of two phases. The first was pilot studies aimed to verify the questionnaire by participants of DIGIFoF project. The pilot study allowed to assess the extent to which the questions were well understood and allow reliable answers to be obtained, thus meeting the aim of the survey. The sequence of questions and the way in which they are presented has been rearranged, descriptions of scales have been clarified and unclear terms and concepts have been improved. The questionnaire was prepared in the appropriate languages of the respondents from each country of the survey. The revised version of the questionnaire consisted of four main sections:

1. General information: includes companies profile.
2. Digital competency needs and demands: includes questions related to the needed design skills and required training for the need of FoF;
3. Designing background: includes questions exploring understanding the companies' attitude towards design concepts, methods and tools;
4. Area of interest and implementations of: questions explore the interest areas to be treated in the FoF training and digital skills development.

The final questionnaire form contains 44 items (points 1-4). It was distributed to respondents and the results were collected and analysed in the second phase of the quantitative research. The paper presents the results of the selected aspects of the whole study which are related to digital skills in design and automation. This part of the study was performed using twelve questions from the second section of the questionnaire form (point 2). They addressed two issues: vocational training needs (form, scope, duration) and the role of digital design competences to support FoF development (digital competency level, digital design skills needs and demands). The questions in this section of the questionnaire were closed (vocational training needs) and multiple choice questions (most important digital competencies of the employee of the Factory of the Future).

## Data Collection

The survey was conducted using Computer-Assisted Web Interview (CAWI) and Paper & Pen Personal Interview (PAPI) approach. Both the electronic and paper form were used for gathering information. To collect data, we use convenience sampling (volunteer sample). Convenience sampling involves drawing samples that are both easily accessible and willing to participate in a study (Teddlie & Tashakkori, 2009). Data were collected from 87 representatives of manufacturing companies from six European countries (Italy, Finland, France, Germany, Poland, Romania). The survey was carried out from 14.04 to 27.05.2019 within the DIGIFoF project.

The respondents were primarily employed in large enterprises with 250-4,999 workers (39% respondents) and medium enterprises with 50-249 employees (28% respondents). The representatives of small and micro enterprises constituted respectively 14% and 10% of the sample. The least numerous group were representatives of very large companies (9%).<sup>1</sup>

The respondents mainly represented the following fields:

- development and production of electronic devices for the automotive industry,
- development and testing of software,
- metalworking industry.

The roles of the respondents were as follows:

- engineers involve in product and/or service design,
- IT and enterprise architects,
- strategists and innovators in charge of service/product/business model innovation.

The participation of domain professionals from the above-mentioned areas plays an important role in determining the business-driven digital skills required by the FoF. One third of the respondents were employees who had been working for 1 to 3 years. A relatively significant group were employees with work experience of 5 to 10 years (21% of respondents). A slightly narrower group of participants were those with 3 to 5 years of experience (17% of respondents), as well as those with more than 10 years of work experience (13% of respondents). On the one hand, the roles of respondents fit into the professional profiles of FoF employees, while on the other hand, their knowledge and professional experience can significantly support the verification of needs in terms of digital skills for process design and automation.

## RESEARCH RESULTS

In order to answer the research questions, an attempt was made to identify the significance of transversal competencies for the professional activity of the respondents and the enterprise operation. Based on the results of the literature review and opinions of experts cooperating within the DIGIFoF network, a list of 12 transversal digital competencies was defined that entailed: (1) adaptive learning, (2) creativity, (3) critical thinking, (4) complex problem solving, (5) information and data literacy, (6) digital content analysis & creation, (7) digital identity management, (8) data protection, (9) teamwork in a virtual environment, (10) social

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<sup>1</sup> It is assumed that very large enterprise employs more than 4,999 people small enterprise from 10 to 49 workers, and micro enterprises not larger than 9 people.

networking, (11) communication and collaboration supported by digital technologies and (12) netiquette. Respondents were asked to indicate the most important transversal digital competences of a Factory of the Future employee that they believe are needed now and those that will be required in 5 years' time. A summary of the relevance to FoF development of the selected competences is shown in Figure 1.

The five most important competences currently on the labour market (70% of indications) are creativity, critical thinking, data protection, adaptive learning and problem solving, respectively. These are also the most frequently co-occurring competences. This set of transversal digital competences was indicated by about 60% of the respondents. They can therefore be seen as the most desirable set of competences for FoF's employees according to the interviewees. Furthermore, about 64% of respondents have indicated that the ability to communicate and collaborate using modern digital technologies is a key skill from the perspective needs of FoF. Among the important competencies information and data literacy and teamwork in a virtual environment were also highlighted. In the opinion of the respondents, competences related to management of digital identity and netiquette are relatively less necessary for the functioning of FoF in the present circumstances (Fig. 1). It is interesting to note that this last competence did not appear in the set of key transversal digital competences in almost 30% of respondents. Besides, about 20% of them did not include in their sets of competences social networking and the previously mentioned digital identity management. These are employees who usually have been with the company for no more than 10 years and who mainly hold management positions (CEO, managing director, manager).

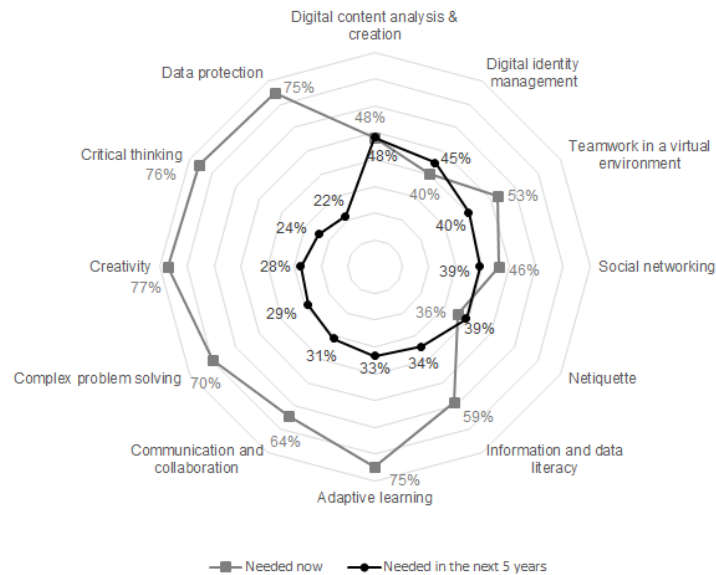
Looking at changes in the perception of particular ones, it is worth noting that some of them are perceived by respondents as indispensable in the context of labour market needs. These include: adaptive learning, creativity, data protection. They were indicated as necessary competences now and in five years by about 10% of respondents. These were usually indicated by respondents with less than 3 years of work experience.

Whereas, in the perspective of 5 years, the set of key competences of a FoF employee indicated above was considered relatively less important. In the opinion of the respondents, competences related to digital content analysis and creation, digital identity management and data protection will increase, although to a relatively small extent (Figure 1). Among the most important transversal digital competences of FoF's employees in five years' time, respondents included:

- digital content analysis & creation,
- digital identity management,
- teamwork in a virtual environment,
- social networking,
- netiquette.

The respondents who indicated these competences are strongly diversified in terms of their professional profile and the positions they hold. They represented both the industrial production sector and software manufacturers. In the majority of them, the length of their work experience in the currently occupied position did not exceed three years. From the perspective of respondents from large companies, a key competence is the ability to teamwork in a virtual environment. They clearly link this with the need to know netiquette rules. Among the five key competences in next five years, there have also pointed out skills connected with social

networking. It was most often indicated by the respondents together with competences connected with communication and cooperation using modern digital technologies (35-45%).



**Figure 1.** Top transversal digital competences of FoF's employees - present and future needs

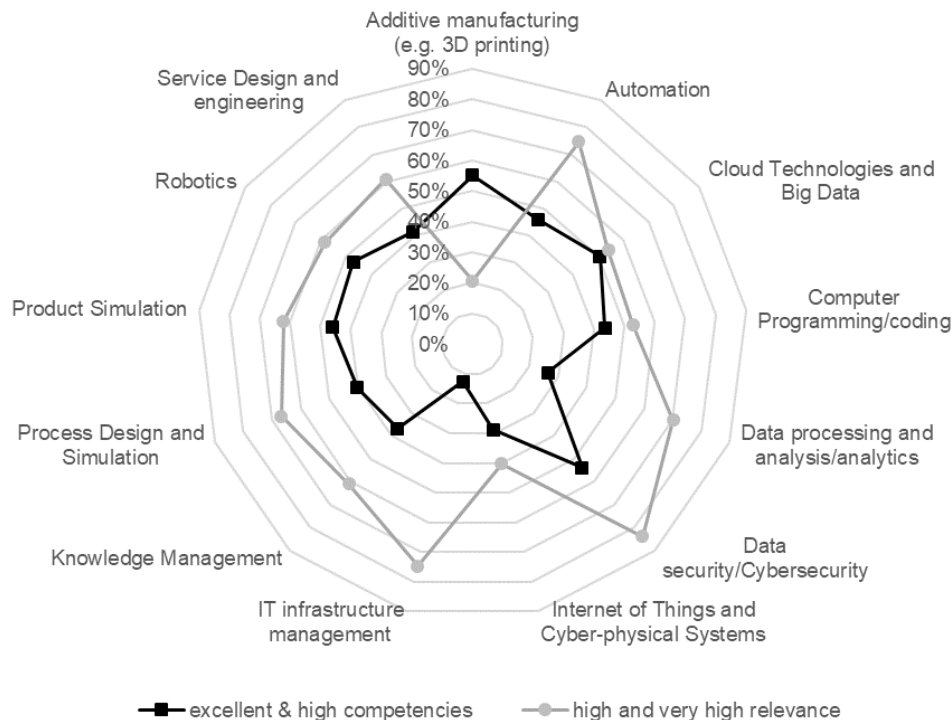
A further important issue of the survey was the identification of needs and competence gaps in the design context of digitisation and process automation. Respondents were given a set of 13 key competencies representing both business and engineering areas. It included the following areas of competence: (1) IT infrastructure management, (2) data processing and analysis, (3) data security/cybersecurity, (4) computer programming/coding, (5) internet of things and cyber-physical systems, (6) automation, (7) robotics, (8) additive manufacturing, (9) cloud technologies and big data, (10) product simulation, (11) process design and simulation, (12) service design and engineering and (13) knowledge management. This set was developed based on the results of the literature review and the opinions of experts collaborating within the DIGIFoF network.

Respondents assessed both the level of relevance of competences in a specific area for the company and its current level among their employees. The assessment was made using a five-point scale, where these values in the first area of evaluation mean respectively: 1 – “no relevance”, 2 – “low relevance”, 3 – “medium relevance”, 4 – “high relevance” and 5 – “very high relevance”. In the assessment of the current level of digital competence in design, the values of the scale from 1 to 5 were assigned as follows: 1 – “no competencies”, 2 – “low competencies”, 3 – “medium competencies”, 4 – “high competencies” and 5 – “excellent competencies” of the employees of the company in the key fields of the FoF. The results of the survey allowed us to determine the importance of digital design competencies for the surveyed companies and their level among employees. Figure 2 illustrates the respectively diagnosed needs and gaps in digital competences indicated by employees of companies operating in six European Union countries.

The most important and desired competence areas in the surveyed enterprises are related to: data security/cybersecurity, process automation and management of IT infrastructure. The data security/cybersecurity has been perceived as the most important competency by almost

85% of respondents. The group of key competences also includes automation skills and knowledge (75%) and issues related to the development of IT infrastructure (75%).

The very high importance of automation in shaping the development of manufacturing enterprises can be evidenced by the fact that this area was considered extremely important by both managing directors (management board, production, human resource), specialists and also employees directly involved in production. Data processing and analysis/analytics (70%) and process design and simulation (67%) were also in the top five most frequently indicated competence areas by the respondents. The above-mentioned areas are in the group of high and very high relevance digital design competency. In the opinion of the respondents, skills and knowledge of employees in the field of product simulation, knowledge management and robotics are also very important for the development of FoF. The area related to additive manufacturing was considered to be the least important. Respondents considered this to be a low to moderately relevant area of competence needed in their companies (Figure 2). This may suggest that they do not see the potential of 3D printing in industrial manufacturing or rapid prototyping.



**Figure 1.** Gaps of digital design competency

The second aspect of the survey was to identify the level of digital competence in design (Figure 2). The performed diagnosis revealed relatively high shortages of competences in this area (no & low competency). The biggest deficiencies of competences concerned the aforementioned area of additive manufacturing. This is reflected in the respondents' relatively low knowledge of computer-aided-design and engineering. About 60% of respondents understand these issues and use them in practice. Almost 50% of respondents indicated that they did not have well established knowledge and skills in service design and engineering. These are the two areas with the relatively largest digital design competency deficits among

employees participating in the survey. Furthermore, between 30 and 40% of respondents indicated that they have no or low competencies in the areas of cloud technologies and Big Data, robotics, programming/coding, Internet of Things and cyber-physical systems, product simulation.

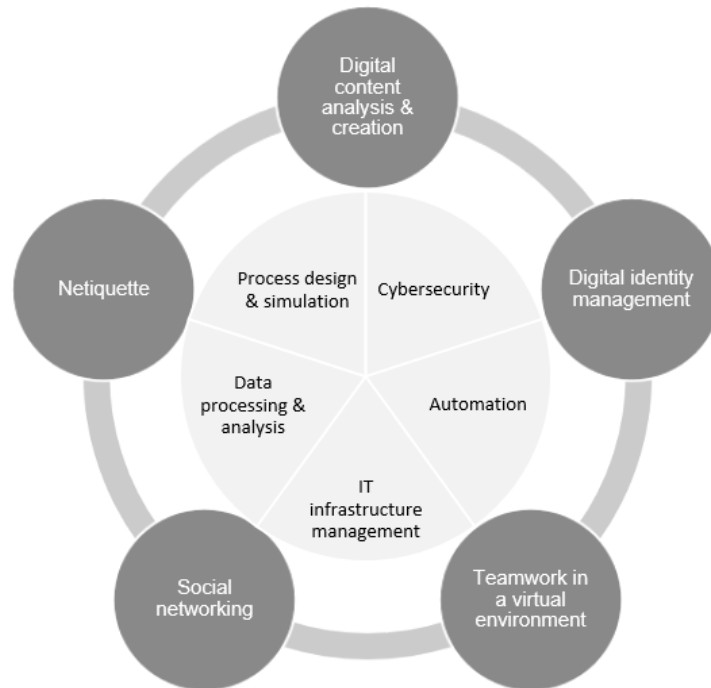
By comparing the level of digital design competency indicated by the respondents with the potential needs of enterprises, gaps in individual areas were identified. They are shown in Figure 2 by the differences between the relevance of competences from particular areas in the company's activity (high & very high relevance) and their levels among the surveyed employees (excellent & high competency). The greatest need for improvement is seen in the areas of IT infrastructure management and data processing and analysis. Despite the fact that these competences are very useful in the company's activity, their level among employees is relatively low. High level of skills and knowledge in those areas was declared by only 13% and 26% of employees respectively. Having regard to the needs of enterprises, the shortages are also visible in three areas: automation, knowledge management, process design and simulation.

## **FUTURE-ORIENTED DIGITAL DESIGN COMPETENCY FRAMEWORK**

Considering the increasing role of digital skills, especially in the field of automation, robotization of processes and machine-to-machine communication, an attempt has been made to develop digital competences frameworks. The proposal for a future-oriented digital design competency framework was based on the results of empirical research conducted among employees of companies from six European countries and the results of a literature review. The future digital design competency framework summarises the capabilities that are required of the FoF's employees for process design and automation. It can provide a basis for the development of guidelines and requirements for professional training, as well as for the revision and improvement of curricula for the learning of future FoF employees.

The proposed new approach to the set of competencies takes into account the respondents' opinions on the usefulness of digital competencies from specific areas supporting the Factories of the Future. Therefore, its core part is based on the subjective opinions of professionals from a manufacturing sector. The objectivity of the application of the framework depends on the user's perception and understanding of the essence of the skill sets included. Figure 3 shows a visual illustration of the proposed framework.

In the proposed future-oriented digital design competency framework, two sets of competencies were identified, i.e. digital transversal and digital design competencies. The first group encompasses five key areas: collaboration and networking, digital content creation, safety & data protection, teamwork and netiquette. It responds to requirements specific to European companies in the manufacturing sector. Moreover, the proposed framework reflects the competences identified by the European Parliament (2018) as key to lifelong learning that every European citizen should possess. Properly fostering entrepreneurial skills, combined with cross-cutting social skills, emotional intelligence, personal development and learning skills, is the way to increase Europe's competitiveness, the European Parliament (2018) underlines.



**Figure 2.** Future-oriented digital design competency framework

The set of expertise competences comprises competences from two areas, i.e. business and engineering. The survey results showed that among the business competencies supporting digital design, knowledge and skills related to understanding enterprise processes and knowledge management are expected to play an important role. The set of subject-related competences includes competences from two areas, i.e. business and engineering. The survey results showed that among the business competencies supporting digital design, knowledge and skills related to understanding enterprise processes and knowledge management are expected to play an important role. However, it is worth noting that relatively the biggest competence shortages were identified in the knowledge management. The recognition of process understanding as a key competence area of the future may stem from the growing need to shift from a functional to process-orientated approach to management. The engineering competency set highlighted three key areas: data analysis, cybersecurity and Robotic Process Automation. According to the surveyed representatives of European companies, these represent the most desirable future set of domain-specific competencies of Factories of the Future employees. This set of competences and skills relates to the area of STEM competences (Science, Technology, Engineering and Mathematics) for lifelong learning for European citizens (European Parliament, 2018). Alongside "cultural awareness and expression" and "digital literacy and language" skills, they are, in the European Parliament's opinion, the cornerstone of the social and economic development of modern Europe.

## DISCUSSION AND GENERAL REMARKS

Changes associated with digital transformation do not have only technological implications but also implications for the structure of a labour market and workforce (Ozkan & Ozen, 2020). Moreover, the way and form of human-machine interaction related to the Factory of the Future is evolving as a result of advancing virtualisation and automation of processes (Kumar & Kumar, 2019; Pontes et al., 2021). The integration of technologies on the FoF platform on the one results in increased potential of process design, automation, control (Yao et al., 2017; Anagnoste, 2018) and on the other required new capabilities. One of the main challenges of implementing the FoF concept therefore becomes the adaptation and development of the knowledge and skills of smart factory's employees (Florea, 2019). Moreover, as highlighted by Lasi et al. (2014) technology driven changes in manufacturing systems may initiate the appearance of new types of enterprises in the value-creation chain with new roles and competences. To meet these challenges, attempts are being made to identify the competency needs and demands of manufacturing industry (Hecklau et al., 2017; DIGIFoF, 2019) as well as business and education related entities (Ilomäki et al., 2016; Carretero et al., 2017; Oberländer et al., 2020).

The models and frameworks of digital competency presented by the many scholars (Hecklau et al., 2017; Universities of the Future, 2019; Shet & Pereira, 2021) agree that the essential requirement for the development of FoF is the acquisition of transversal skills in problem solving, communication, and collaboration with ICT. They are, according to many researchers, relevant to the need for creative and innovative approaches to process design (DIGIFoF, 2019; Flores et al., 2020; Hernandez-de-Menendez et al., 2020) as well as successful working in distributed and multidisciplinary teams (Veile et al., 2020; Kipper, et al. 2021). As argued by van Laar et al. (2020), the significant role of such competences is a consequence of the mutual diffusion of technology and society development and the fact that they have a strong influence on the way digital technologies are used. So called "digital shift" also very significantly influences the reconfiguration of design skills in terms of both business and technical skills. These are crucial, above all, for building a company's competitive advantage (Müller et al., 2018). Despite some divergence in the perceived rank of individual skills in these areas (Universities of the Future, 2019; Shet & Pereira, 2021), the foundation for building them is, according to many researchers, process understanding, design thinking, digital modelling, robotic process automation as well as data analysis and programming and coding (Anagnoste, 2018; Flores et al., 2020; Spöttl & Windelband, 2021).

## CONCLUSIONS

The proposed framework reflects the real needs of the manufacturing sector in Europe and develops existing competency frameworks to some extent. The use of domain-specific models supports the development of adequate carrier paths for employees or job candidates, as well as the design of tailored FoF training for the acquisition of specific digital skills and competences. The proposed framework is a contribution to the ongoing discussion (Flores et al. 2020, Kipper, et al. 2021) on identifying current and future competence needs in the labour market. It reflects the results of a diagnosis of the digital design skills needs and requirements of manufacturing



companies from six European countries. Based on critical and cross-sectional literature studies and empirical survey results, we proposed a framework of future-oriented digital design competency. It is formed by two sets of skills and competencies, digital transversal and digital design competencies respectively. Within each of them there are five skills and competences that we expect to remain relevant in the coming years. It expands and complements the theoretical framework previously given in domain literature. Moreover, through its focus on the specifics of the manufacturing sector, it has strong practical implications. Through the confrontation of theoretical guidelines with the expectations of employees and employers, the framework proposed by us may provide a reliable argument in designing training, educational and self-development programmes.

Due to the size and selection of the sample, the results cannot be generalised but could be seen as a set of common guidelines for stakeholders having a significant involvement in the field of training and education. Future research could be focused on assessing the relevance of education paths to the FoF requirements. Furthermore, cross-sectional and longitudinal research to identify skills needs and demands could be a promising avenue for further research, especially concerning the emerging technologies and a new business models.

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