Humanities and Social Sciences **2024**
Research Journal 31, No. 2 (2024), pp 53-73 **April-June**

Received: July 2023
Accepted: June 2024
DOI: 10.7862/rz.2024.hss.18

Paulina GOŁUCH[1]
Maciej STEC[2]
Patryk GAŃCZORZ[3]
Konrad BIAŁEK[4]
Anna KILJAN[5]

AN ANALYSIS OF THE CHALLENGES AND OPPORTUNITIES FACING THE INTERDISCIPLINARY ENGINEER OF THE 21ST CENTURY BASED ON THE CONCEPT OF INDUSTRY 4.0

This article focuses on analyzing the challenges and opportunities that modern engineers encounter. In the context of a dynamically changing technological environment, the authors identify key areas such as the growing importance of interdisciplinarity, the need for flexibility in acquiring new skills, and ethical dilemmas related to technological progress. At the same time, they discuss the opportunities presented by the emerging technological revolution and how engineers can contribute to solving global problems through their comprehensive approach. The article is an important contribution to understanding the role of the interdisciplinary engineer in the 21st century and how to cope with new challenges and exploit opportunities in the world of science and technology.

Keywords: characteristics of engineers, industry 3.0, industry 4.0, industry 5.0, interdisciplinary engineer, technical challenges, non-technical challenges.

1. INTRODUCTION

The modern world has created a demand for the requalification of engineers. The transformation of highly qualified Engineers 3.0 into interdisciplinary Engineers 4.0 is ongoing. The knowledge and experience defining an Engineer 3.0, combined with appropriate soft skills, ensure that they will excellently meet the tasks entrusted to contemporary Engineers 4.0. In the literature, one can already find research and analysis on the Engineer 5.0, who in the near future will be considered the standard model. Every person is characterized by one predominant personality type classified based on the

[1] Paulina Gołuch, Silesian University of Technology, Gliwice, Poland.
[2] Maciej Stec, Silesian University of Technology, Gliwice, Poland.
[3] Patryk Gańczorz, Silesian University of Technology, Gliwice, Poland.
[4] Konrad Białek, Silesian University of Technology, Gliwice, Poland.
[5] Anna Kiljan, Silesian University of Technology, Gliwice; e-mail: anna.kiljan@polsl.pl (corresponding author). ORCID: 0000-0002-1560-3408.

principles of Hippocrates, combined with other variants, which influence the predispositions to meet the requirements of modern Engineers (Ośmiałowska et al., 2022).

The required knowledge, skills, and characteristics of the ideal, interdisciplinary engineer have been summarized as: a strong technical base, engineering approach, professional values, but also creativity in problem-solving, strong communication skills, and readiness for flexibility in carrying out assigned tasks. It has been noted that currently, universities mainly focus on creating a technical knowledge base (Nandurkar et al., 2016).

The aim of the article is to compare the existing considerations on the profiles of Engineer 3.0, 4.0, and 5.0, along with the characteristics of the occurring industrial revolutions, and to present a subjective review of the technical and non-technical challenges facing the modern engineer, along with the opportunities that lie behind them.

2. BRIEF CHARACTERISTICS OF PERSONALITY TYPES ACCORDING TO HIPPOCRATES, ALONG WITH THE PRACTICE OF USING PERSONALITY TESTS IN THE PROCESS OF RECRUITING EMPLOYEES

The ancient Greek physician and philosopher Hippocrates was the first to study human temperament. His concepts were further developed by Galen and Pavlov. Their work is illustrated by Pavlov's characterization of the nervous system, which is related to the Hippocrates-Galen temperament typology.

❑ The Strong, Balanced, and Slow Type (Phlegmatic)

Along with the sanguine type, this is one of the types of nervous systems adapted to life. It is a healthy and resilient type with a high density of features of the nervous system and a balance between excitatory and inhibitory processes. Both positive and inhibitory conditioned reflexes are easily formed, and their stability is high. It is difficult to induce neurosis in representatives of this type, even in supposedly difficult living conditions. Individuals of this type have difficulty adapting to rapidly changing living conditions (Strelau, 1985).

❑ The Strong, Balanced, and Lively Type (Sanguine)

A healthy, flexible, and efficient type of nervous system, which, along with the phlegmatic trait, possesses the so-called golden mean on the scale of temperament. Vivacious and active when stimulated by the environment, but prone to drowsiness and sleep when not feeling stimulated. Susceptible to both positive and inhibitory conditioned reflexes. It is difficult for individuals of this type to develop neurological disease, even in adverse living conditions. Pavlov considered this type to be the most perfect of all types and the one that best guarantees the maintenance of an ideal balance between the organism and the conditions in which it lives (Strelau, 1985).

❑ The Strong, Unstable Type (Choleric)

Prone to neurotic states, as the excitatory processes significantly outweigh the inhibitory ones. Difficulty in avoiding activity when necessary. Representatives of this type become excessively restless up to exhaustion, and this state of anxious exhaustion sometimes periodically transitions into depression and lethargy. They can also become aggressive, hostile, and uncontrollable in such situations (Strelau, 1985).

❑ The Weak Type (Melancholic)

Its existence requires special conditions. The onset of a positive conditioned reflex is very slow and can be easily weakened or eliminated under the influence of unknown secondary factors. They also show weak resistance to inhibitory stimuli. Behavior is disrupted in situations where certain behaviors should be avoided. Rapid and frequent changes in the living environment also disrupt the behavior of the melancholic. This type is not adapted to life, easily becomes disoriented, and is often neurotic. Generally, this type cannot be significantly improved through training or discipline (Strelau, 1985).

It is also worth paying attention to another classification by C.G. Jung. He distinguishes two types of temperament: extraversion (Latin extra – outside; vertere – right, directive) and introversion (Latin intro – inside). The former are characterized by their main attention and activity being directed towards the external world, they easily communicate with people and adapt well to changing circumstances. Introverts, on the other hand, focus on themselves, are not interested in the external world, and are shy in expressing their feelings and thoughts (Zdrojewski, Gajewski, 2009).

In summary, it is worth noting that the personality types presented above are shown in ideal conditions, i.e., a person's personality is usually a complex of all or several personality types, with one being dominant. The complexity of human personality makes it difficult to predict human behavior or identify traits that predispose.

Tests are measurement tools and, like other tools, can yield useful results. They are objective, standardized, accurate, reliable, and normalized instruments that contain principles for calculating the value of the measured psychological trait and clearly define the scope and type of behaviors acceptable to the diagnostician. They are an excellent factor in recruitment, where personality and behavior are most important, such as in project management, sales, marketing, and communication with external or internal customers – all areas that an interdisciplinary engineer encounters. They are very effective in making choices and predicting future results in an organization. They serve as a complement to traditional job interviews and other recruitment methods, providing information that significantly improves the efficiency and objectivity of the entire selection process. They allow for the identification of even seemingly competent and reliable employees before they are employed in the organization (Szkop, 2012).

Testing is no longer a service initiated by professional psychologists. There is now a market for specialized services for companies and organizations. Today, there are firms operating in the areas of HR audit, personal consulting, recruitment, and selection. When using tests in recruitment, it is important to remember that the test should not be the only evaluation factor. It should always be supplemented with another method or at least a careful job interview (Zimnowłocka-Łozyk, 2011). We distinguish several types of tests:

- Intelligence tests – assess the ability to combine facts, analytical and logical thinking, and the most used are the Stanford-Binet and Wechsler tests.
- Achievement tests – assess knowledge and skills acquired through professional experience and include performing specific tasks required for a given position.
- Skill tests – examine the level of skills required to perform a specific job. They can be conducted in situations similar to the work environment and can be of two types: tests of learning abilities and tests of innate abilities.
- Personality tests – assess personality and work-related behaviors of the person being tested.
- Interest tests – often used as a complement to the test to identify areas of particular interest to the person being tested and assess whether the work is enjoyable for the candidate.
- Honesty tests – a specialized way of testing honesty, overt or covert, to determine the likelihood of theft (Roczniak, 2017).

What can be the implications of overusing tests?

- Misunderstanding intelligence as the sole or primary trait determining success in a very narrowly defined task

A major challenge for psychologists becomes the need to develop measurement instruments that reflect the full spectrum of educational and professional goals and do not lead to the identification of test behaviors of subjects according to only one criterion.

- Labeling in terms of intellectual status and predicting future functioning

Since labeling is a simplified form of social categorization, it has all the characteristics of a form of racism. The effect of labeling categorization is therefore to determine the future of a person, not to describe their current skills.

- Placing the psychologist in the role of controller and decider of the fate of the subjects

Instead of using the results of psychological tests as a basis for free and autonomous choices of the person tested, they can decide for them about their further education or career path. The real danger is that the results of the tests are used to reproduce old structures, instead of creating space for individual choice.

- Bureaucratic and mechanized decision-making regarding the assessment of subjects

Algorithmic forecasts allow people without specialized psychological education to use tests. This is a step towards the bureaucratization of psychological diagnosis, i.e., the detachment of algorithmic procedures from their psychological significance and importance. From this mechanistic approach to diagnosis, it is easy to imagine the development of computerized diagnostic systems.

- Rights of the subjects

The professional use of psychometric tests requires not only the application of well-developed psychometric methods and proper interpretation of results but also respect for the rights of the subjects. Taking into account the rights and interests of the subjects is the most important duty of test administrators. The main goal of developing such standards is not only to raise awareness of the rights of the subjects but also to make test administrators aware of the ethical aspects of testing (Zimnowłocka-Łozyk, 2011).

3. EXPLANATION OF THE TERM "COMPETENCE" ALONG WITH A SET OF KEY TRAITS DESIRED IN THE LABOR MARKET

The Polish language dictionary defines 'competence' as the scope of someone's knowledge, skills, and responsibilities ("Kompetencja". *Słownik języka polskiego PWN,* n.d.). The synonym dictionary states that competence also encompasses ability, knowledge, capacity, professionalism, and expertise ("Kompetencja". *Synonimy*, n.d.). Meanwhile, a competent person is characterized as confident, reliable, authoritative, proficient, experienced, and professional ("Kompetentny". *Synonimy*, n.d.).

The process of competence management has brought about positive outcomes, such as highly qualified, appropriately placed, and trained employees. Therefore, it is important to pay attention to and demonstrate an understanding of the significance of competence and its components. The table below presents the components of competence, according to various theories.

Many authors emphasize that it is not primarily hard competencies, such as knowledge and skills, that determine an employee's effectiveness, but also soft competencies related to personality traits, attitudes, and behaviors. In particular, the importance of skills in building competencies in interpersonal relations is highlighted.

Table 1. Table of component competences

COMPONENTS OF COMPETENCES			
M. Kocór, A. Strzebińska	**D.C. McClelland**	**S. Borkowska**	**L.M, S.M Spencer**
Knowledge	Knowledge	Knowledge	Motives
Skills	Abilities	skills	Traits
Attitudes	Skills	motivation	Attitudes and values
	Personality traits	Attitudes	Knowledge
			Skills
K. Padzik	**R. Walkowiak**	**A. Sajkiewicz**	**T. Oleksyn**
Knowledge	Knowledge	Knowledge	Capabilities
Skills	Skills	Experience	Education
Improvements	Personality traits	Abilities	Knowledge
Intrinsic motivation	Experience	An aptitude for team activities	Experience
Behavior	Attitudes	Personal culture	Practical skills
Personality traits	Behavior		Intrinsic motivation
			Attitudes
			Behavior
			Health
			Values

Source: Own elaboration based on (Górska-Rożej, 2014).

Although the core value of an engineer is technical qualifications, the advantage of individual experts, their significance, and potential are spoken of not only in terms of hard skills but also increasingly in terms of soft skills and their importance in the perspective of the coming years. According to experts from Bergman Engineering, currently, the most valued soft competencies among engineers include comprehensive problem solving, critical thinking, creativity in approaching various issues, coming up with innovative ideas in the field of product and technological innovations, the ability to manage people, self-learning and teaching others, collaboration, active learning and listening, coordination, as well as emotional intelligence, assessment skills, negotiation, and independent decision--making (Marszycki, 2021).

The engineer of the future must be able to process and analyze large amounts of data from various sources, be able to do research in electronic media, skillfully use Big Data tools, be knowledgeable in agile project management. Employers will require engineers to have technical skills, such as following trends in Industry 4.0, knowledge of the Internet of Things (IoT), and technologies such as CbM, which enables machine condition monitoring. Furthermore, candidates with experience in implementing production process automation, process and device integration, cloud computing, and 3D printing will have a market advantage. Additionally, knowledge of DCS/SCADA control and monitoring systems is gaining importance (*10 kompetencji inżyniera przyszłości*, 2021).

At the same time, one can expect a progressive loosening of the relationship between the employee and the company, where career development and planning will be carried out independently of a specific company or even industry. People will increasingly focus on acquiring a certain set of skills and experience that they can use in different companies, independently steering their development and using career opportunities in the most flexible way possible. Working in a particular company will be an element of a personal, individualized plan, one of the stages allowing for the acquisition of desired skills, competence development, and gaining valuable experience, as well as expanding social and professional networks, whose role will grow. A pragmatic approach to such developmental added value of a company is particularly evident in the case of representatives of the younger generation, where questions about career paths, learning opportunities, etc., are among the most frequently asked by candidates during job interviews (Bajor et al., 2021).

4. INDUSTRIAL REVOLUTIONS WORLDWIDE AND IN EUROPE

- The First Industrial Revolution

This revolution took place at the turn of the 18th and 19th centuries and marked the transition from artisanal production to mechanized factory production. The invention of spinning machines, followed by the steam engine, which became the main source of power, significantly eased many previously labor-intensive jobs. These machines revolutionized work, having a huge impact on factories, mines, and transportation. A turning point was the substitution of coal with coke in metallurgy. The development of industry led to population influx into cities, which in turn led to dynamic city growth and urbanization. Cities became centers of industry, trade, and services, and inhabitants left villages to seek work in factories (Wodnicka, 2021).

- The Second Industrial Revolution

Dated to the 1870s, the most important inventions created and widely used during this period include the internal combustion engine and electrification. Other significant inventions that changed societal life include the widespread use of railways and telephone communication. Urbanization and city development continued, and the working classes grew in strength, leading to various social and political movements. The Second Industrial Revolution contributed to the globalization of the economy, with an increase in international trade and technology exchange between countries. This was also the period when new industries, such as the automotive and chemical industries, developed and continue to play a significant role in today's global economy (Sharma et al., 2020).

- The Third Industrial Revolution

In the late 1960s and early 1970s, engineers and scientists developed programmable controllers, which allowed for the programming and control of machines and production processes using a computer. This significant achievement marked the beginning of a revolution in the industry. Programmable controllers became the main tool for industrial automation. They replaced traditional mechanical control systems with electronic systems that could be programmed to perform various tasks. This increased production flexibility and efficiency and made it easier to adapt machines and processes to changing needs. As information technologies evolved in the 70's and 80's, the industry was able to use computers to monitor and control production processes in real-time. SCADA (Supervisory Control and Data Acquisition) systems became commonplace in plants, chemical industry, food industry, and many others. Automation and digital control of production processes contributed to increased efficiency, improved product quality, and cost reduction (Prisecaru, 2016).

❑ <u>The Fourth Industrial Revolution</u>

The Fourth Industrial Revolution is a current era based on advanced digital technologies and automation. It is a continuation of the Third Industrial Revolution, but with a greater emphasis on modern IT tools, such as the Internet of Things (IoT), artificial intelligence (AI), machine learning, data analytics, as well as augmented reality (AR) and virtual reality (VR). In the Fourth Industrial Revolution, devices, machines, products, and people are connected into a global network, enabling remote monitoring, control, and real-time data analysis. Artificial intelligence plays a key role in automation, process optimization, and data-driven decision-making. Large amounts of data generated by IoT systems are analyzed to detect patterns, make forecasts, and take strategic decisions. Digital models of factories, products, and processes are created, enabling virtual testing, optimization, and problem solving. Augmented reality (AR) and virtual reality (VR) are used to improve training, product design, maintenance, and many other aspects of industry. Automation and robotics continue to evolve, and people collaborate with technology. Sustainable development is an important goal, aiming to reduce the impact on the natural environment and use resources efficiently. The Fourth Industrial Revolution aims to create intelligent, flexible, and sustainable production systems that are more competitive in the global market (Furmanek, 2018).

❑ <u>The Fifth Industrial Revolution</u>

Industry 5.0 represents a new era of manufacturing characterized by the integration of advanced technologies and human creativity to create a more collaborative and flexible production environment. While Industry 4.0 focused on digitization, Industry 5.0 aims for a fuller integration of human workers into the production process, collaborating with machines to maximize productivity and quality. One of the key features of Industry 5.0 is humanization, sustainable development, and ecology. Instead of treating machines and humans as separate entities, Industry 5.0 seeks to create a production environment where workers and machines collaborate, utilizing their mutual strengths to achieve greater productivity and quality. This collaboration is made possible by advanced technologies such as collaborative robots, augmented and virtual reality, and live monitoring and feedback systems. Another important aspect of Industry 5.0 is a greater emphasis on human creativity and intuition. While Industry 4.0 introduced the concept of smart factories, Industry 5.0 goes a step further, using technology to help workers more fully express their ideas and designs. Technologies like virtual and augmented reality can help workers visualize and test new products and designs in a more immersive and interactive way, leading to greater innovation and creativity in the manufacturing process (Wolniak, 2023).

Table 2. Comparision of industrial revolutions

I revolution	**II revolution**	**III revolution**	**IV revolution**	**V revolution**
Steam propulsion in machinery and vehicles	The invention of assembly line electricity	Production automation using PLCs,	Information and communication technologies	**Developed technologies:** Artificial Intelligence (AI), Augmented Reality (AR), Virtual Reality (VR), Internet of Things (IoT), fully integrated into processes, Global digital supply chain
Human muscle work changed to machine work	**Inventions:** Gas engine, dynamite, telephone, light bulb, vacuum cleaner, electric	**Industrial software such as:** SCADA, ERP, MES, industrial robots	**Main pillars:** Internet of Things (IoT), Machine Intelligence	
Development of means of locomotion				

Source: Own elaboration based on (Wodnicka, 2021; Sharma, et al., 2020; Prisecaru, 2016; Furmanek, 2018; Wolniak, 2023).

5. CHARACTERISTICS OF ENGINEERS 3.0, 4.0 AND 5.0

Competence is a set of knowledge and experience, as well as appropriate personal skills and attitudes, that enable us to perform assigned functions. They show a cause-and-effect relationship with work efficiency and the results achieved while carrying out a specific task or situation. Characteristics that distinguish and define a person's competencies include self-perception, knowledge, practical skills, character traits, attitude, thought patterns (Ośmiałowska et al., 2022).

Engineer 3.0 operated according to strictly established norms and in accordance with specified procedures, felt anxious during changing situations, focused more on task execution than on the people around him, and was able to work in a team he already knew. They are meticulous individuals aiming to achieve set goals. Engineer 3.0 likes to work at their own pace and prefers independent work. In summary, they are very attentive, organized, courteous, methodical, and predictable (Płuska, 2017). According to the personality type profiling based on Hippocrates' principles, these traits best describe introverts: melancholics, who easily adapt to regulations at work and pay great attention to detail, and phlegmatics – professional and reliable in their work (Stoch, Gracel, 2017).

Engineer 4.0, like Engineer 3.0, possesses technical knowledge in their area of specialization and adheres to established norms and procedures. They are open and able to influence the people around them. They don't focus solely on their narrow specialization but understand concepts and ideas from other fields. They differ from Engineer 3.0 mainly in character traits related to communicativeness and readiness for rapid changes, and diversity in both tasks and interactions with other people. Engineer 4.0's duties are increasingly less about repetitive actions, which are replaced by machine work, and more often about optimization and ensuring safety. The ability to properly interpret facts, foresee upcoming events, and make quick decisions is very important (Stoch, Gracel, 2017).

Engineer 5.0 is a person strongly oriented towards advanced technologies and industrial innovations. They possess advanced technical knowledge and the ability to work in a dynamic digital environment. Their skills include analyzing large data sets and using technologies like the Internet of Things (IoT) and blockchain to solve complex industrial problems. Engineer 5.0 is also an expert in sustainable development and environmental care, which is crucial in an era where reducing environmental impact is a priority. Their interpersonal skills allow them to effectively collaborate in interdisciplinary teams, integrating diverse skills and knowledge. As a professional focused on innovation and creativity, Engineer 5.0 is capable of generating new ideas and approaches to industrial problems. They are flexible, ready for continuous learning, and adapting to changes in technology and industry. In the era of the Fifth Industrial Revolution, Engineer 5.0 plays a key role in shaping the technological and industrial future (Traczyk, 2021).

However, the similarities that exist between the three generations of engineers include: performing work perfectly from start to finish, adhering to norms, rules, procedures, and delivering high-quality services.

Key components of a reliable, contemporary engineer include their behavior, respect for others, and the value system they represent. Nowadays, increasing attention is paid to finding such characterized employees, despite the fact that it is becoming a more complicated process. Personality tests are increasingly used in workplaces to determine the personality types of employees, which allow for the examination of their strengths and weaknesses, predispositions, and verification of their skills. Character traits influence the predispositions of people to find themselves in the role of Engineers 4.0, fulfilling their specific requirements, and meeting the tasks set for them.

Thanks to developed interpersonal skills, a good engineer is characterized by the ability to analyze a large amount of data from various sources, assess how significant and reliable they are, as well as readiness for change and openness to other fields and people (Gracel et al., 2017). The differences between Engineers 3.0, 4.0 and 5.0 are shown in the table below:

Table 3. The differences between Engineers 3.0, 4.0 and 5.0

Engineer 3.0	Engineer 4.0	Engineer 5.0
Hard competencies	Soft competencies	Operates according to procedures and strict standards, but pays attention primarily to social responsibility
Concentration only on your field	Ability to combine different disciplines	Its communication is no longer focused only on humans, but also on technology, which is made possible by artificial intelligence
Job stability	Work flexibility	
Lack of variety in the work performed	Variety of work performed	
A person who does not like change	Person open to new tasks, situations	In addition to combining knowledge from various fields, it is particularly focused on sustainable and flexible project implementation
Working only in a known team	Ability to work in a group of new people	
Does not engage in human relations	Able to influence others	

Source: Own elaboration based on (Płuska, 2017; Stoch, Gracel, 2016; Traczyk, 2021; Gracel et al., 2017).

6. A SUBJECTIVE OVERVIEW OF THE TECHNICAL CHALLENGES FACING THE MODERN ENGINEER

A challenge is called a difficult task, a new situation that requires putting in effort and dedication to its implementation, which is a test of knowledge and resilience in the broadest sense ("Wyzwanie". *Słownik języka polskiego PWN*, n.d.).

In an era of rapid technological development, the engineer of the future faces extraordinary challenges, the solution of which will be shaped by the rapidly advancing technological evolution. We will take a look at the main challenges that engineers must face in order to effectively drive technological progress and create innovative solutions. In a world where the only constant is change, the engineer of the future becomes not only a technical expert, but also a strategist, ethicist and leader, ready to meet the demands of a dynamic and unpredictable technological landscape. Engineers face numerous challenges that require innovative approaches and adaptability.

- Complexity of systems

The complexity of engineering systems manifests itself on many levels. Engineers must deal with a diversity of technologies, protocols and standards. For example, the growth of the Internet of Things (IoT) is making systems increasingly decentralized, consisting of distributed devices communicating with each other. The challenge is not only to communicate effectively between the various components of the system, but also to ensure secure and reliable data transfer. As a result, engineers must not only deal with the overall complexity of engineering systems, but also with the unique challenges posed by domain-specific specifications, such as the development of IoT technologies. In pursuit of these goals, flexibility of thinking becomes a key element, allowing engineers to effectively deal with differences and collectively shape the future of technological progress. Interoperability is becoming a key challenge. System components often come from different vendors, which can result in diverse communication protocols and data formats. Engineers must implement interfaces to enable communication between these heterogeneous components. Standards such as OPC-UA (Unified Architecture) and MQTT (Message Queuing Telemetry Transport) are examples of attempts to standardize communications in industry, but their effectiveness depends on their widespread use.

The use of advanced algorithms and artificial intelligence introduces an additional layer of complexity. Engineers must not only implement these technologies, but also understand how they work, adapt them to specific applications and manage data, which is a key element for the effectiveness of many AI algorithms. In addition, ethics and data security issues are becoming increasingly important, requiring engineers to thoughtfully design systems for privacy and information protection. In terms of complexity, energy management is becoming a key challenge, especially for embedded systems such as IoT devices and sensors. Energy efficiency becomes a priority, and engineers must adapt to power constraints while maintaining high system performance (Dao et al., 2023).

Finally, cyber security is inherent in the complexity of systems. As the number of inter-device connections increases, so does the potential threat to data security. Engineers must design systems with security in mind with security in mind, using encryption, authentication and other defense mechanisms to effectively protect the system from attacks (Elgnar et al., 2022).

- ❑ Rapid technological progress

Never before has the pace of technological progress been as intense as it is today. The engineer of the future must be ready to constantly improve his or her skills and quickly adopt new technologies. Keeping in mind that what is on the cutting edge today may be obsolete tomorrow, engineers must be ready to continuously learn and adapt to change. In recent decades, we have seen extremely intense technological progress, unparalleled in any historical period. In view of this, engineers of the future must be constantly engaged in the process of improving their skills and rapidly adopting new technologies. Due to the dynamic nature of this development, even today's most modern solutions can quickly become obsolete. As a result, engineers are required to be flexible, always ready to adapt immediately to evolving technological conditions. The awareness that what is now considered the latest development may be obsolete in the near future prompts engineers to keep an open mind and constant readiness for a process of continuous education to meet the demands of the accelerated pace of technological progress (Elgnar et al., 2022).

- ❑ Ethics in technology

The development of technology also brings new ethical challenges. The engineer of the future must be aware of the impact of his work on society and the environment. Finding a balance between technological progress and ethical implications becomes an integral part of the work of the engineer of the future. Technological progress, despite its benefits, generates new ethical aspects that require attention. The engineer of the future is required to consciously understand the impact of his work on society and the environment. Issues related to privacy, artificial intelligence and work automation place engineers in the role of moral decision-makers. Finding harmony between technological advances and ethical implications is becoming an integral aspect of the engineering profession of the future (Elgnar et al., 2022).

- Sustainability

In the context of climate change, the role of engineers is becoming crucial in the search for solutions that promote sustainable development. The need to reduce the negative impact of technology on the environment challenges them to develop innovative, ecosystem-friendly solutions. The engineer of the future should pay attention not only to the functionality of his designs, but also to their impact on the planet. In the perspective of climate change, engineers are key in the search for sustainable solutions. Faced with the need to reduce the negative impact of technology on the environment, they are faced with the task of developing innovative green solutions. The engineer of the future must be aware not only of the functionality of his designs, but also of their impact on the planet. Adopting a sustainability perspective becomes an indispensable part of an engineer's profession, which seeks to minimize negative environmental effects in the process of developing technological solutions (Philbin, 2021).

- Cyber security

With an increasing number of systems and devices integrating with the network, cyber security challenges are becoming more significant. Engineers are required to develop attack-resistant systems that not only protect data, but also ensure the security of infrastructure from potential cyber threats. The need to monitor, detect and neutralize potential attacks requires engineers to constantly update and optimize security to effectively counter increasingly sophisticated cyberattack techniques. In this context, engineers play a key role in developing solutions that not only repel current threats, but also anticipate future cyber security challenges (Gupta et al., 2019).

- Big Data and data analytics

Large amounts of data generated by various systems and devices require advanced data analysis techniques to transform information into valuable business conclusions and decisions. There are publications in the literature devoted to the use of "Data Mining" tools for the purpose of finding not only ready-made technical and technological solutions, but also inspiration for research searches and undertaking relevant R&D work (Kaźmierczak, 2016).

- Autonomy and Artificial Intelligence

In the quest to improve autonomous systems, engineers are faced with the task of not only implementing but also continuously improving advanced machine learning algorithms. Machine learning algorithms are a key component, allowing autonomous systems to adapt to a changing environment and make intelligent decisions. Engineers must not only create these algorithms, but also adapt them to a variety of situations, which requires constant monitoring, data analysis and software updates. In the area of artificial intelligence, engineers must explore not only traditional methods, but also modern approaches such as deep neural networks and natural language processing techniques. These advanced technologies enable autonomous systems to better understand their surroundings, resulting in more efficient operation in various situations. In addition, safety aspects are becoming a priority in the context of autonomous systems. Engineers must not only ensure the effectiveness and efficiency of the system, but also its reliability and resistance to possible attacks or failures. Creating autonomous systems is therefore a complex challenge that requires engineers not only to be technically proficient, but also to be able to anticipate and manage potential risks (Karim et al., 2023).

❑ Internet of Things (IoT)

The development of Internet of Things technology opens up new opportunities but brings with it a number of challenges. IoT enables devices to communicate and collect data in real time, significantly contributing to advances in fields such as medicine, industry, transportation and many others. Industry 4.0 engineers must effectively implement the Internet of Things, which allows real-time data collection, monitoring and control of industrial processes. In addition, scalability is becoming a key aspect, as engineers must ensure that industrial networks can support a growing number of devices. Managing and analyzing massive amounts of data poses another challenge, requiring engineers to develop efficient information processing tools. The introduction of Industry 4.0 also involves adapting to the changing regulations and standards governing the field. Industry 4.0 engineers must stay abreast of with technological innovations and adapt to the evolving industrial landscape (Gupta et al., 2019).

❑ Complexity of projects

Today's engineering projects are increasingly complex, requiring an understanding of multiple technical disciplines and the ability to manage a team of experts, as engineering projects, challenging the engineer 4.0 with increasing technological complexity, require an interdisciplinary approach. The engineer of the future must effectively combine different technical disciplines, managing a team of experts with diverse competencies. A key skill is the ability to communicate and mediate, translating complex concepts into understandable language. In addition, an engineer 4.0 must be flexible, ready for continuous improvement and the rapid acquisition of new skills to meet the dynamic changes of the in technology and the market. Ultimately, the 4.0 engineer plays a key role in technological development, integrating different disciplines and creating innovative solutions (Cabała [red.], 2018).

❑ Education and professional development

Engineers must invest in continuous education and development of their skills to meet the tasks presented to them. In considering the potential new directions of consideration arising from the proposed view of the engineer, who performs tasks as part of the process of meeting needs, we should undoubtedly look at the modern engineer more broadly than the traditional view associated strongly with the history of the development of technology, including so-called technical progress. Considerations so far have been limited to the relationship of the modern engineer with the world of technology. The engineer in the 21st century, for many reasons, must go beyond the standard activities in which technical progress was practically the exclusive task of his predecessors (Cabała [red.], 2018).

7. A SUBJECTIVE OVERVIEW OF THE NON-TECHNICAL CHALLENGES FACING THE MODERN ENGINEER

In today's engineering world, in addition to the technical aspects, the engineer of the future must confront ever-evolving non-technical challenges. In a social, economic and ethical context, there are issues that go beyond the purely technological realm and affect the way engineers shape the world. In the most simplistic terms, analyzing the history of technology, we can assume that the first "non-technical" aspects of the development of technology became considerations of an economic and social. Another aspect that emerged as needing to be taken into account and taken into account in engineering works, were the widely understood connections (relations) of technosphere elements with the environment. In modern reality, all of the aforementioned non-technical aspects are present, although both the perception of them and the relations linking them to engineering activities are changing (Cabała [red.], 2018).

- Interdisciplinary communication

Modern engineering projects bring complex challenges, combining technological aspects with social sciences. The key to their success is effective communication between specialists with diverse backgrounds. The engineer of the future often referred to as "Engineer 4.0," is an expert who not only excels in technical aspects, but also easily combines them with social issues. His work requires working with a variety of specialists, understanding the interrelationships between different disciplines, and adapting projects to diverse cultural contexts. He is not only an excellent communicator, but also a mediator capable of translating intricate technical issues into a language that can be understood by different audiences. In addition, he acts as a manager of a diverse team, building bridges between theory and practice for the successful implementation of innovations. His integral figure in the engineering landscape brings a holistic view to projects, supporting social, economic and technological development. The capabilities of an engineer 4.0 should combine science with practice and incorporate diverse perspectives with the creation of coherent, interdisciplinary solutions. This combination puts him at the heart of modern technological progress. This approach not only integrates different fields of technology, but also society in a continuous process of development (Cabała [red.], 2018).

- Managing a multicultural team

Nowadays, thanks to the possibilities of network communication, team members are often geographically and culturally dispersed, and inter-country relocations for contacts and international experience are becoming an everyday occurrence. As a result, it becomes a potential challenge to effectively manage multicultural teams, taking into account language differences, work habits and cultural expectations. The engineer of the future must excel not only in dealing with technical diversity, but also with a wealth of different perspectives and experiences. Therefore, managing a multicultural team in the context of engineering projects is becoming a key aspect of the in today's global business environment. The 4.0 engineer must excel at managing not only technical diversity, but also the wealth of different perspectives and cultural experiences in order to effectively use diversity as a source of creativity and global perspective. This is not only a challenge, but also a huge opportunity to create projects with even greater potential and relevance on a global scale (Cabała [red.], 2018).

- Ethics and social responsibility

Engineer 4.0, as technology becomes an integral part of society, must incorporate ethics, social, environmental and economic aspects into projects. He must take care ethics of projects, minimize negative impacts on people and the environment, and take responsibility for his actions. In addition, engineers must take into account the needs of society, engage in dialogue with various stakeholder groups and balance the benefits and costs of projects. Environmental aspects are becoming increasingly important, so sustainable design and production are key. Engineers should promote environmentally friendly technologies and minimize consumption of natural resources. The economic value of projects is also important, so engineers must balance short-term profit with long-term sustainability. In addition, continuous development and the ability to work in interdisciplinary teams are key. As a result, an engineer 4.0 integrates these aspects to create effective, responsible and sustainable solutions, promoting technological progress and social progress (Cabała [red.], 2018).

- Adaptability and self-education

The engineer of the future must have the ability to continuously self-educate and adapt. This is crucial in a dynamic engineering environment where technological change is inevitable. The ability to be flexible and ready to quickly learn new skills and adapt in the face of changing situations both within the company and in the marketplace is becoming crucial. But equally important is dealing with the uncertainty that accompanies innovation. An engineer must be willing to experiment, solve problems and take risks in the process of developing new technologies. Self-learning is a process that never ends, making Engineer 4.0 always strive to improve and update his knowledge. This is a key element for success in the modern engineering environment (Michael Page Poland, 2022).

8. CHANGING ENGINEERING COMPETENCIES AND EMERGING ENGINEERING POSITIONS IN THE INDUSTRY 4.0

With the rapid development of technology, the industry is evolving, going through various stages of transformation. We are now in the era of Industry 4.0, characterized by the full integration of digital technologies, the Internet of Things (IoT) and other innovative solutions. This phenomenon brings new challenges, especially for engineers who must adapt to increasingly advanced technologies. This chapter focuses attention on the changing competencies of engineers and the new engineering positions that are emigrating in the face of industrial change. Traditional engineering skills, such as knowledge of materials, construction and knowledge of manufacturing processes, are the foundation of the engineer's 3.0 competencies. Taking a percentage perspective, it can be said that these traditional competencies accounted for about 70% of engineering skills in the Industry 3.0 era. In the Industry 4.0 era, these traditional competencies are still key, but their percentage is decreasing in favor of new requirements. Knowledge of materials, design and manufacturing processes now make up about 50% of an engineer 4.0's competencies, with the remaining 50% comprising skills in information technology, data analysis and project management. Engineers 4.0 must be more oriented toward interdisciplinarity and flexibility in adapting to rapidly changing technologies. The Industry 4.0 era has seen the emergence of new specialized engineering positions, some of which had no equivalent in previous eras. “Data Engineer” (Data Engineer) and “Internet of Things Engineer” (Internet of Things Engineer) are examples of new professions that are shaping up as technology advances. The Data Engineer, dealing with the management of large amounts of data, represents about 15% of the new engineering ethos in the era of Industry 4.0. Internet of Things Engineers, specializing in the design of IoT-based systems, represent another 15% of the new competence structure. “Artificial Intelligence Engineer” (AI) shapes the remaining 20%, while serving as a link between traditional and new engineering skills (Piwowar-Sulej, 2022; Furmanek, 2018).

The charts below show the proportions of competencies that 3.0 engineers have in various positions:

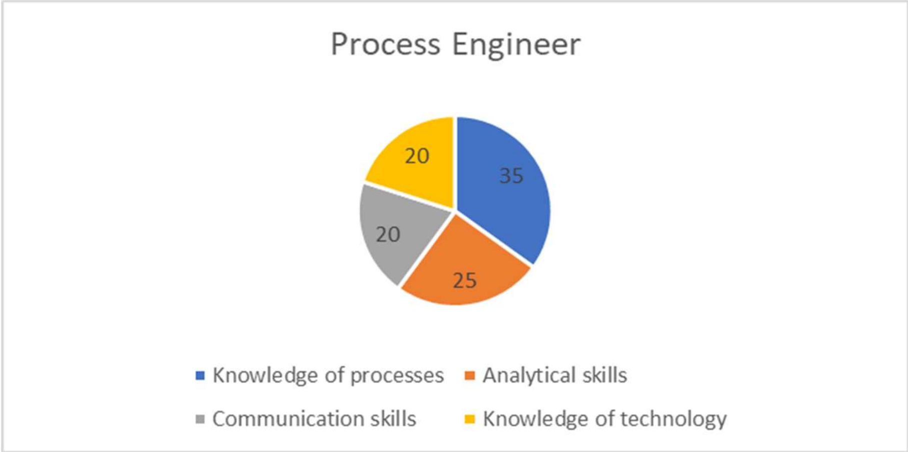

Figure 1. Process engineer skills

Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

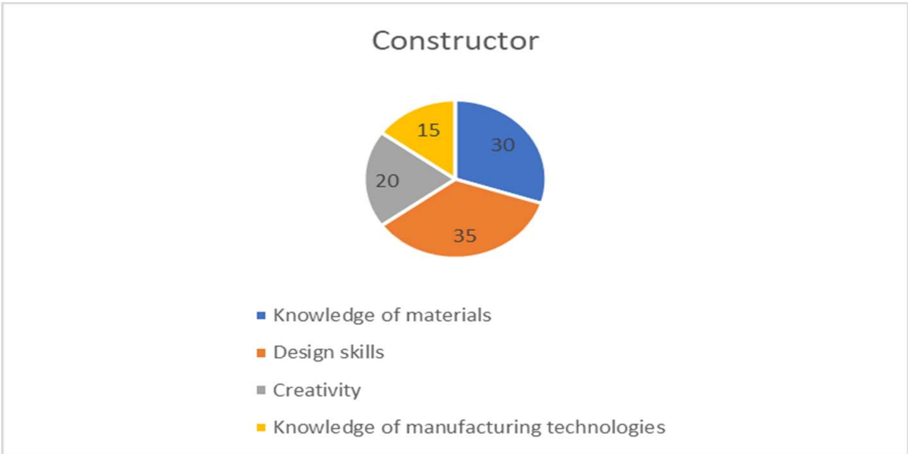

Figure 2. Constructor skills

Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

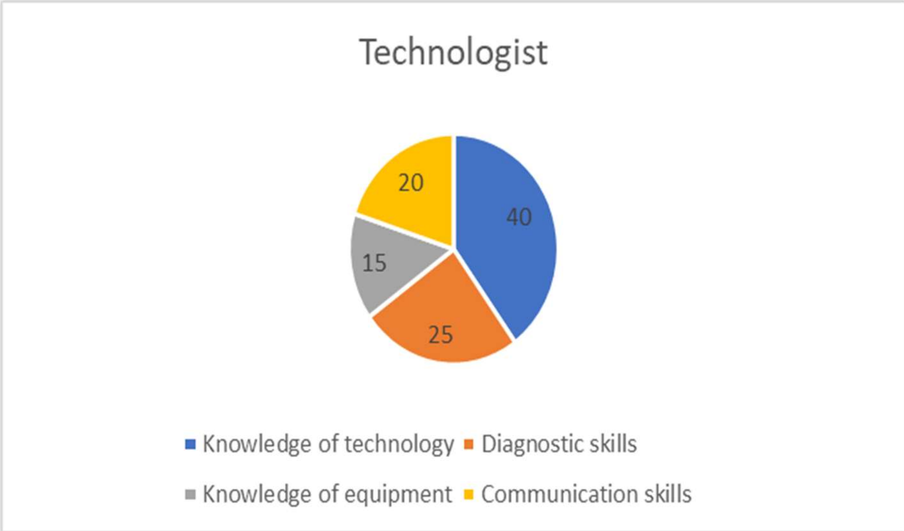

Figure 3. Technologist skills
Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

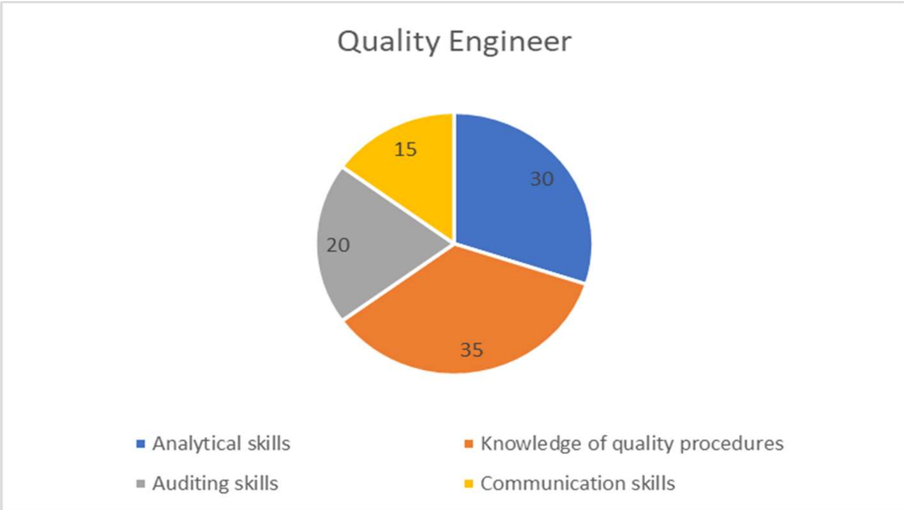

Figure 4. Quality engineer skills
Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

The charts below show the proportions of competencies that 4.0 engineers have in various positions:

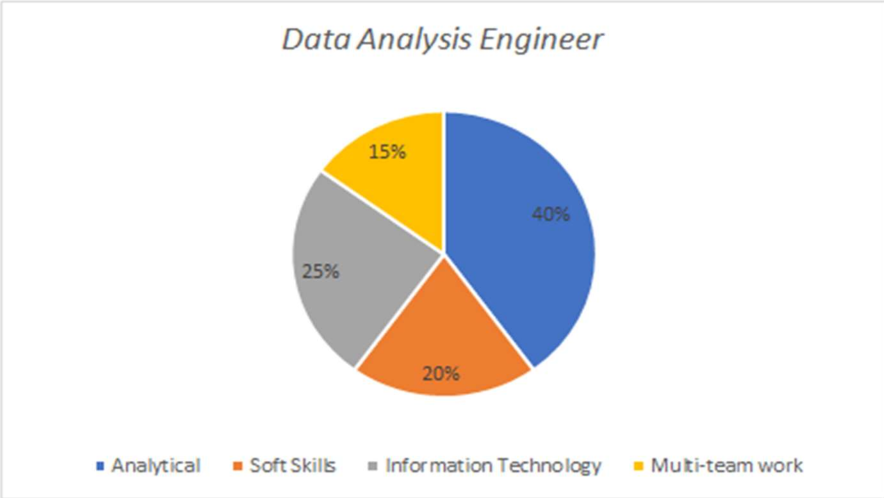

Figure 5. Data analysis engineer skills
Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

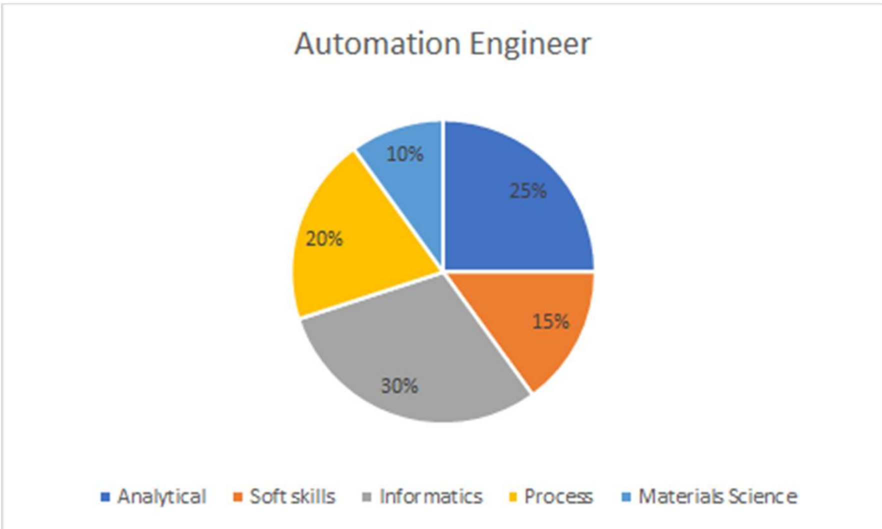

Figure 6. Automation engineer skills
Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

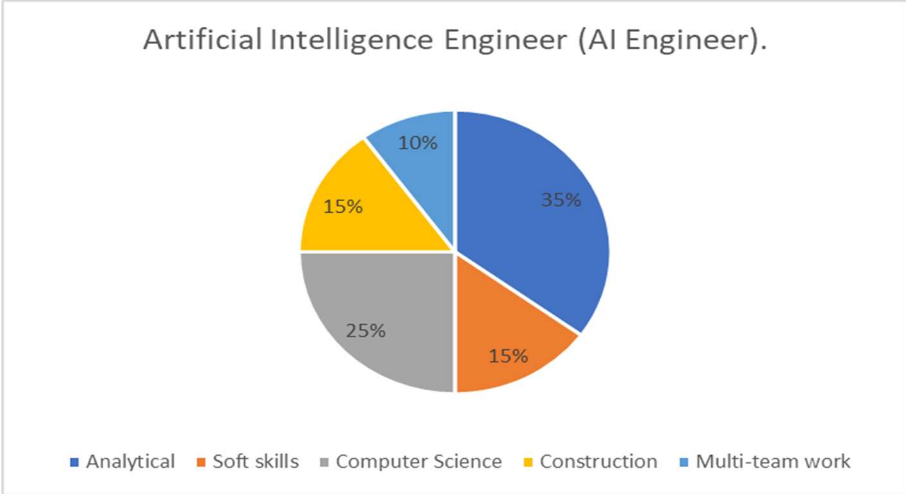

Figure 7. Artificial Intelligence (AI) engineer skills

Source: Own elaboration based on (Piwowar-Sulej, 2022; Furmanek, 2018).

The changing competencies of engineers and emerging new positions are a natural consequence of technological advances. In the era of Industry 4.0, engineers must continually develop their skills to meet the challenges of this dynamic space. Traditional engineering skills, such as knowledge of materials, construction and manufacturing processes, were the foundation of the engineer 3.0 competencies. However, on the road to Industry 4.0, the proportion of these traditional competencies has changed. Technical knowledge remains important but is no longer sufficient. The changing competencies of Engineers 4.0 can be traced by analyzing the new skill proportions. In an era where data analytics and artificial intelligence are becoming integral parts of an engineer's job, analytical and IT skills are gaining a dominant role. Today's Data Engineer, who manages massive amounts of information, or Artificial Intelligence Engineer, who designs and implements machine learning algorithms, are the new faces of Engineering 4.0. The skill proportions for these professionals reflect a shift in priorities, where analytical skills are outpacing traditional technical areas. Understanding the social, economic and ethical aspects of new technologies is becoming as important as technical expertise itself. Engineers 4.0 must not only be specialists in their fields, but also leaders, able to lead change and adapt to new challenges. Ultimately, their ability to adapt and innovative thinking is the key to success in the era of Industry 4.0, where innovation is becoming a key component of industrial development (Furmanek, 2018).

9. SUMMARY

In conclusion, this article sheds light on the need for an evolution in thinking about engineering and engineers. This requires changes in theory and practice to prepare professionals capable of working in a rapidly changing, technologically advanced world, while maintaining the social and ethical responsibility necessary in the era of Industry 4.0. It should be emphasized that the dynamic technological changes occurring within the framework of rapidly developing technologies imply significant transformations in the role of the engineer. The challenges posed by the modern era require not only a continuous expansion of technical competence, but also adaptability, interdisciplinarity and the ability to solve complex problems. The engineer of the future must be prepared to work in a constantly advancing and changing technological environment, which involves the need for continuous learning and improvement. In addition, the ethical and social aspects of technological development are becoming as important as engineering progress itself. In the face of these changes, engineers must demonstrate not only expertise, but also soft skills such as teamwork, communication and creativity. These are key competencies that allow them to function effectively in the complex engineering systems that are characteristic of Industry 4.0. Consequently, an interdisciplinary engineer is a figure who not only reacts to change, but actively participates in shaping the technological future, contributing to innovation and creating responsible solutions to global challenges.

REFERENCES

Bajor, A., Bąk, K., Brzezińska, B., Brzozowski, M. et al. (2021) [In:] Pollak, A., Ozubko, A., red., *Przedsiębiorstwo 4.0, 360°: rekomendacje dobrych praktyk.* Warszawa: Polsko--Niemiecka Izba Przemysłowo-Handlowa.

Cabała, P., red. (2018). *Zarządzanie portfelem projektów w organizacji: Koncepcje i kierunki badań.* Kraków: Mfiles.pl.

Dao, N.-N., Thinh, T.N., Nguyen, N.T. (2023). *Intelligence of Things: Technologies and Applications. "Springer Nature Switzerland".* DOI: 10.1007/978-3-031-46749-3.

Elngar, A., Nadesan, T., Elhoseny, M., Sagayam, M. (2022). *Cyber Security and Operations Management for Industry 4.0.* CRC Press LLC. DOI: 10.1201/9781003212201.

Furmanek, W. (2018). *Najważniejsze idee czwartej rewolucji przemysłowej (Industrie 4.0). „Dydaktyka Informatyki"*, No. 13. DOI: 10.15584/di.2018.13.8.

Gracel, J., Stoch, M., Biegańska, A., Rząca, A. (2017). *Inżynierowie 4.0. (Nie) gotowi do zmian?* DOI: 10.13140/RG.2.2.11530.77769.

Górska-Rożej, K. (2014). *Identyfikacja składowych kompetencji w kontekście efektywnego zarządzania kompetencjami. „Obronność – Zeszyty Naukowe Wydziału Zarządzania i Dowodzenia Akademii Obrony Narodowej"*, Vol. 2, No. 10.

Gupta, S., Banerjee, I., Bhattacharyya, S. (2019). *Big Data Security*. Berlin, Boston: De Gruyter. DOI: 10.1515/9783110606058.

Kaźmierczak, J. (2016). *Inżynier XXI wieku w wymiarze nie tylko technicznym. „Zeszyty Naukowe. Organizacja i Zarządzanie"*, Politechnika Śląska, No. 99.

Karim, R., Galar, D., Kumar, U. (2023). *AI Factory: Theories, Applications and Case Studies*. Boca Raton: CRC Press. DOI: 10.1201/9781003208686

Kompetencja (n.d.). *Słownik języka polskiego PWN* [Access: 16.11.2023]. Access on the internet: https://sjp.pwn.pl/sjpkompetencja;2564077.html.

Kompetencja (n.d.). *Synonimy.pl* [access: 16.11.2023]. Access on the internet: https://www.synonimy.pl/synonim/kompetencja/.

Kompetentny (n.d.). *Synonimy.pl* [Access: 16.11.2023]. Access on the internet: https://www.synonimy.pl/synonim/kompetentny/.

Marszycki, M. (2021). *Jakie kompetencje powinien posiadać inżynier przyszłości?* ITwiz. [Access: 16.11.2023]. Access on the internet: https://itwiz.pl/jakie-kompetencje-powinien-posiadac-inzynier-przyszlosci/.

Nandunkar, K., Mhasde, C., Shahabadkar, P.K. (2016). *Enhancing placement opportunities for engineering graduates: A case study.* 45th ISTE National Convention and International

Conference at Amravati [Access: 16.11.2023]. Access on the internet: https://journaleet.in/articles/enhancing-employability-skills-and-placements-in-technical-institutes--a-case-study.

Ośmiałowska, L., Ullman, P., Kiljan, A., Jonda, E. (2022). *Różnice osobowościowe pomiędzy inżynierem 3.0 oraz 4.0.* [In:] Bonek, M., ed., *TalentDetector2022_Summer*: Międzynarodowa Studencka Konferencja Naukowa, Gliwice, 13 czerwca 2022.

Philbin, S. (2021). *Driving sustainability through engineering management and systems engineering. "Sustainability"*, Vol. 13, No. 12. DOI: 10.3390/su13126687.

Piwowar-Sulej, K. (2022). *Zrównoważony rozwój personelu poprzez szkolenia.* Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu.

Płuska, K. (2017). *Cztery typy osobowości wg Hipokratesa – którym jesteś? + Test*. Miękko o kompetencjach by Katarzyna Płuska [Access: 16.11.2023]. Access on the internet: https://www.katarzynapluska.pl/cztery-typy-osobowosci-wg-hipokratesa-ktorym-jestes-test/

Prisecaru, P. (2016). *Challenges of the fourth industrial revolution. "Knowledge Horizons-Economics"*, Vol. 8, No. 1.

Roczniak, B. (2017). *Rola testów psychometrycznych w procesie rekrutacji.* Inforakademia [Access: 16.11.2023]. Access on the internet: https://akademia.infor.pl/kurs/FOB0000000000000753062,rola-testow-psychometrycznych-w-procesie-rekrutacji.html.

Sharma, A., Singh, B.J. (2020). *Evolution of Industrial Revolutions: A Review. "International Journal of Innovative Technology and Exploring Engineering"*, Vol. 9, No. 11. DOI: 10.35940/ijitee.I7144.0991120.

Stoch, M., Gracel, J. (2016). *Inżynierowie przemysłu 4.0: jak ich rozwijać?* Warszawa: ICAN Institute.

Strelau, J. (1985). *Temperament, osobowość, działanie*. Warszawa: Państwowe Wydawnictwo Naukowe.

Szkop, K. (2012). *Trafność metod doboru personelu wykorzystywanych w przedsiębiorstwach* [In:] Gregorczyk, A., ed., *Procesy decyzyjne w warunkach niepewności*. Warszawa: Wyższa Szkoła Promocji.

Traczyk, W. (2021). *Jaki będzie inżynier w Przemyśle 4.0?* Elektrotechnik AUTOMATYK [Access: 16.11.2023]. Access on the internet: https://elektrotechnikautomatyk.pl/artykuly/jaki-bedzie-inzynier-w-przemyśle-4-0

Wolniak, R. (2023). *Industry 5.0 – characteristic, main principles, advantages and disadvantages. "Scientific Papers of Silesian University of Technology – Organization and Management Series"*, No. 170. DOI: 10.29119/1641-3466.2023.170.40.

Wodnicka, M. (2021). *Wpływ czwartej rewolucji przemysłowej na innowacyjność usług. „Optimum. Economic Studies"*, Vol. 3, No. 105. DOI: 10.15290/oes.2021.03.105.04.

Wyzwanie (n.d.). *Słownik języka polskiego PWN* [Access: 16.11.2023]. Access on the internet: https://sjp.pwn.pl/sjp/wyzwanie;2541345.html.

Zdrojewski, E., Gajewski, D. (2009). *Koncepcje osobowościowe i ich zastosowanie w procesie naboru pracowników. „Zeszyty Naukowe Wydziału Nauk Ekonomicznych Politechniki Koszalińskiej"*, Vol. 1, No. 13.

Zimnowłocka-Łozyk, E. (2011). *Testy psychologiczne jako narzędzie skutecznego procesu rekrutacyjnego* [In:] Urbaniak, B., ed., *Efektywność zarządzania zasobami ludzkimi*. Łódź: Wydawnictwo Uniwersytetu Łódzkiego. DOI: 10.18778/7525-546-1.34.

10 kluczowych umiejętności w branży inżynierii i produkcji (2022). Michael Page Poland [Access: 16.11.2023]. Access on the internet: https://www.michaelpage.pl/advice/poradydla-pracodawców/rekrutacja-i-selekcja/10-kluczowych-umiejętności-w-branży-inżynierii.

10 kompetencji inżyniera przyszłości. Zobacz, jak zrobić karierę w przemyśle i na produkcji (2021). Strefa Biznesu [Access: 16.11.2023]. Access on the internet: https://strefabiznesu.pl/10-kompetencji-inzyniera-przyszlosci-zobacz-jak-zrobic-kariere-w-przemysle-i-na-produkcji/ar/c10-15485328.