

# Knowledge and Skills Development for Implementing the Industry 5.0 Concept

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**Abstract.** The dehumanisation of the industry due to focusing only on the implementation of Industry 4.0 technologies has resulted in numerous concerns among workers, governments and societies regarding new working conditions and the role of humans in industry and the economy. Hence, the European Commission proposed the new concept of Industry 5.0. Industry 5.0 complements and extends the characteristic features of Industry 4.0. It highlights aspects that will be decisive factors in industry placement in future European society. Numerous scientific studies indicate the need to take into account, in the assumptions of the future industry's development, the crucial role of human beings. The humanisation of the technological Industry 4.0 environment was one of the first factors in the evolution of Industry 4.0 towards the Industry 5.0 concept. The new approach in the fourth industrial revolution focuses on the interaction between humans and intelligent machines. The fifth industrial revolution will continue the push for more advanced human-machine interfaces using artificial intelligence (AI) algorithms. It will mean better integration, enabling faster, better automation combined with the power of human brains, but it will also mean changing the demands placed on managers and engineers. Hence, the article aims to identify the critical knowledge and skills of engineers responsible for implementing the Industry 5.0 concept. The presented achievements and results in the article are from surveys conducted among experts representing companies with experience in implementing Industry 4.0 technologies and with a high level of knowledge and engineering and managerial competencies. The research results presented in the paper are dedicated to researchers and practitioners implementing the Industry 5.0 concept in smart organisations (smart factories).

**Keywords:** Industry 5.0, Human-centric, Humanisation of industry 4.0. knowledge and skills, Managerial skills, Personal management

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## 1. Introduction

The Widespread digitalisation of the economy, which is the result of the fourth industrial revolution and the Industry 4.0 concept implementation, implies the need to analyse the effects concerning the changes in the economy and society. The changes affect all areas of human life to an unprecedented extent. The emerging smart factories, smart cities, and smart homes use cyber-physical systems (CPSs) and open social engineering systems. CPSs use increasingly sophisticated artificial intelligence algorithms that operate on large data sets collected and processed in real-time, affecting physical processes across the entire network of relationships with limited participation of humans (Demir and Cicibas 2017).

The fourth industrial revolution, characterised by the widespread automation and digitisation of industry, weakened the social role of industry as an employer and a generator of commonly understood prosperity. The emergence of smart factories understood as "factories without people" based on digital technologies eliminating man from the production process, has caused significant concerns in the production environment about the role of man in the future industry (Cellary 2019).

Human orientation is a new trend in the development of the fourth industrial revolution. So far, focusing on implementing digital technologies has resulted in the dehumanisation of CPS and the marginalisation of humans in the manufacturing process. This has caused significant concerns among workers, governments and societies about new working conditions and the role of humans in future industries. The result of widespread dissatisfaction with the process of dehumanisation is the evolution of views on the implementation of new technologies and consideration of man's key role. (Brousell, Moad and Tate 2014). The new concept of industry called Industry 5.0 draws attention to aspects that will be decisive for the location of industry in the future European society. The environmental and social part significantly develops the strongly developed aspects of digital technologies affecting economic efficiency. According to the new approach, the use of technology must not violate the fundamental rights of workers, respect for the right to work and earn a living, respect for independence and human dignity (Di Nardo and Haoxuan 2021).

The concept of Industry 5.0 focuses on the interaction between people and machines. The new approach emphasises more advanced human-machine interfaces that use employees' knowledge and skills and artificial intelligence (AI) algorithms (Sachsenmeier 2016). The use of digital technologies related to creating cyber-physical systems based on intelligent machines and devices communicating with each other in real-time in terms of the Industry 5.0 concept requires the use of new knowledge and skills of engineers and management staff. It

means better human integration with the digitised system, enabling faster, better automation of production processes supported by the power of human minds.

Hence the need to research to identify the requirements for future industry employees. Accordingly, the following research questions were posed:

- What are the key areas of required knowledge and competencies of industrial employees for successful implementation of the Industry 5.0 concept?
- What groups of competencies should be developed for the Industry 5.0 implementation?

The article aims to identify the critical knowledge and skills of engineers responsible for implementing the Industry 5.0 concept.

## **2. Industry 4.0 Idea Towards Industry 5.0 Concept**

The Industry 4.0 idea means digital technologies implementation such as Additive Manufacturing, Augmented Reality, Modeling and Simulation, Autonomous Robots, Systems Integration, Industrial Internet of Things, Big Data, Cybersecurity Technologies, and Cloud Computing (Ghobakhloo 2020). The development and implementation of the Industry 4.0 idea have been made possible by widespread digitisation and digital technologies. Digital technologies such as, Data Mining, Big Data Analytics, and ICT allow machine-to-machine and machine-to-human communication in real-time regardless of the geographic location of resources. The development of ICT networks has made it possible to create a fully integrated system of suppliers, manufacturers and customers operating in open virtual networks. According to this concept, ICT-based solutions integrate all subsystems within a single value chain with a particular customer orientation. Therefore, newly designed ICT systems will integrate entire supply chains, creating Cyber-Physical Systems (CPS) and open social engineering systems. CPS systems should provide for the collection of large amounts of data, its processing and its impact on the physical processes of the entire enterprise network through an unlimited number of network connections at the same time (Jamwal et al. 2021, Xu et al. 2021, Bai et al. 2020).

The Industry 4.0 concept caused a paradigm shift from standard (mass) production to non-standard (personalised) production tailored to personal customer expectations. Changes in the production organisation, employment structure, and the use of new and smart technologies often replacing employed workers allow customers to offer highly personalised products at low prices (Zhou and Jiao 2013, Młody 2018). The goal of the Industry 4.0 concept is to achieve the highest level of integration between customer and producer and to ensure low prices. It requires significantly increased productivity and efficiency by using digital technologies. Significant increases in manufacturing efficiency become possible through the design of smart factories and the use of material, production, and labour resources in cyber-physical systems of collaborative intelligent resources (Wang, Wan and Zhang 2016).

The currently observed dynamic increase in the implementation of Industry 4.0 technologies and the orientation of companies towards the dehumanisation of production systems have resulted in many concerns of employees, society and even governments. In Industry 4.0, the work environment is determined by integrated and advanced production technologies equipped with sensors to track the work of machines and communication systems to report data and perform advanced simulations. The role of existing employees is very rarely mentioned. Numerous scientific studies (Romero et al. 2015, Longo, Padovano and Umbrella 2020) emphasise the need to include the crucial role of the man in the assumptions of industry development. In this regard, from 2 to 9 July 2020, the Industry 5.0 concept was discussed amongst participants from research and technology organisations organised by the Directorate "Prosperity" of DG Research and Innovation EC. In the EC document, one can find the assumptions for the Industry 5.0 concept. The essence of this document is critical directions of change to make the industry more sustainable and human-centred. The EC document (Industry 5.0 2021) identifies six challenge areas for Industry 5.0:

1. Human-Machine Interaction;
2. Biotechnologies and smart materials;
3. Digital twins and simulation;
4. Data (iv) technologies for data transfer, storage and analysis;
5. Artificial Intelligence;
6. Technologies for energy efficiency, renewables and renewable energy.

The Industry 5.0 concept assumes the return of the human factors to the industry, i.e. increasing cooperation between people and intelligent production systems. Combining the best features of the two worlds - speed and

accuracy guaranteed by automation with cognitive skills and critical thinking of people- ensures the success of Industry 5.0 (Yordanova 2021, Doyle-Kent and Kopacek 2019).

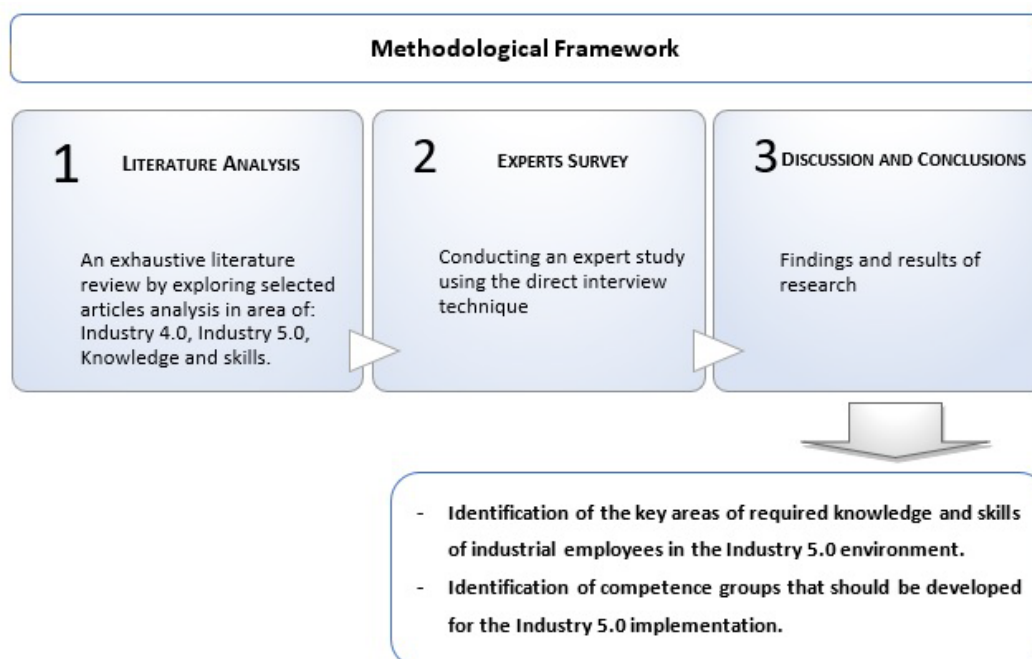
Industry 5.0 goes back to the origins of sustainability, emphasising that a purely profit-driven business is becoming increasingly difficult to sustain in a globalised, highly volatile, and unpredictable environment. Underlying the development of the new concept are social and environmental needs. The industry must include societal and ecological aspects to become a provider of true prosperity. The symbiosis of the three segments: technological, social, and environmental, is the essence of Industry 5.0 (Elfar et al. 2021).

Industry 4.0 puts technology at the centre, while Industry 5.0 focuses on manufacturing workers who perceive progressive automation as threatening lost jobs. Industry 5.0 recognises the power of technology for industrial (business) development but combines the achievement of business goals with social goals in the workplace and beyond (social and environmental responsibility). Cyber-physical systems intertwined with social and ecological frameworks are the basis of the production process. Nowadays, CPSs functioning in smart factories lead to economic growth and put people at the centre of cooperation with intelligent resources and a more robust perception of sustainable development (Sachsenmeier 2016, Demir, Döven and Sezan 2019).

### 3. Material and Methods

The first stage of the research was a literature analysis. A research gap was identified based on a systematic review of the literature and its critical analysis. Then (in stage 2), using expert survey was conducted among 44 Polish companies. The research was conducted with a group of experts hailing from the automotive and food sectors. They were made up of a diverse range of professionals, including 16 mid-level managers, three CEOs, and 15 engineers who specialized in implementing digital technologies and IT systems. Additionally, 10 experts were brought in from the Research and Development department to contribute their expertise. Together, this team of experts worked diligently to provide valuable insights and data for the results of the research.

Interviews were conducted between 01 May and 31 August 2021 using a questionnaire comprising 15 questions (closed, filtering, complex, conditional and tabular) and a metric. The questionnaire was validated, and a pilot survey was conducted among eight experts knowledgeable about the fourth industrial revolution. The companies were selected purposively, and each company had implemented at least two Industry 4.0 solutions in the last three years. The third stage of the research was the analysis of the results. The methodological framework of research adopted in the paper is shown in Figure 1.

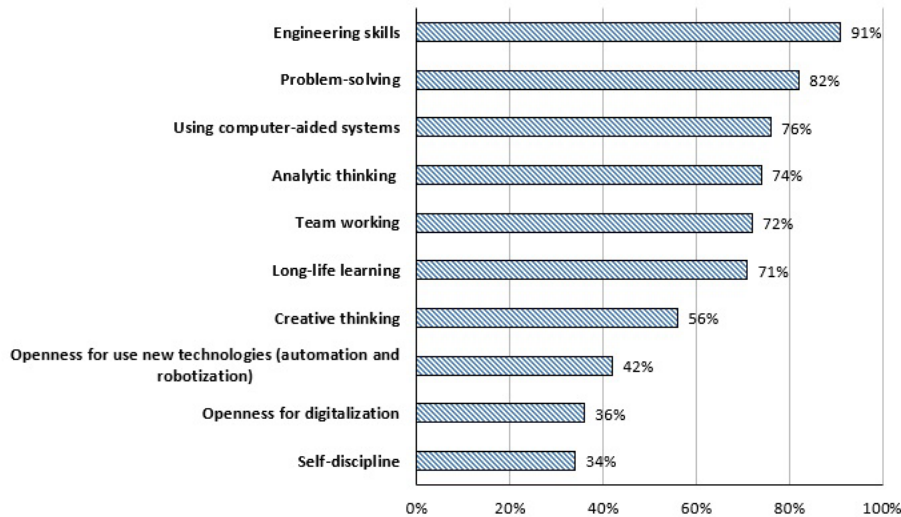


Sources: Own elaboration

**Figure 1: Research Methodology Model**

#### 4. Results

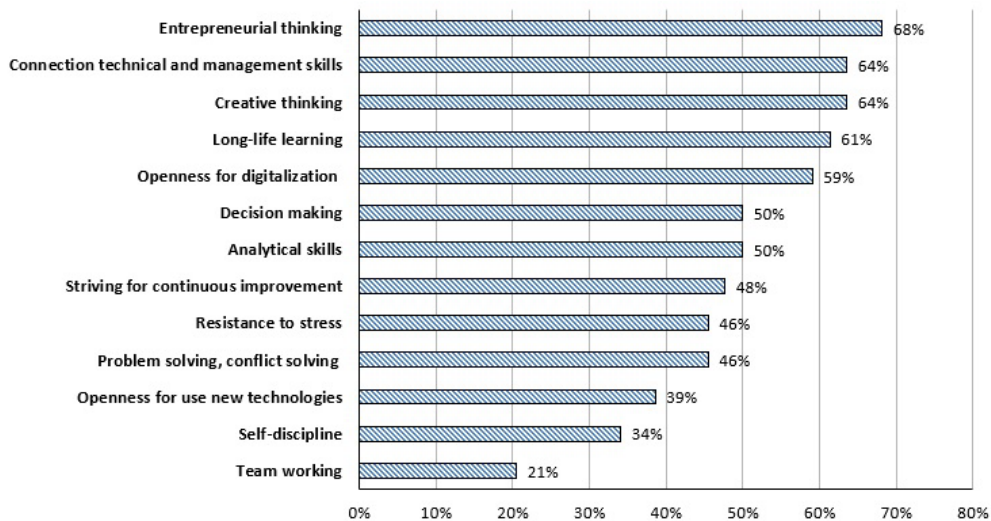
The demand for employees in industrial enterprises that declare willingness to implement the Industry 5.0 concept is closely related to the specific skills that enterprises expect. A significant level of expectations concerns problem-solving skills (82% of experts), skills in using computer-aided systems (76% of respondents), analytic thinking (74% of respondents), team working (72% of respondents). Experts have stated the required engineering skills in 91% of employees working as engineers. For experts representing companies, the motivation for long-life learning (71% of respondents) and creative thinking (56%) are noteworthy. Experts also pay attention to openness to new technologies (automation and robotisation) (42% of respondents). Figure 2 shows a chart with the remaining expectations of the respondents.



Sources: Own elaboration

**Figure 2: Required Skills for Industrial Employees (Engineers) in an Industry 5.0 Environment**

The experts also pointed to managerial skills as necessary for properly implementing the Industry 5.0 concept. Apart from the required skills for managers, i.e. entrepreneurial thinking, they also indicated the ability to connect technical and management skills (64% of experts). At a similar level, there is creative thinking (64% of experts) and long-life learning (61% of respondents). Experts also indicated the required openness for digitalisation (59% of experts), decision-making ability, and analytical skills (50% of respondents). The rest of the mentioned are standard abilities of every manager, which determines their suitability for managerial functions. Figure 3 presents detailed results of the declared required skills of managers.



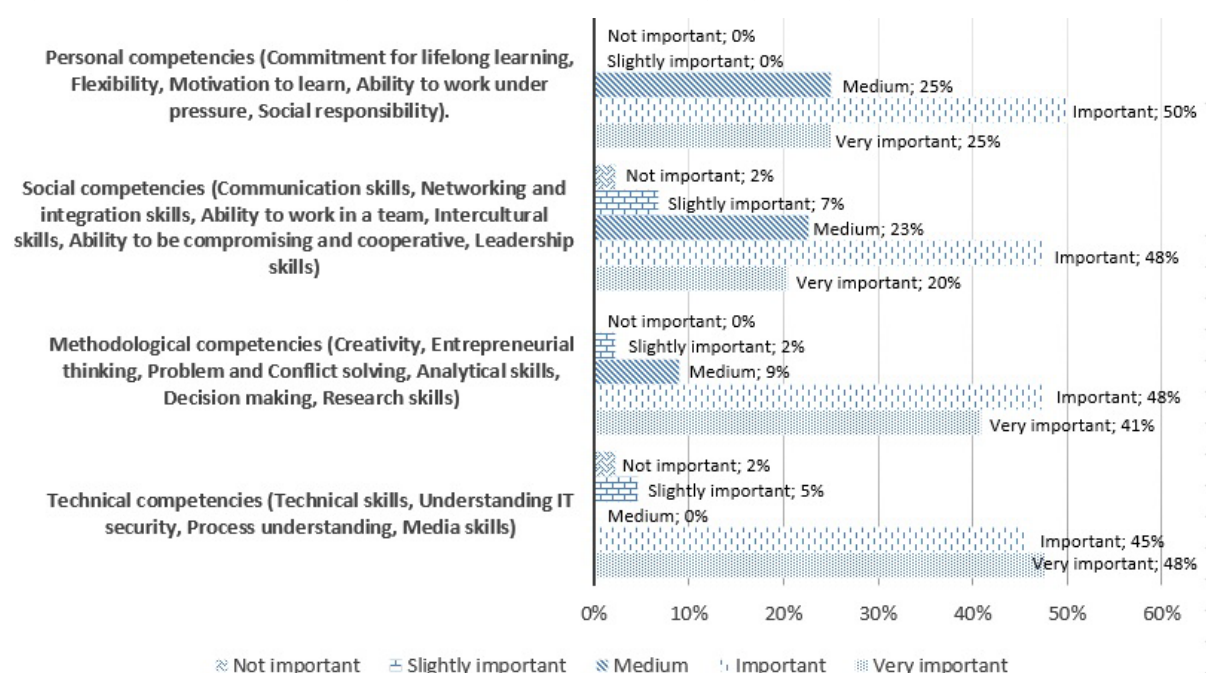
Sources: Own elaboration

**Figure 3: Required Skills of Managers in the Industry 5.0 Environment**

The experts have indicated on a 5-point Likert scale the importance of four groups of competencies to be developed for the Industry 5.0 implementation:

- Personal competencies (commitment to lifelong learning, flexibility, motivation to learn, ability to work under pressure, social responsibility) - are assessed by experts as important (22), very important and of medium importance (11);
- Social competencies (communication skills, networking and integration skills, ability to work in a team, intercultural skills, ability to be compromising and cooperative, leadership skills) - this group of competencies, according to most experts, is moderately important (10), important (21) and very important (9);
- Methodological competencies (creativity, entrepreneurial thinking, problem and conflict solving, analytical skills, decision making, research skills) - similarly as above, most experts rated this group of competencies as important (21) and very important (18);
- Technical competencies (technical skills, understanding IT security, process understanding, media skills) - were rated by most experts as very important (21) and important (20).

Figure 4 presents the percentage share of declarations for each group of competencies.



Sources: Own elaboration

Figure 4: The Percentage Share of Declarations for each Group of Competencies

## 5. Discussion

The Industry 5.0 concept is a massive challenge for enterprises not only because of the application of modern technologies (such as the Internet of Things, Big Data Analytics, Cloud Computing, etc.) related to creating Cyber-Physical Systems.

There is a need for a completely new, more modern and innovative approach to production and business management that will dramatically increase flexibility, productivity and customer orientation. Industrial workers and managers are expected to have additional knowledge and practical skills.

According to experts, the skills needed to implement the Industry 5.0 concept are mainly related to the digitisation of the production environment, collection and analysis of large data sets, ensuring data security, and the effective creation of cyber-physical networks of intelligent resources of cooperating enterprises. Experts participating in the survey declared that employees employed in technical positions mainly require engineering skills, problem-solving skills, analytic thinking, teamwork skills and using computer-aided systems, which seem necessary for enterprises' digitalisation.

Experts indicate that an essential feature of a modern employee should be motivation for long-life learning, openness to new technologies, and creative thinking. This attitude of the employee affects the development of competencies during employment. In general, the development of technology and frequent changes force the lifelong learning process on employed workers.

The demand for new skills stems primarily from the growing need for complex information integration and transparency, increased automation of production systems, increased autonomy of operation, self-management and self-decision-making by facilities, digital communication, and a more flexible workforce (Ahrens and Spottl 2015).

Nevertheless, implementing the Industry 5.0 concept is also challenging for management science. It requires research in the following areas: strategy and analysis, planning and implementation, collaboration and networks, business models, human resource management, change and leadership (Schneider, 2018). Employees also need knowledge and skills in decision-making, process management, and combining engineering and managerial expertise (Kazancoglu and Ozkan-Ozen 2018).

An essential aspect of successfully implementing the Industry 5.0 concept is an appropriate set of managerial skills that guarantee successful the Industry 5.0 concept implementation. The experts emphasised the manager's importance of having such qualities as openness for digitalisation, decision-making, and analytical thinking. The most relevant experts included entrepreneurial thinking, connecting technical and management skills, creative thinking, and long-life learning.

Experts in the study emphasised developing technical and methodological competencies, which is unsurprising. However, it is interesting to indicate the high importance of developing personal competencies (very important - 25% of experts and important - 50% of experts). Similarly, experts attach great importance to the social competencies of the future engineer (very important - 20% of experts and important - 48% of experts). According to experts, a modern engineer must be educated in interdisciplinary.

Also interesting are the experts' opinions on the level of competence currently represented by engineers in their preparation for performing their duties at the company. The experts have poorly assessed engineers' social and personal competencies. Technical and methodological competencies were rated better. According to the experts, no group of competencies can reach a very high level. Regarding personal competencies, as many as 20% of experts indicated a deficient level. Each group of competencies declared level can be considered average and need development, which is confirmed by the previous observations.

Based on expert opinion, knowledge, and skills of industry employees who are involved in the implementation of Industry 5.0 requires development in the following areas:

- the workforce needs expertise and a new skills paradigm resulting from digitisation, which should lead to the increased overall productivity of production systems, the efficiency of operations management, and the efficiency of production and support processes;
- there is a need to recruit highly skilled personnel characterised by openness to change, ability to transfer knowledge, and teamwork;
- it is essential to combine learning in the area of information and production technologies in the Industry 5.0 environment with management sciences, especially in the areas of strategy development and case analysis, planning and implementation, collaboration and networking, business models, human resources, change and leadership;
- there is a definite increase in the importance of lifelong learning in the Industry 5.0 environment, which requires: promoting a climate of innovation and education, changing the ways of learning (e.g., remote learning), new approaches to the talent development of the workforce;
- there is a need to combine different groups of technical, methodological, social and personal competencies to educate future engineers.

The research results confirm that employees' knowledge and competencies are becoming important factors of competitiveness for the company. The company's ability to make rapid technological and organizational changes and implement operation methods related to achieving high profitability and customer satisfaction, as well as financial benefits for shareholders or shareholders, is of great importance. In the competitive race, it is primarily intelligent companies that are ahead, capable of innovative and quick adaptations, digital technologies of the fourth industrial revolution. The direction of development of enterprises is based on the so-called resource-based view, well-known from strategic management, whose main task is the thesis that only the knowledge

contained in the so-called vital skills or competencies can provide a sustainable competitive advantage and, thus - long-term development of the company.

## **6. Conclusion**

The approach to implementing the technologies of the fourth industrial revolution is changing. Although the Industry 4.0 concept was introduced more than a decade ago, in 2011, it has already evolved, and research is currently being conducted on its new iteration called Industry 5.0. Industry 5.0 is a concept that pays more attention to the role of the human being in the production system and critical phenomena for current trends in the economy, such as sustainability and resilience to disruptions in production processes caused by various crises, such as COVID-19 or the war in Ukraine. The Industry 5.0 concept is not a new revolution but only an evolution of the trends exhibited in the Industry 4.0 concept. Today's challenge for companies is to apply technological innovations that take into account the social and environmental priorities indicated by the European Union. Special attention is being paid to the comprehensiveness of technology implementation and combining individual technologies into areas to affect all three critical pillars of the Industry 5.0 concept, i.e. human-centric, sustainability and resilience. Among the highest priority areas of the industry 5.0 technologies to be developed and implemented are human-centric solutions, technologies for energy efficiency, digital twin and simulation, cyber security and data analytics, and artificial intelligence.

Implementing and maintaining new technologies related to Industry 5.0 requires interdisciplinary knowledge and a combination of technical, organisational and social competencies and skills. The results of the study confirmed that in an Industry 5.0 environment, there is a need for employees with interdisciplinary knowledge and technical and management skills.

From the considerations carried out, combining technical, methodological, social and personal skills and competencies is necessary, especially in applying human-centred solutions. Recruiting highly qualified employees with openness to change and the ability to transfer knowledge and work in a team is required.

This exciting observation has particularly relevant to adjusting the vocational training system and educating students. It means changes in the way education is provided, which should be directed toward the development of such professions as a production engineering manager, data analyst, cyber security specialist, logistician, project manager and ICT specialist, among others. Engineers' knowledge should be supplemented with environmental protection aspects, environmental pollution problems and energy consumption. This awareness is essential for understanding the need for intelligent solutions to increase productivity and reduce waste. In the Industry 5.0 concept, developing soft skills necessary for collaboration, communication, and interpersonal relationship-building skills is also essential.

Currently, the education system, especially in vocational education and universities, needs to prepare for changes in training future industrial workers who will operate in a cyber-physical world and the widespread use of technologies identified with the fourth industrial revolution. The direction of further research should be an in-depth analysis of the impact of the development of interdisciplinary competencies of engineers and the implementation of digital technology solutions on sustainability, industrial humanisation and resilience.

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