



Article

Knowledge and Skills Development in the Context of the Fourth Industrial Revolution Technologies: Interviews of Experts from Pennsylvania State of the USA

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Abstract: Fourth industrial revolution is the introduction of ICT (mostly IoT) in industry and elsewhere, which enables the creation of cyber-physical systems, i.e., digital twins of reality. The application of widespread digitization of processes brings changes in terms of increased efficiency of processes, increased flexibility of production, and the possibility of realizing prosocial and pro-ecological goals, such as sustainable development, sustainable production and consumption, and reducing the consumption of increasingly expensive energy. Nowadays, the high autonomy of cyber-physical systems and benefits to society are expected by including human factors within the Industry 5.0 concept. Implementing the Fourth Industrial Revolution technologies and meeting the expectations of sustainable development also means new challenges for the knowledge and skills of industry employees, mainly engineers implementing modern solutions. Hence, the article's aim is to identify the critical knowledge and skills of engineers responsible for implementing the Fourth Industrial Revolution technologies. The achievements and results presented in the article were obtained based on research conducted among experts from the University of Pennsylvania (USA). The study considers aspects connected to the problems of implementing the Fourth Industrial Revolution technologies and identifies the benefits and risks of their implementation for Society 5.0.

Keywords: Fourth Industrial Revolution; Industry 5.0; human factors; knowledge and skills of engineers; sustainable production and consumption; energy consumption



Citation: Saniuk, S.; Grabowska, S.; Grebski, W. Knowledge and Skills Development in the Context of the Fourth Industrial Revolution Technologies: Interviews of Experts from Pennsylvania State of the USA. *Energies* **2022**, *15*, 2677. <https://doi.org/10.3390/en15072677>

Academic Editors: Wen-Hsien Tsai, Anetta Barska and Joanna Wyrwa

Received: 6 March 2022

Accepted: 1 April 2022

Published: 6 April 2022

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1. Introduction

Today, the world faces many changes in technological, economic, and social areas. These changes create new opportunities but also many fears. For society to actively support the development of the Fourth Industrial Revolution, it must understand this revolution will increase the quality of life for the average person [1]. Most industrial employees fear the changes associated with the digitization of modern enterprises, which is the main reason for the growing fear of replacing people with robots in smart factories and general increasing technological unemployment. Hence, it is easy to get social indignation and fear of technological progress [2].

The Fourth Industrial Revolution (just like the previous three revolutions) is a challenge for the economy and society [3]. Academics are discussing the nature of these changes. Specialized research centers, universities, and consulting firms are conducting studies on various aspects of the implementation of the Fourth Industrial Revolution and its consequences not only for consumers and society as a whole but also for the future labor market, sustainable development, reduction of energy consumption, increasing the resilience of the economy, etc. [4].

The progressive process of digitization of all areas of the economy, which is the result of the current changes in the industry, implies the need to analyze the effects that concern the changes in the economy and society. The changes affect all areas of human life to an unprecedented extent [5,6]. The Fourth Industrial Revolution is distinguished by the unlimited access to data and information that constitute a competitive advantage. The data providers are emerging smart factories, smart cities, and smart homes that use open socio-technological systems that connect intelligent machines and equipment with human users within so-called cyber-physical systems (CPS). CPSs use increasingly refined artificial intelligence algorithms that operate on large data sets, collected and processed in real-time, affecting physical processes across the entire network of relationships [7,8]. In addition, the application of widespread digitization of processes in the economy brings changes in terms of increased efficiency of resource use and increased flexibility of production. It also provides an opportunity to achieve a high level of sustainable development, sustainable production, and consumption (SPC), and reduction of energy consumption [9,10]. Adjusting the economy to new conditions offered by the Fourth Industrial Revolution requires the barriers and opportunities identification associated with the implementation of new technologies and socio-economic changes [11]. The Fourth Industrial Revolution leads to changes in employment structure, and there is a need for new competencies, skills, and knowledge for employees and managers [12,13]. Hence, the main aim of the paper is to identify the critical knowledge and skills of engineers responsible for implementing digital technologies. The research considers aspects related to ensuring sustainable development of the economy, sustainable production and consumption, and the currently developed concept of Industry 5.0. The authors obtained the findings and results presented in the article based on a survey conducted among experts from the University of Pennsylvania (USA).

2. Theoretical Framework

2.1. *The Fourth Industrial Revolution—Consequences*

The Fourth Industrial Revolution means a significant change in the approach to industry development because it combines modern technological solutions with the challenges of sustainable development. The elements that can even be called megatrends of the Fourth Industrial Revolution are: Industry 4.0, Industry 5.0, Economy 4.0, Smart Factories, Society 5.0, Sustainable production and consumption (SPC) [14].

The development of the Fourth Industrial Revolution is often equated with the Industry 4.0 concept proposed by German experts. Nowadays, it is common to use cyber-physical systems (CPS) consisting of intelligent machines, equipment, autonomous transport. All elements of CPS communicate within digital technologies (big data, industrial Internet of Things, cloud computing, augmented reality, etc.) capable of collecting, processing, and exchanging vast amounts of information throughout manufacturing products while reducing high labor costs [15,16]. Moreover, modern digital technologies allow machine-machine and machine-human communication in both real and virtual environments for efficient management of production processes by monitoring and controlling system elements in real-time [17].

Industry 4.0 technologies are reducing energy consumption. According to the International Energy Agency, industry accounts for 37% of global energy consumption. At the same time, up to 50% of it is wasted, e.g., with heat exchange by machines or during the transmission process [18]. Industry 4.0 technologies are characterized by the increased energy efficiency of production processes, which affects, among others, maintaining energy security, reducing energy expenses, and protecting the environment [19,20]. Modern industrial energy management means taking advantage of technological capabilities in terms of a single machine, as well as a production line or the entire infrastructure functioning in each organization [21,22]. The implementation of wireless sensors, which have minimum energy requirements, allows them to make accurate measurements and analyze any deviations from the norm or signals that may indicate malfunction [23,24]. As calculated by the New York State Energy Research and Development Authority (NYSERDA), investing in new,

smart technologies and systems that enable real-time energy management can yield an average 15% reduction in business operating costs while reducing energy consumption [25].

Modern companies are facing significant socio-economic changes forced by applying new technologies. The use of advanced digital technologies allows for a better adjustment of the product offer to customers' expectations while ensuring a high level of quality and low price [26]. The Fourth Industrial Revolution changed a paradigm from standard (mass) production to non-standard (personalized) production, tailored to individual customer expectations. It is now called individualized production [27]. Changes in the organization of production, employment structure, and new and smart technologies allow offering personalized products at a favorable price for the customer [28]. Customization and personalization can provide sustainable production and consumption (SPC) for a long time.

SPC means decoupling economic growth from environmental degradation, increasing resource efficiency, and promoting sustainable lifestyles [29]. The industrial revolutions have led to changes in the economy and environment by increasing consumerism and excessive waste production and pollution [30]. On the one hand, the solution to the problems caused by the shrinking resources and, on the other, by the growing mountains of waste is to be personalized production leading to sustainable consumption. Such an approach requires the customer's involvement in the manufacturing process, which is made possible by Industry 4.0 technology. Sustainable production and consumption mean providing the consumer with a high standard of living, generally reducing consumption with the efficient use of limited resources, especially natural resources, by encouraging conscious purchasing, recycling, using renewable energy sources, and minimizing waste [31].

The Fourth Industrial Revolution strives for the highest possible level of sustainable production. These actions are to reduce the harmful effects of consumption and production on the state of the environment and the protection of natural resources. This revolution brings many opportunities for the symbiosis of industry and the environment [32].

Modern technology is accelerating the transformation of the industry and the labor market, changing current business models and the economy's structure. Modern enterprises are increasingly interested in investing in new technologies at the expense of reducing human capital. Widespread automation and digitization contribute to the high quality of products and services [33].

The rapid increase in the Industry 4.0 technologies implementation and the dehumanization of manufacturing systems have implied much of the apprehensions of workers, society, and governments. The digital production environment eliminates humans by using autonomic, intelligent robots and machines equipped with sensors and communication systems to report data and perform advanced simulations. Man cannot compete with such advanced "smart" systems [34]. The role of existing workers is very rarely mentioned. Numerous scientific studies emphasize the need to include the human role in the presumptions of future industrial development. Accordingly, in 2019, the discussion about Industry 5.0 began. This concept implies the return of the human factor to industry, i.e., increased collaboration between people and intelligent production systems. Combining the best of two worlds, the speed and accuracy guaranteed by digitalization and automation with the capabilities of the human brain (creative thinking and cognitive skills) [35].

2.2. Industry 5.0—Knowledge and Skills

The key ideas of the Industry 5.0 concept were assumed by the participants of the research and technology organizations forum organized by the European Commission EC on 2–9 July 2020 [36]. The Industry 5.0 concept focuses on the interaction between humans and machines. The evolution from Industry 4.0 to Industry 5.0 is identified with combining the best human and machine worlds. According to the assumptions, the new concept will push for advanced human-machine cooperation e.g., as in Augmented Reality technology [37]. The consequence will be a better human-machine integration, enabling faster digitalization of processes joined with the human roles [38,39]. This, therefore, means that robots will not take control of businesses, as was so feared in the Industry 4.0 era [40].

Industry 5.0 emphasizes the framework of sustainable development, stressing that running a purely profit-driven business is becoming increasingly difficult to sustain in a globalized, highly volatile, and unpredictable environment. Underpinning this new concept are social and environmental needs [41]. Industry must incorporate social and ecological aspects to give genuine prosperity. The symbiosis of three segments: technological, social, and environmental is the essence of Industry 5.0 [42,43].

To organize company processes and supply chains, digitalization in Industry 5.0 should be comprehensive. Industry 5.0 has emerged from the Industry 4.0 megatrend. The emerging picture of the Industry 5.0 paradigm is the penetration of artificial intelligence into people's daily lives [44,45]. In contrast to Industry 4.0, the Industry 5.0 concept is not limited to the industry sector but the economy by integrating the social and ecological environment [46,47]. Industry 5.0 combines industry and society where advanced technologies are actively used in everyday life. Along with the focus (of scientists and researchers) on society, Industry 5.0 puts a premium on human resource development [48]. New occupations, production worker functions, and skills are emerging [49].

Industry 4.0 puts technology at the center, while Industry 5.0 focuses on manufacturing workers who perceived progressive automation as a threat to their jobs. Industry 5.0 recognizes the power of technology in industrial development but combines business goals with social goals. The center of the manufacturing process is still cyber-physical systems [50]. Still, they are now intertwined with social and environmental frameworks, the recognition of which by Industry 4.0 technologies is expected to lead to economic growth and place humans at the center of CPS collaboration. The limits of the planet's capabilities are being recognized more strongly than before. The emerging picture of the new Industry 5.0 concept is based on the penetration of artificial intelligence into people's everyday lives [51,52].

New skills and competencies of managers and employees are needed. The whole education system, especially vocational education and universities, must prepare for changes in educating the society, which will function in the cyber-physical world of Economy 4.0 based on networking and widespread use of technologies identified with the Fourth Industrial Revolution [53,54]. This applies both to future employees of the production and service sphere and ordinary consumers, who increasingly interact with the producer through product personalization, reactions to marketing 4.0, and dynamically developing the e-commerce market [55]. The progressive digitalization of various spheres of human life requires new skills from both users and designers of the cyber-physical world [56]. Companies need to start preparing quickly, especially in terms of changes in the qualifications and competencies of employees [57,58].

3. Materials and Methods

The methodological framework consisted of literature analysis, expert survey, and discussion and conclusions—the critical analysis of the content of selected publications allowed to identify the research gap and formulate research questions. The following research questions were formulated:

1. What are the benefits and risks associated with the implementation of Fourth Industrial Revolution technologies?
2. What are the key areas of required knowledge and skills of workers for the Fourth Industrial Revolution?
3. What groups of competencies should be developed in the education of engineers for the Fourth Industrial Revolution?

The expert survey provided the required answers to achieve the article's purpose. The interview was standardized and based on a survey questionnaire containing 15 questions. The questionnaire was validated, and a pilot study was conducted among eight Polish and American experts with knowledge of Industry 4.0. The questionnaire included the following questions:

- Q1: Enterprise size
 Q2: Industry of the company
 Q3: Position of the expert
 Q4: Seniority of the expert
 Q5: How would you rate your level of experience with Industry 4.0 technologies?
 Q6: Which pillars of Industry 4.0 have been implemented in your company?
 Q7: What are the key issues related to the implementation of Industry 4.0?
 Q8: What is the demand for employees in industrial companies implementing the concept of Industry 4.0
 Q9: What are the skills required of executives in an Industry 4.0 environment?
 Q10: What are the required skills of industrial workers in an Industry 4.0 environment?
 Q11: Which groups of competencies in your opinion should be developed more in the process of educating engineers?
 Q12: How would you rate the current system of engineering education based on your own experience based on individual competence groups?
 Q13: In your opinion, what threats may arise from the implementation of the Industry 4.0 concept?
 Q14: What benefits do you think the implementation of Industry 4.0 concept may bring?
 Q15: In your opinion, should there be standardization of the required qualifications for Industry 4.0 in obtaining an industrial engineer's license according to w/the Accreditation Board for Engineering and Technology (ABET)?

Interviews with 24 experts were conducted between 15 April and 15 June 2021. Figure 1 shows the methodological framework of research adopted in the article.

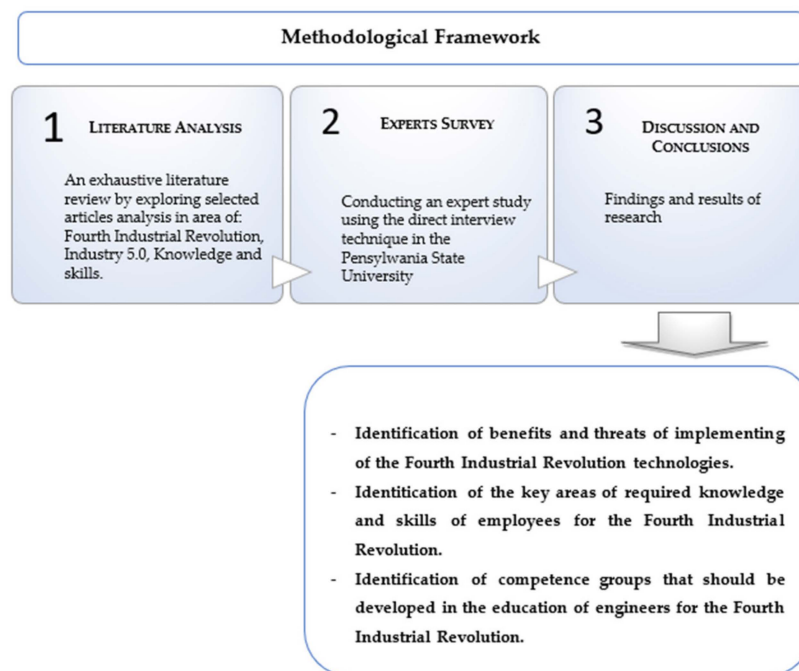


Figure 1. Methodological framework of research.

Experts are representatives of companies located in the US, mainly Pennsylvania, one of the US's most industrialized and developed states. The experts are selected as the best specialists in engineering and industrial management by Penn State Hazleton, Hazleton, PA, USA. They are involved in shaping the trends in the development of the technical education system in the region. The experts can be considered one of the best in the USA. Most experts are engineers graduates from Pennsylvania State University and other technical universities in the USA. Experts are members of Industry Committees and members of the Accreditation Board for Engineering and Technology (ABET) and are

actively involved in the accreditation of technical courses at U.S. universities. Furthermore, they are engineers and managers working in companies at the stage of partial application of the Industry 4.0 concept or at the first stage of implementation of this idea (in the USA called reindustrialization).

A total of 24 experts participated in the survey (Figure 2), including 2 experts representing small companies (8%), 1 expert representing large companies (4%), and 21 experts employed in medium companies (88%). In addition, most of them (15 experts) hold managerial experience in these companies (Figure 3). The experts mainly represented manufacturing, R&D, and service companies and all are engineers with practical experience for many years.

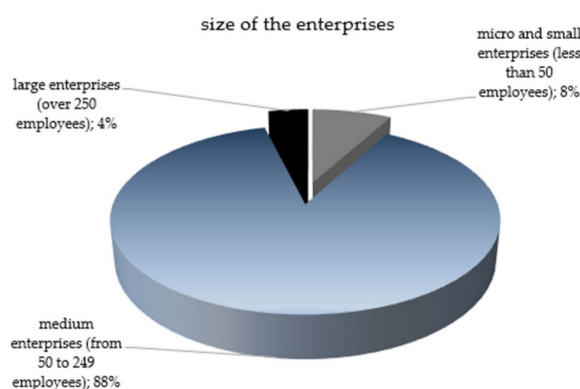


Figure 2. Representation of enterprises participating in the study.

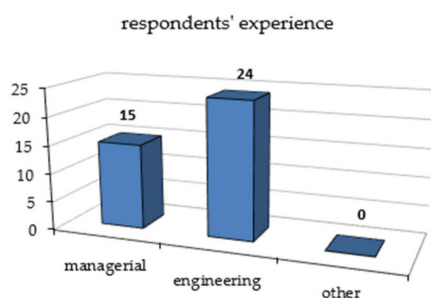


Figure 3. The number of experts representing engineering and managerial experience.

4. Results

The application of the Fourth Industrial Revolution technologies is connected with many barriers encountered by enterprises. Experts from Pennsylvania State University, in their enterprises as the most crucial barrier, mentioned the problem of data security (cybersecurity) (24 indications—100% of respondents). A high level of concern is also associated with a low level of automation and robotization (21 responses) and the risk of investing in new advanced (digital) technologies (18 answers). The absence of business models for the Industry 4.0 environment is a problem according to 10 experts. A barrier to implementing the Fourth Industrial Revolution technologies is also a low level of employee qualifications identified by 9 experts. The surveyed experts do not perceive problems related to the high costs of consultancy in the digitalization of processes (5 experts). Figure 4 shows the Pareto-Lorenz diagram used to rank the most critical problems of implementing digital technologies identified by the experts.

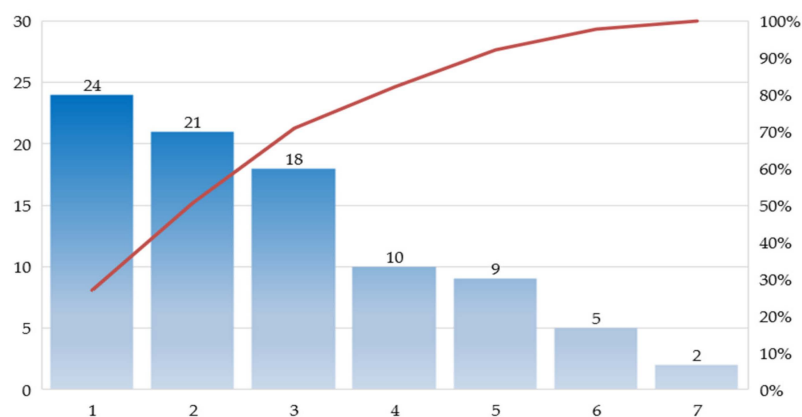


Figure 4. Key problems in implementing of the Fourth Industrial Revolution technologies. Legend: 1—data security problem (cybersecurity); 2—low level of automation and robotization; 3—high risk of investment in advanced technologies; 4—absence of business models for Industry 4.0; 5—low level of employee qualifications; 6—high costs of consultancy in the field of digitization of processes; 7—low level of knowledge in terms of the Industry 4.0 technologies.

As the main threat resulting from the implementation of digital technologies, experts emphasized a possible decrease in the competitiveness of manufacturing SMEs, which don't have the funds to invest in new technologies (92% of respondents) and a change in the employment structure, which is related to higher qualification requirements from employees working in industry (83% of respondents). Experts do not associate the implementation of the Fourth Industrial Revolution technologies with an increase in energy consumption or excessive growth in the level of production and consumption (only 4%) and thus the risk of increased energy consumption and environmental pollution (8%). Figure 5 presents the detailed responses of experts.

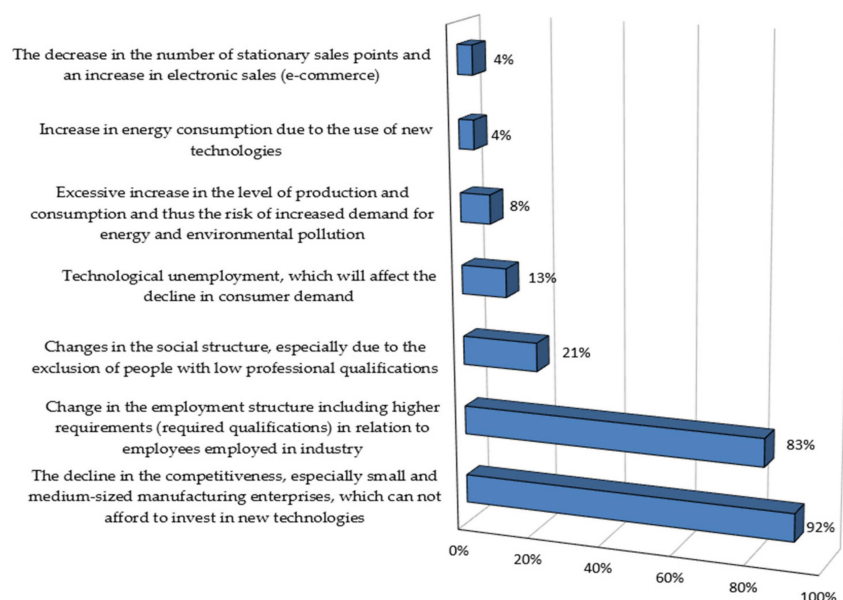


Figure 5. Threats related to the implementation of the Fourth Industrial Revolution technologies.

Apart from threats indicated by experts, there are many expected benefits from implementing Industry 4.0 technology (Figure 6). Experts point to the possibility of quick response through an on-time order's delivery (100% of respondents), increased productivity (92% of respondents), an adequate adaptation of the offer to the customer's needs (92% of respondents), manufacturing of personalized products at a satisfactory (low) price (92%). Pro-ecological aspects are also interesting. Experts associate the introduction of

new technologies with the increase in sustainable production and consumption (88% of respondents) and a reduction in energy consumption (79% of respondents). Less than half of respondents expect increasing the availability of a wide range of products (46%) and the possibility of active involvement of customers in the design of personalized products (42%). According to experts not, finally, Industry 4.0 can solve the problem of an insufficient number of employees with basic skills (only 8%).

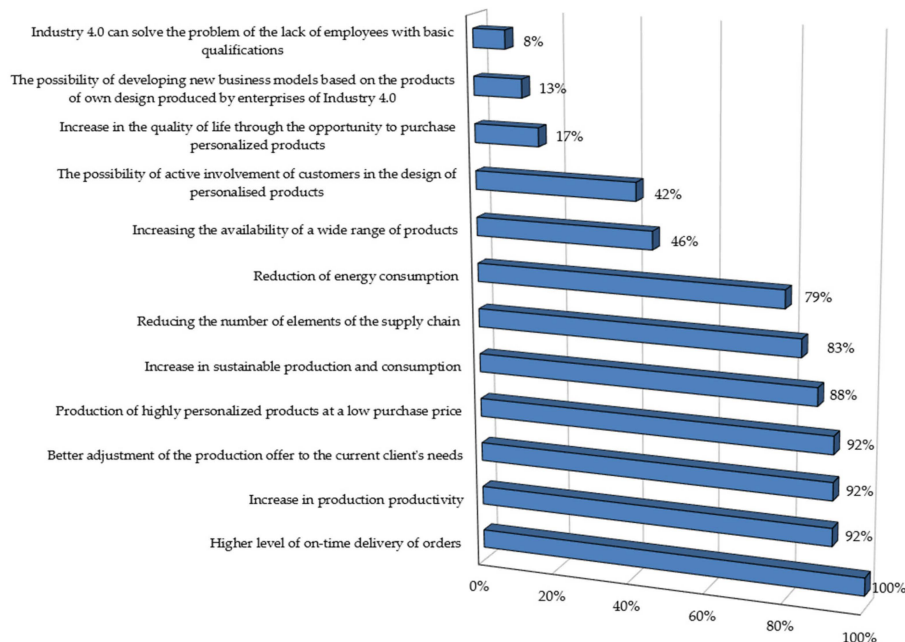


Figure 6. Benefits of implementing the Fourth Industrial Revolution technologies.

Although only 38% of experts indicated the problem of a low level of employee qualifications, they suggest demand for specialists in Industry 4.0 technologies. The most sought-after specialists in the analyzed enterprises are production engineering managers (100%), data analysts (83%), cyber security experts (63%), logisticians (63%), project managers (58%), and ICT specialists (58%). Experts show no demand for machine operators (automation engineer, mechatronics) (13% of respondents) and low-skilled manual workers (13% of respondents). The exact demand for all occupations declared by experts is shown in Figure 7.

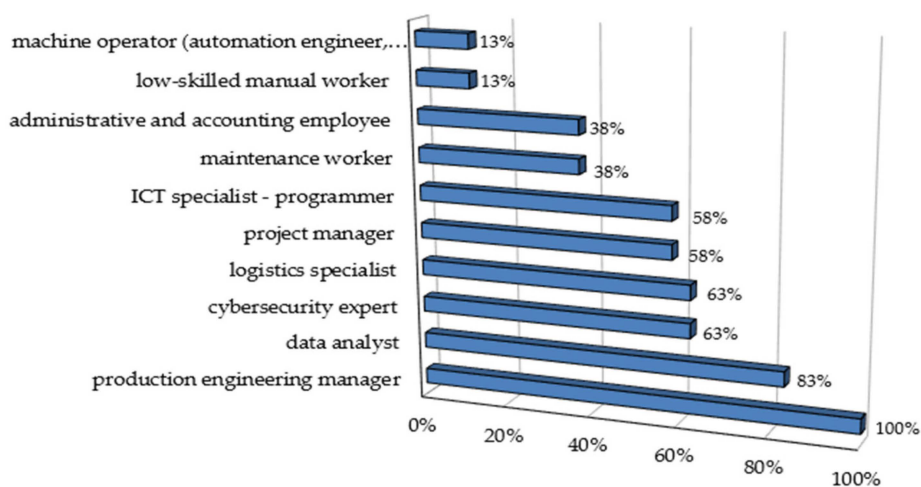


Figure 7. Demand for employees in industrial enterprises implementing the Fourth Industrial Revolution technologies.

The demand for employees in industrial enterprises is closely related to the specific skills of engineers responsible for implementing the technologies of the Fourth Industrial Revolution. In this area, experts declared 100% of the required engineering skills. A high level of expectations applies to problem-solving skills (92% of respondents), openness to sustainable development (88%), openness to digitalization (83%), and analytical thinking (83% of respondents). The ability for long-life learning (75%) and use computer-aided systems (75%) are very important. Experts also pay attention to openness to the use of new technologies (automation and robotization) and teamwork (71% of declarations). Figure 8 shows a graph with respondents' answers.

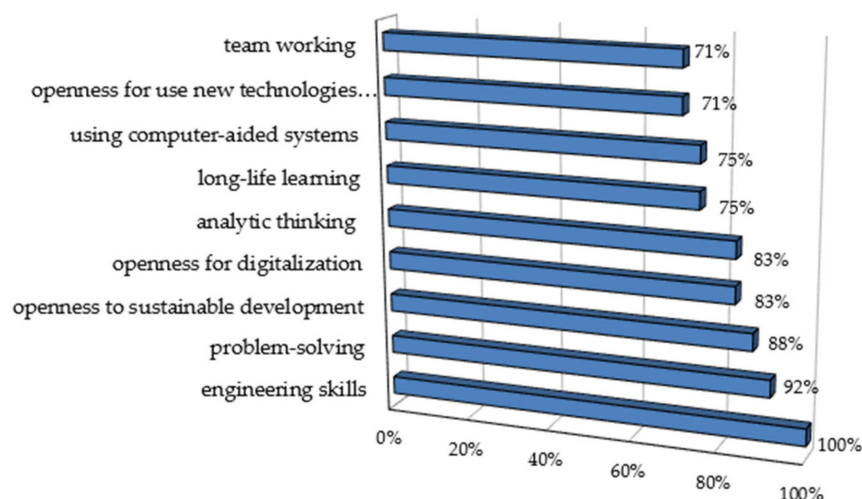


Figure 8. Required skills for engineers in the Fourth Industrial Revolution environment.

Experts also highlighted managerial skills as essential for implementing the technologies of the Fourth Industrial Revolution (Figure 9). Lifelong learning (100%), striving for continuous improvement (96%), and teamwork (92%) were identified as the most important managerial skills. The following skills also received many indications: problem-solving, conflict resolution, and creative thinking (88%), combining technical and management skills, and openness to use new technologies (83%). Slightly less often, experts indicated the following skills: resistance to stress and openness to digitization (75%), and self-discipline (71%).

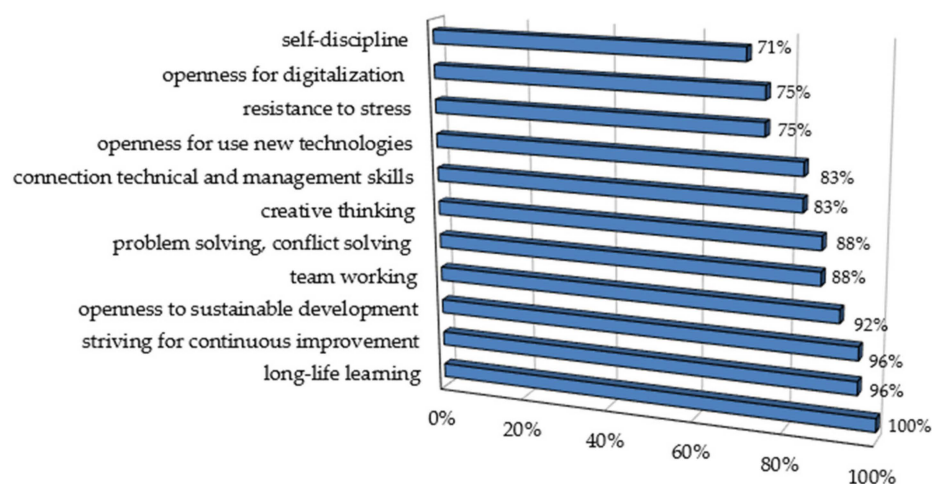


Figure 9. Required managerial skills in the Fourth Industrial Revolution environment.

Experts answering the question: Which groups of competencies, in your opinion, should be more developed during the education of engineers evaluated four groups of

competencies on a 5-degree Likert scale (Table 1, Figure 10). Technical competencies (technical skills, IT security (cybersecurity), process understanding, media skills) are very important (58%) and important (42%) for an engineer. Methodological competencies (creativity, entrepreneurial thinking, problem and conflict solving, analytical skills, decision making, research skills) were most often rated as important (75%) and very important (17%). 8% of experts considered this group of competencies as moderately important. Another group of competencies—social competencies (communication skills, networking and integration skills, team-working, intercultural skills, ability to be compromising and cooperative, leadership skills) is important (58%) and moderately important (33%). Only 8% of experts considered social competencies as very important. The last group evaluated was personal competencies (commitment to lifelong learning, flexibility, motivation to learn, ability to work under pressure, social responsibility). Most experts (67%) consider personal competencies as moderately important, 25% as important, and only 8% as very important.

Table 1. Groups of competencies to be developed during engineering education.

Group of Competencies	Very Important	Important	Medium	Less Important	Not Important
Technical competencies (technical skills, IT security (cybersecurity), process understanding, media skills)	14	10	0	0	0
Methodological competencies (creativity, entrepreneurial thinking, problem and conflict solving, analytical skills, decision making, research skills)	4	18	2	0	0
Social competencies (communication skills, networking and integration skills, team-working, intercultural skills, ability to be compromising and cooperative, leadership skills)	2	14	8	0	0
Personal competencies (commitment to lifelong learning, flexibility, motivation to learn, ability to work under pressure, social responsibility)	2	6	16	0	0

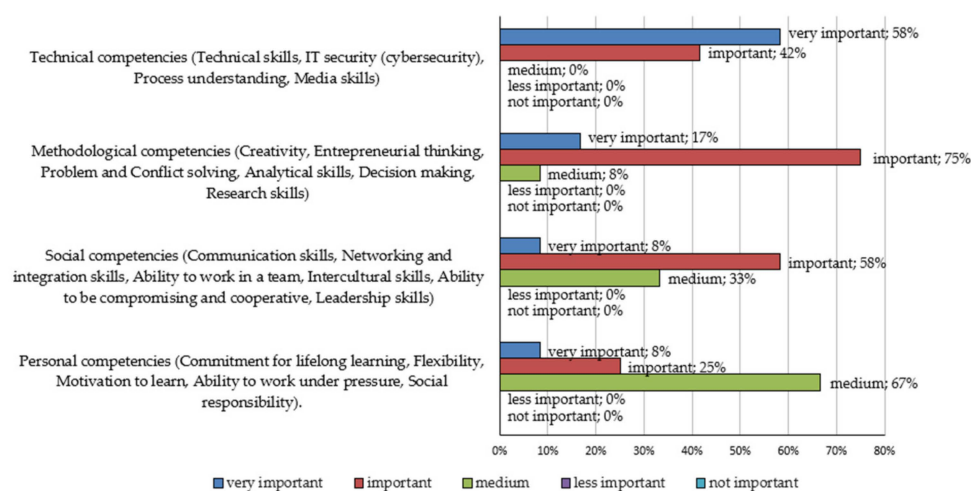


Figure 10. Groups of competencies to be developed during engineering education.

In the next question, the experts evaluated the level of competence represented by the engineers. The assessment was made using a 5-point Likert scale. Competences were divided into four groups:

1. Social competencies—according to experts, these competencies are at a low level (15) and medium level (9);
2. Methodological competencies—rated as medium level (14) and high level (10);
3. Technical competencies—14 experts rated these competencies in engineers as high level and 10 as very high level;
4. Personal competencies—according to experts, they are at a low level (14) and medium level (10).

Table 2 and Figure 11 show the detailed responses of the experts.

Table 2. Number of experts assessing the level of competence represented by engineers in terms of each competence group.

Group of Competencies	Very Important	Important	Medium	Less Important	Not Important
Social competencies	0	0	9	15	0
Methodological competencies	0	10	14	0	0
Technical competencies	10	14	0	0	0
Personal competencies	0	0	10	14	0

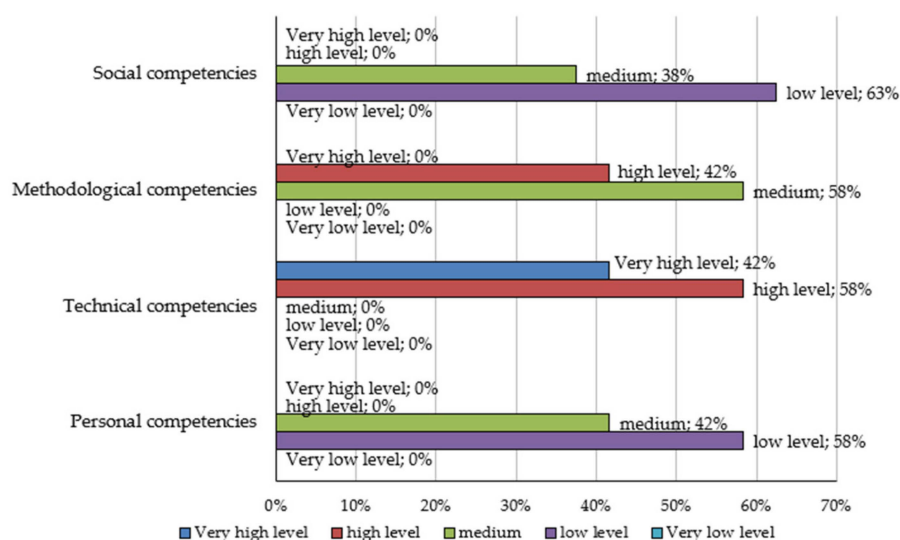


Figure 11. Assessment of the level of education of engineers based on expert's experience in the following groups of competencies.

5. Discussion

The Fourth Industrial Revolution is a new approach to business and customers that significantly changes the modern factories and economy using new technologies (industrial Internet of Things, big data, cloud computing, augmented reality, etc.) [59]. Digital technologies identified mainly in Europe with the concept of Industry 4.0 provide entirely new possibilities by the increased efficiency, productivity and flexibility of production processes and better customer orientation [60]. Despite the many benefits connected with the use of intelligent machines and technologies in cyber-physical systems, such as increased productivity, high flexibility, high level of customization [61,62], companies report numerous problems associated with reindustrialization (implementation of modern technologies).

Experts associated with the business council of Pennsylvania State University in their companies cited the problem of data security (cybersecurity) as the most critical barrier. This problem is mentioned in many scientific studies and indicates the concern about the possibility of data loss, and taking control of the production process as a result of cyber-attacks [7,8,13]. In addition, according to many experts, the problem is the still low level of

automation and robotization, the risk of investment in new advanced (digital) technologies, and the absence of business models that supported the Industry 4.0 concept. The barrier to implementing modern CPSs supported by the Industry 4.0 technologies is also a low level of employee qualifications. This means that the mentioned problems should be solved first.

Similar problems were identified in other studies conducted in Poland, where most respondents highlighted problems related to the lack of skilled employees (77%), low return on investment in advanced technologies (75%), lack of business models (72%), low level of cybersecurity (68%), insufficient level of knowledge related to Industry 4.0 technologies (41%) [58].

The problems connected with the Industry 4.0 technologies implementing mean general threats to employees and society. Experts emphasized the possible decrease in the manufacturing SMEs' competitiveness due to high costs of investments in new technologies and changes in the employment structure. Modern companies using digital technologies show a need for highly qualified employees. The demand for new skills stems from increased automation and robotization of production systems, increased autonomy of smart equipment, autonomous decision-making by resources, and digital communication. In addition, greater workforce flexibility is required [1,13,19].

The use of digitized production of goods and services is a global business trend that significantly changes the reality of enterprises that must base their *modus operandi* on new technologies. The main reason motivating the use of new technologies is the increased power of real-time processing of vast amounts of data, increased productivity and flexibility enabling high levels of customization and better customer orientation [63,64]. Simultaneously, an important impact of digitized systems on sustainable development, sustainable production, and consumption can be observed [8,13,65]. Confirmation of the presented effects of the implementation of the Fourth Industrial Revolution technologies is provided by experts' opinions. They emphasized the possibility of achieving high flexibility through on-time orders deliveries, increased systems productivity, better adjustment of the offer to the customer needs, and manufacturing of personalized products with an acceptable price. In addition, they mention the significant level of sustainability benefits achieved through increased sustainable production and consumption. Significant environmental benefits include a decrease in overall product consumption resulting from a more tailored offering to the customer and an orientation toward personalized production. The purchase of personalized products means greater product satisfaction and a longer product life cycle. Hence, experts expect a reduction in energy consumption. The possibility of active involvement of customers in the design of personalized products will also benefit the customer. This means a paradigm shift from standardized to personalized production [4].

Analyzing numerous scientific studies and forecasts, it can be indicated that the digitization of enterprises and the implementation of the Fourth Industrial Revolution technologies causes an increase in demand for new knowledge, skills, and professional qualifications of employees [11]. Boston consulting group made classifications job profiles refer to specific roles within Industry 4.0 in addition to very general ones, such as logistics, sales and customer service, administration and management, maintenance, and production planning, she emphasized IT job profiles important for Industry 4.0, e.g., IT specialist, robot programmer, software engineer, a cybersecurity expert [66]. Experts in the U.S. market indicate a demand for specialists in production engineering management, data analysis, cyber security, logistics, project management, and ICT. Experts do not predict the demand for machine operators (automation engineers, mechatronics) and low-skilled manual workers. It may mean the already high level of applied technologies and saturation of the labor market with low-skilled workers.

Implementing and maintaining digital technologies requires interdisciplinary knowledge and a combination of technical, organizational, and social competencies and skills. The expert survey results confirmed the need for industrial employees who possess interdisciplinary knowledge which combines technical and management skills. Experts emphasized that a modern engineer should have, in addition to a high level of technical knowledge,

also the ability to solve problems, use advanced digital technologies, automation and robotization, and use advanced computer-aided systems. In addition, an engineer should have the ability to think analytically, work in a team, and be open to long-life learning. Openness to working with robots and the need to develop Artificial Intelligence knowledge is also emphasized by Hoeschl et al. [67].

Employees also need knowledge and skills to make decisions, manage processes, and combine engineering and managerial knowledge [58]. The essential managerial skills highlighted by experts in the study include long-life learning, striving for continuous improvement, team working. Managers need to have skills in problem-solving, conflict solving, creative thinking, and openness to use new technologies.

The workforce skill requirements presented by experts imply the need for changes in the vocational education and workforce training system. New CPSs supported by digital technologies of Industry 4.0 no longer require traditional skills but require new ones related to the implementation and operation of digitized smart factories systems. Modern manufacturing companies must promote a climate of innovation and lifelong learning. Adequate training should include technical basics, a systematic approach to the implementation of digitization. This requires the acquisition of detailed methodological and process competencies [65]. Limiting the knowledge and skills of engineers only to the ability to operate hardware can lead to a serious competency gap. The Fourth Industrial Revolution and dynamic changes in the required competencies require an immediate response against the ageing of competencies and applying the approach of continuous development and updating of employees' competencies and skills [11]. Adapting to new working conditions also requires supplementing teachers' knowledge in data analytics, process digitization, communication in CPSs, Artificial Intelligence (AI), and Augmented Reality (AR), which is becoming widely used solutions in modern companies [37].

Liane Mahlmann Kipper et al. in their work, presented results of research focused on identifying competencies of Industry 4.0 based on the Scopus, Web of Science and Science Direct databases from 2010 to 2018. The presented results have highlighted those competencies must be developed in professional education and should be supported by governments, companies and universities. The main competencies indicated by the researchers needed include the following skills leadership, strategic vision, self-organization, creativity, problem-solving, interdisciplinary, team working, initiative, communication, flexibility, and self-management, etc. Furthermore, they indicated the main knowledge of contemporary fields such as automation, ICT, algorithms, software development, cybersecurity, data analysis and sustainable development, etc. S. Leinweber in his study clustered the identified competencies into four main categories which are considered by the experts to assess engineering education. These categories are technical competence, methodological competencies, social competencies, and personal competencies [68].

The cited observations of other authors confirm the opinions of experts who emphasized the importance of interdisciplinary education of engineers. According to the experts, it is essential to develop technical and methodological competencies. Very important competencies are creativity, analytical thinking, the ability to quick decision-making. Experts stressed that it is also essential to develop social competencies, including communication skills, networking, and integration skills. Nevertheless, industrial employees must possess the team-working, the ability to work in an intercultural environment, and leadership skills. Nowadays, technical universities must change their modus operandi and combine these areas in the fields of study. The confirmation of the need to develop the group of social and personal competencies is the expert's assessment of the current level of education based on the experience of experts from their work environment. The experts highly evaluated the level of technical and methodological competencies. In addition, it is also essential to increase the importance of the idea of lifelong learning, which promotes the development of creativity and innovation of employees and talent development [20,23].

It is now essential to understand the characteristics of the knowledge and skills provided in engineering departments to identify emerging patterns in delivering the new

Industry 4.0 educational requirements. Similar studies confirming the results presented by the authors in this paper but from the educational site were also established by Cevik Onar, S. et al. (2018), who defined new academic requirements incorporated into Industry 4.0 and revealed emerging patterns and similarities in engineering education based on examining 124 engineering departments of the world's most prominent universities [69].

6. Conclusions

The Fourth Industrial Revolution brings enormous benefits to society regarding personalization of production, high flexibility, and increased productivity of production processes. Supporters of digitalization of processes see in the new digital technologies the implementation of an increase in the quality of life, reduction of environmental pollution, and reduction of energy consumption. This is possible through digital technologies in smart cities, smart factories, and smart homes focused on low-carbon and reducing energy demand. Society 5.0 is a community that uses digital technologies in all areas of social life, including communication, work, entertainment, shopping, and health care. Nowadays, people are becoming part of the digital world, which causes the need to develop competence and knowledge of applied technologies. This applies both to ordinary users and employees of companies implementing these technologies.

The development of digitization of processes, intelligent interfaces, and augmented reality is changing the way people interact with different systems. Today's workers are required to understand and manage intelligent machine and robot systems. Unfortunately, it means the workforce structure change that comes with increased employee demands. Widespread digitization also raises a lot of concerns related to cyber-attacks, etc. According to research and literature analysis, we can conclude that today's workforce needs a complement of knowledge and skills resulting from widespread digitization, which leads to increased productivity and flexibility of production systems. There is a need to recruit highly qualified employees characterized by openness to change, ability to transfer knowledge, and team-working. Experts stress the need to combine different groups of competencies (technical, methodological, social, and personal) in the education system, emphasizing the importance of developing interdisciplinary in the education of engineers and the need to develop the idea of lifelong learning, which affects the growth of creativity of employees and talent development. This means changes in education, which should be directed at the development of such professions as production engineering manager, data analyst, cyber security specialist, logistician, project manager, and ICT specialist, among others. It is also important to develop soft skills essential for collaboration, communication, and interpersonal relationship-building skills. The knowledge of engineers must also be complemented with an understanding of environmental aspects to encourage them to reduce environmental pollution and reduce energy consumption. This awareness is essential to understanding the need for smart solutions that will contribute to productivity growth and waste reduction.

The conducted analysis of experts' opinions is only a signal of the problem of the need for changes in the development of knowledge and competencies of the employees of the Fourth Industrial Revolution and the demand for new qualifications of employees functioning in Economy 4.0. The direction of further research will be to conduct a deeper analysis of the impact of the development of interdisciplinary competencies of engineers and the implementation of digital technology solutions in "smart" systems on the sustainable development of the economy and the reduction of energy consumption.

Strengthening the knowledge and skills of industrial employees operating in the digital economy is the primary goal. Now, apart from the low level of technologies used, especially in SMEs, it is one of the most critical barriers to implementing the technologies of the Fourth Industrial Revolution. The current dynamics of change should prompt businesses to intensify opportunities to develop employee competencies in the workplace. Companies should partner with local universities to shape their skills and provide new ideas to industrial companies. Future research should consider the problem of adapting

the education system and preparing government instruments to support today's society to adapt to the widespread digitization quickly. A significant issue is the adaptation of older workers to change jobs. Furthermore, the older generation will increasingly use e-health, e-patient, e-government or e-banking services, e-commerce, etc.

Author Contributions: The main activities of the team of authors can be described as follows: conceptualization, S.S., S.G.; methodology, S.S., S.G.; software, S.S., S.G., W.G.; validation, S.S., S.G.; formal analysis, S.S., S.G.; investigation, S.S., S.G.; resources, S.S., S.G.; data curation, S.S., S.G., W.G.; writing—original draft preparation, S.S., S.G.; writing—review and editing, S.S., S.G.; visualization, S.S., S.G., supervision, S.S., S.G.; funding acquisition, S.S., S.G., W.G. All authors have read and agreed to the published version of the manuscript.

Funding: Silesian University of Technology (Faculty of Materials Engineering, Department of Production Engineering) supported this work as a part of Statutory Research BK-11/990/BK_22/0083.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The study collected data from consenting experts, no ethical goods were violated.

Conflicts of Interest: The authors declare no conflict of interest.

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