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DEVELOPMENT OF KNOWLEDGE AND SKILLS OF ENGINEERS AND MANAGERS IN THE ERA OF INDUSTRY 5.0 IN THE LIGHT OF EXPERT RESEARCH

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Purpose: The article aims to identify areas of knowledge, key skills, and competencies of engineers and managers necessary in the Industry 5.0 environment.
Design/methodology/approach: The achievements and results presented in the article were obtained based on literature research and expert research conducted among 25 professionals with experience in management, innovation, and technology of Industry 4.0. The research technique was a standardized interview.
Findings: Based on the research results obtained, the essential knowledge areas and competencies of engineers and managers of industrial enterprises oriented to the implementation of the Industry 5.0 concept were identified.
Research limitations/implications: The analysis of experts' opinions is only a signaling of the problem of the need for changes in the development of knowledge and competencies of industry employees functioning in the Industry 5.0 environment. The research should be extended to other areas of the economy, e.g., services, education, quality of life, and Society 5.0.
Originality/value: Original achievements obtained during the research include getting valuable research results in the areas of knowledge, required key skills, and competencies required of future industry employees. The research results were obtained directly from experts who, through their daily experience, meet the knowledge and competence deficits of modern companies. In addition, experts have the necessary knowledge of new technologies and requirements posed by the Industry 5.0 environment.

Keywords: Industry 5.0, Industry 4.0, skills and competencies of engineers.

Category of the paper: Research paper.

1. Introduction

Industry 4.0 builds cyber-physical production systems to integrate information technology and operational technology in enterprises and supply chains (Lee et al., 2015; Liu et al., 2017). The evolution of industrialization from Industry 4.0 to Industry 5.0 is primarily dictated by the need to expose the role of humans in cyber-physical systems. The technologies used to build Industry 4.0 cannot impose their choices on humans but offer them. The first mentions of the role of operators in Industry 4.0 appeared in the publications of Romero et al. (2016). It was emphasized that symbiosis is needed between humans and new technologies. The authors proposed to introduce the human factor into cyber-physical systems. The new system design is called the Human Cyber-Physical System (H CPS). The humanization of the built-tech environment for Industry 4.0 was one of the first factors in the evolution of Industry 4.0 towards Industry 5.0. In addition to the human factor, Industry 4.0 has noted research gaps in sustainability, accountability, safety, and others. Saniuk et al. (2020) attempted to systematize the barriers of Industry 4.0 in the following categories: social and market, concerning particular stakeholder groups.

Other authors (academics and researchers) have also participated in discussing the social and environmental problems (shortcomings) of Industry 4.0. Ranghino (2019) made a discussion on environmental risks. Bonilla et al. (2018) wrote about the impact of Industry 4.0 technology on the environment and sustainability, creating optimistic and pessimistic scenarios. The sustainability aspect of Industry 4.0 was also a topic of publication. Gajdzik et al. (2020), Luthra et al. (2018), Pagoropoulos et al. (2017) and others.

Industry 5.0 is an industry that focuses primarily on the consideration of the critical role of humans and greater involvement of their knowledge and competencies in a cyber-physical production system. The interaction of human and artificial intelligence is paramount in Industry 5.0. Man and machine work together to improve the quality and efficiency of production (Broo et al., 2021; Haleem, 2019). The upcoming fifth industrial revolution is also expected to be more environmentally friendly as companies develop renewable energy systems and eliminate waste (Nahavandi, 2019).

Participants considered the main ideas of the Industry 5.0 concept at a meeting of research and technology organizations organized by the European Commission (EC) from 2-9 July 2020. At that time, the basic principles of the Industry 5.0 concept were developed, and key changes in directions were proposed to make the industry more sustainable and human-centered (Breque et al., 2021; Council, 2015a, 2018b).

According to EC, the strength of Industry 5.0 is the social goals beyond jobs and economic growth to become a resilient provider of well-being by making production respect the limits of the planet and putting the well-being of the industrial worker at the center of the production process. A favorable factor in the development of the Industry 5.0 concept is society's growing

awareness. This means interest in green products, the sharing economy, and interest in developing a closed-loop economy (Elfar et al., 2021; Aslam et al., 2020; Di Nardo, Yu, 2021).

Industry 5.0 emphasizes the importance of technology for industrial development. Still, at the same time, it promotes social goals in the workplace, e.g. it emphasizes workplace safety with next-generation technologies or human-machine relationships and external purposes, i.e., social and environmental responsibility (Gorodetsky et al., 2019). Industry 5.0 does not deny the necessity of digitising societies, economies, and industries but rather extends it with social and environmental aspects (Doyle-Kent, Kopacek, 2019).

Digitalization in Industry 5.0 is a broad philosophy that organizes enterprise and supply chains processes. Within this philosophy, digitalization and elements of artificial intelligence penetrate into people's everyday life. Hence, there is an opinion among scientists that Industry 5.0 is actually creating the idea of "Society 5.0" (Elim, Zhai, 2020). Society 5.0 is a society in which advanced technologies are actively used in people's lives, industry, health care, and other spheres not for the sake of progress, but for the benefit and quality of life (John et al., 2020). Society 5.0 is not only limited to industry but solves social problems by integrating physical and virtual space.

The premise of Industry 5.0 is to create interaction in the human-machine system. The interaction involves connecting humans with smart devices and the cyber-physical system through smart mobile devices (Demir et al., 2019; Vollmer, 2018). Nowadays, robots seem to be replacing humans due to advances in artificial intelligence development and the possibility of brain-machine interface development (Longo, 2020). This means, in the future, a potent combination of robots with the human brain and using them as a collaborator and executor of commands, rather than a competitor (Nahavandi, 2019). Therefore, the idea of Industry 5.0 will focus on developing more advanced human-machine interfaces using artificial intelligence algorithms. This represents an opportunity to utilize the capabilities of human brains to increase the efficiency of automated and robotization systems (Aslam et al., 2020). This means breaking with the view of losing control of the cyber-physical world dominated by thinking robots which was feared in the era of Industry 4.0 (Haleem, Javaid, 2019). The transformation of the Industry 4.0 concept to Industry 5.0 combines the advantages of the cyber-physical system of intelligent machines and common sense thinking, which can mean a focus on productivity and sustainability. (Özdemir, Hekim, 2018).

In human-machine integration, it is also essential to develop competence and knowledge in new technologies and the trend of talent management. The future is based on investments in employee retraining and the lifelong learning process. According to Forbes, about 34% of HR leaders invest in developing strategies to prepare for new technologies (Esbah, 2022). This implies the need to focus on talent development and talent management of employees to improve the systems' productivity and better orient to the needs of the economy and society (Humayun, 2021).

Industry 5.0 is expected to create many new jobs in human-machine interaction (HMI) and human computational factors (HCF). Some of the most important areas where jobs will be created include intelligent systems, artificial intelligence and robotics, machine programming, machine learning, maintenance, training, etc. (Martynov et al., 2019) or (Madesn, Berg, 2021). The goal of Industry 5.0 is to achieve a higher standard of living and creativity through high-quality custom-made products that lead to sustainable production and consumption. Along with the focus (of scientists and researchers) on people, Industry 5.0 places a premium on human resource development. New occupations, skills, and functions of production workers are emerging. Hence, there is a need for research on changes in the skills and competencies needed by workers in modern industry. This article aims to identify areas of knowledge, key skills, and competencies of engineers and managers necessary in the Industry 5.0 environment.

2. Materials and Methods

The research carried out consisted of two parts. The first part of the research consisted of a literature analysis. A systematic review of the literature and a critical analysis of the content of selected publications allowed the identification of the research gap. In the second part, research questions were formulated, and interviews with experts were conducted. The interview was standardized; its basis was a survey questionnaire containing 15 questions. The questionnaire was validated, and a pilot study was carried out among eight Polish experts with knowledge of Industry 5.0. Interviews with 25 experts were conducted between 15 January and 15 April 2022.

The experts who participated in the survey were selected by three competent judges (academics with knowledge of Industry 4. 0 and Industry 5.0). The experts were business professionals and managers from manufacturing companies implementing Industry 4.0 technologies.

3. Results

According to experts, the most sought-after specialists in the analyzed companies are production engineering managers (100%), data analysts (80%), cyber security experts (64%), logisticians (60%), project managers (56%), and ICT specialists (56%). Experts show no demand for machine operators (automation engineer, mechatronics) (12% of respondents) and low-skilled manual workers (12% of respondents). The exact demand for all occupations declared by experts is shown in Figure 1.

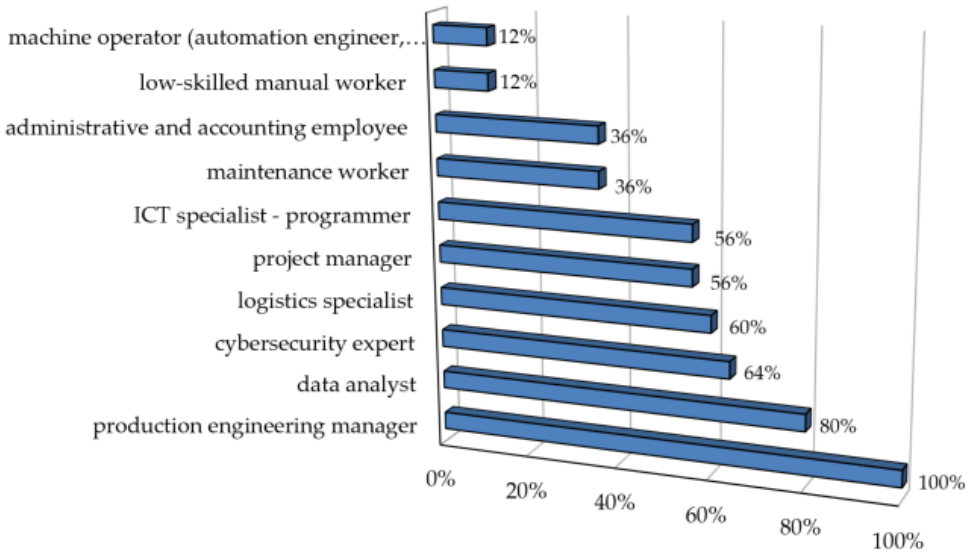

Figure 1. Demand for employees in industrial enterprises implementing the Industry 4.0 technologies.

The demand for employees in manufacturing companies is closely related to the skills of engineers responsible for implementing Industry 4.0 technologies. In this area, experts declared 100% of the required engineering skills. A high level of expectations concerns the ability to solve problems (92% of respondents), openness to sustainable development (88%), openness to digitalization (80%), and analytical thinking (80% of respondents). Essential are: the ability to learn long-life (72%) and to use computer-aided systems (72%). Experts also pay attention to openness to new technologies (automation and robotization) and teamwork (68% of declarations). Figure 2 shows a graph with the answers of respondents.

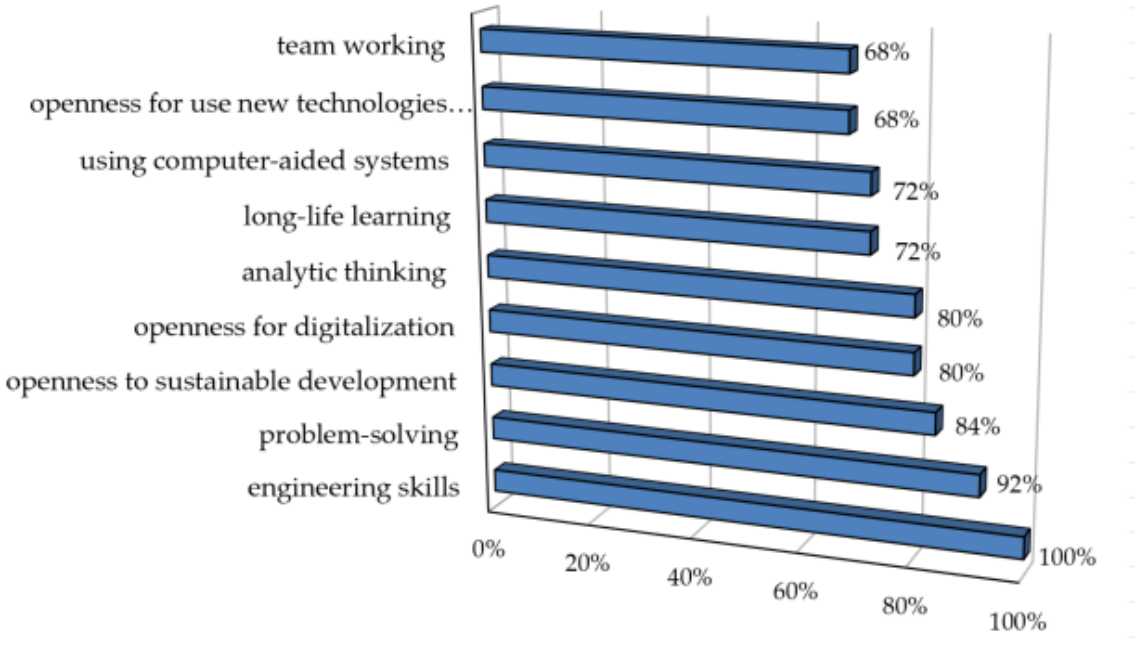

Figure 2. Required skills for engineers in the era of Industry 5.0.

Experts also highlighted managerial skills as essential for the technologies of the fourth industrial revolution (Figure 3). High expectations include the ability to strive for continuous improvement, openness to sustainability and teamwork (92% of respondents), problem-solving, conflict resolution and creative thinking (84%), technical and management skills for connections, and openness to the use of new technologies (80% of respondents). Resilience to stress and openness to digitalization is significant (72%). Experts also pay attention to self-discipline (68% of declarations).

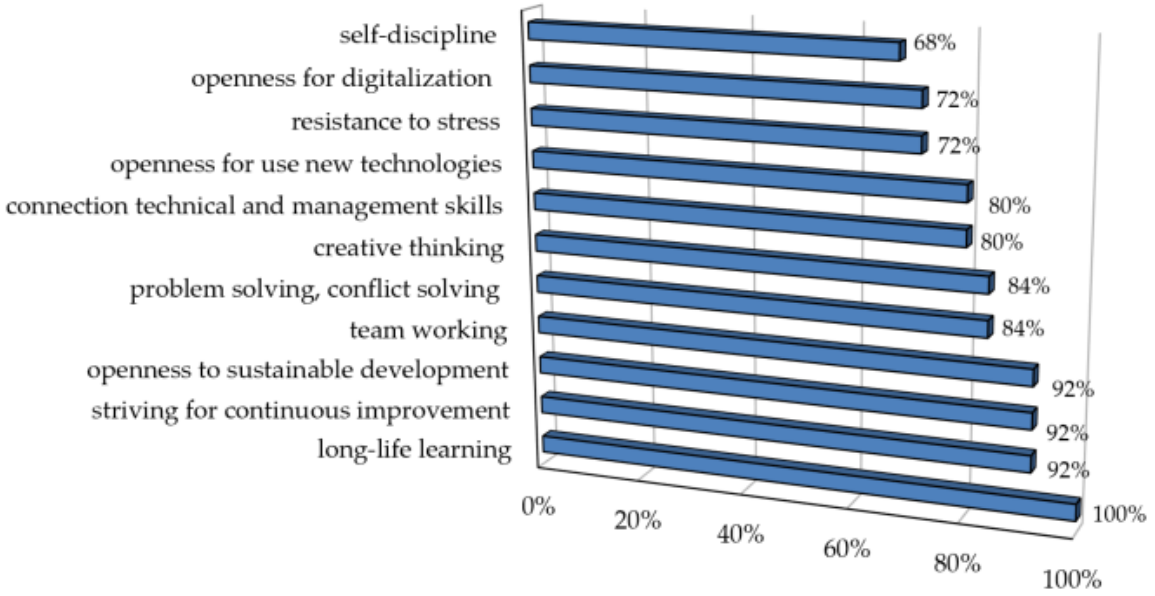

Figure 3. Required managerial skills in the Industry 5.0 era.

Experts, answering the question: Which groups of competencies, in your opinion, should be more developed during the education of engineers? They assessed four groups of competencies on a 5-point Likert scale (Figure 4). Technical skills (Technical skills, Understanding IT security, Process understanding, Media skills) for an engineer are very important (60%) and important (40%). Methodological competencies (Creativity, Entrepreneurial thinking, Problem and Conflict solving, Analytical skills, Decision making, Research skills) were most often assessed as important (72%) and very important (20%). 8% of experts considered this group of competencies moderately important. Another group of competencies, Social competencies (Communication skills, Networking and integration skills, Ability to work in a team, Intercultural skills, Ability to be compromising and cooperative, Leadership skills), is important (56%) and medium (36%). Only 8% of the experts considered social competencies to be very important. The last group assessed were personal competencies (Commitment to lifelong learning, Flexibility, Motivation to learn, Ability to work under pressure, and Social responsibility). Most experts (64%) consider personal competencies moderately important, 28% as important, and only 8% as very important.

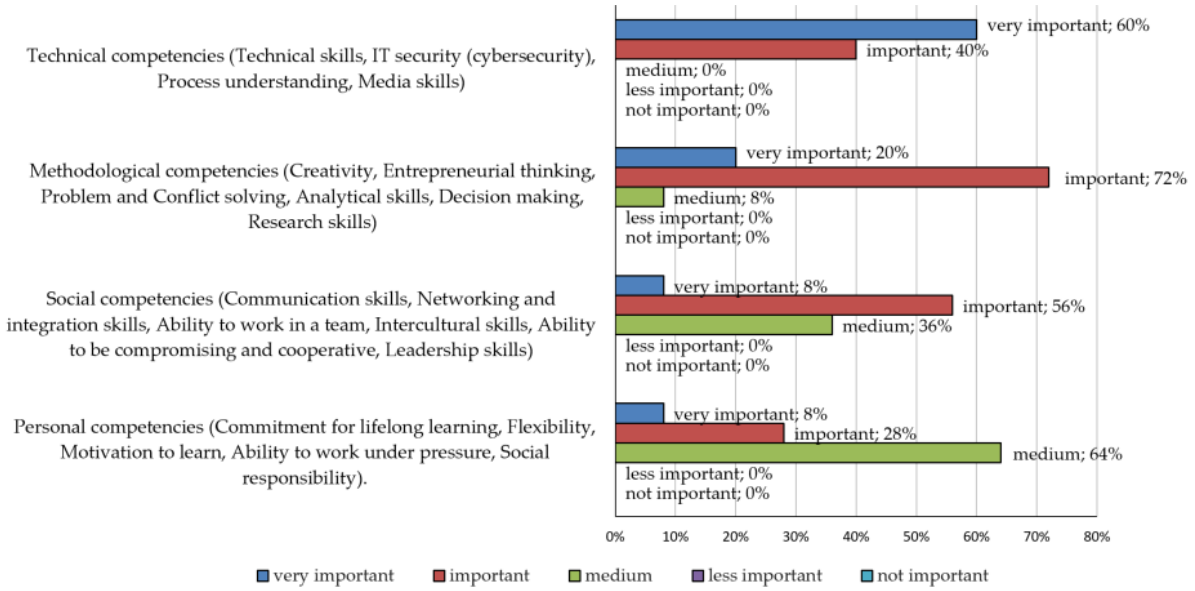

Figure 4. Groups of competencies to be developed during engineering education.

In the following question, the experts evaluated the level of competence represented by the engineers (Figure 5). The assessment was carried out 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 a medium level (10).
2. Methodological competencies – rated as medium level (14) and high level (11).
3. Technical competencies – 14 experts rated these competencies in engineers as high level and 11 as very high level.
4. Personal competencies – according to experts, they are at a low level (14) and medium level (11).

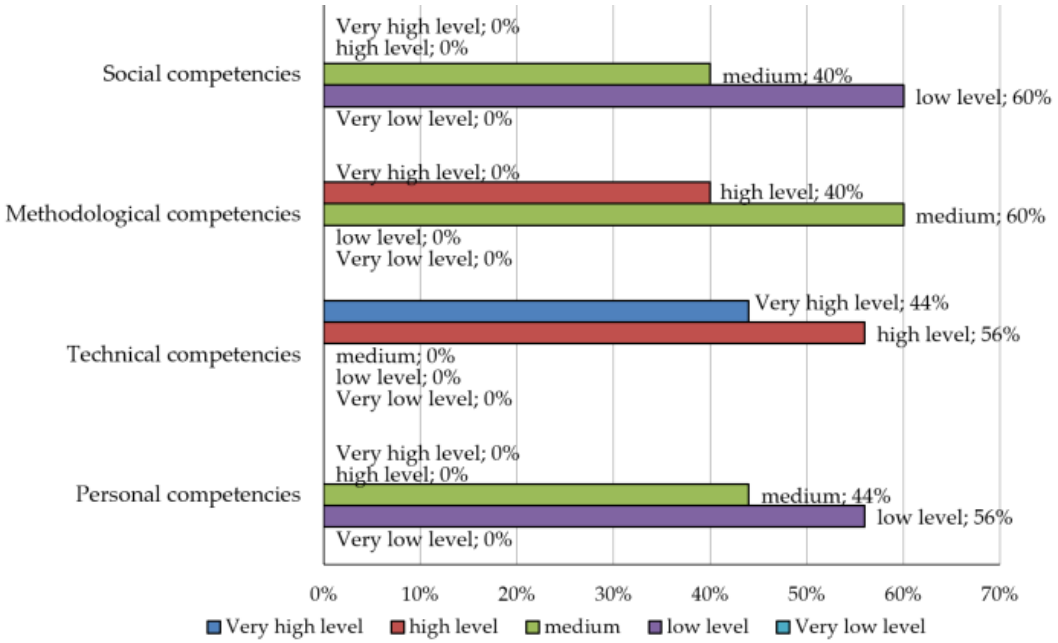

Figure 4. Assessment of the level of education of engineers based on expert experience in the following groups of competencies.

4. Discussion and Conclusions

The fourth industrial revolution brought enormous benefits to society regarding personalization of production, high flexibility, and increased productivity of production processes. Supporters of digitalization of processes see in the implementation of new digital technologies an increase in the quality of life, environmental pollution reduction, and 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. Today, people are becoming part of the digital world, which leads to the need to develop competence and knowledge of applied technologies. This applies to both 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 types of systems. Today's workers must understand and manage intelligent machines and robotic systems. Unfortunately, this means a change in the workforce structure that comes with increased employee demands. Widespread digitization also raises a lot of concerns related to cyber-attacks, etc. Based on research and literature analysis, it can be concluded 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 skilled employees with openness to change, the ability to transfer knowledge, and the ability to work in a team.

Experts emphasize the need to combine different groups of competencies (technical, methodological, social, and personal) in the education system, stressing the importance of the development of interdisciplinarity 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.

Modern manufacturing companies must promote a climate of innovation and learning and change the culture of knowledge, which means changing values and expectations (Mohelska and Sokolova, 2018). This means changes in education, which should be directed towards the development of professions such as production engineering manager, data analyst, cybersecurity specialist, logistician, project manager, and ICT specialist, among others. The current education system is exposed to the ageing of competencies. It lacks mechanisms to introduce continuous updating and development of knowledge and skills required by the current and future labor market (Ghislieri et al., 2018). Gonzalez and Calderon emphasize the need for learning for both students and teachers, especially for knowledge and skills covering areas such as advanced automation, surveillance, robotics, and communication in industrial networks,

including integration of systems, sensors, actuators, etc. (Gonzalez and Calderon, 2018). There should be the development of support programs for academics to organise practical internships in modern enterprises, intensifying the participation of researchers in solving specific enterprises' specific problems. Currently, the focus on the development of basic research in a dynamically changing environment is becoming useless and overdue. Unfortunately, this negatively reflects the education process of students who lack up-to-date and practical knowledge.

Engineers' knowledge must also be complemented with environmental aspects, the need to reduce environmental pollution, and reduce energy consumption. This awareness is essential to understand the need for smart solutions that contribute to growth in productivity and reduction of waste. It is also important to develop soft skills necessary for collaboration, communication, and interpersonal relationship building skills.

Future research should address the social effects of widespread digitization, changes in the employment structure, and the required humanization of industry. Research should also cover other areas of the economy's functioning and human living conditions after implementing the Industry 4.0 and Industry 5.0 concepts. This requires strengthening cooperation between industrial enterprises and academia in applied research and developing new study programs.

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