SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 174

ANALYSIS OF QUALIFICATIONS IN VOCATIONAL SECONDARY SCHOOLS IN THE ASPECTS OF INDUSTRY 4.0 DEVELOPMENT

Michał ZASADZIEŃ

Silesian University of Technology, Faculty of Organization and Management, Department of Economics and Informatics; michal.zasadzien@polsl.pl, ORCID: 0000-0002-3181-9815

Purpose: The paper presented here was intended to describe the extent to which secondary technical education in Poland is oriented towards the acquisition of qualifications needed in modern factories in line with the Industry 4.0 concept.
Design/methodology/approach: The study was conducted by analysing information contained in the Ministry of Education and Science's classification of vocational education professions and in the core curriculum for vocational education professions. The professions analysed were those which, according to literature research, are the most desirable in an industry based on the concept of Industry 4.0. Information contained on the websites of selected schools was also analysed.
Findings: As a result of the analysis carried out, it was found that the knowledge describing the qualifications of future technical staff in terms of Industry 4.0 is insufficient or even negligible. The core curricula do not require teachers in technical schools to address issues related to the concept of Industry 4.0. A lack of concepts related to Industry 4.0 in both the learning objectives and outcomes and professional qualifications was identified.
Research limitations/implications: The research concerned only the professions taught in Poland in 5-year technical schools on the base of the primary school. Comparison of the studied aspects in other countries, e.g. the European Union, is difficult and requires more in-depth research. This is due to the diversity of systems of secondary technical education in individual countries and the non-uniform form of curricula.
Practical implications: Several important conclusions emerge from the study. First and foremost, it should be emphasised that Polish schools do not prepare students studying in them for the phenomenon of dynamic development of manufacturing techniques represented by the idea of Industry 4.0. Graduates are not familiar with the assumptions, opportunities and threats related to it. Even if the substantive preparation of school graduates meets the requirements and expectations of Industry 4.0, schools do not promote this fact among potential candidates.
Originality/value: The paper presents the state of qualification requirements in Polish secondary technical schools in the context of the development of manufacturing techniques associated with the concept of Industry 4.0. It answers the question of whether and to what extent curricula and professional qualifications contain requirements concerning knowledge of Industry 4.0? The results of the study may be an element in the discussion on the condition of Polish vocational education in the context of requirements for employees in modern factories.

Keywords: industry 4.0, smart factory, education, technical school, qualification.

Category of the paper: research paper.

1. Introduction

One of the most important characteristics of modern companies is innovation. Nowadays, in order to succeed in the market, a company must be able to respond quickly to the changing needs of customers and the dynamic market. Innovation is a key element that allows companies to continuously improve their products and services, as well as to introduce new technological solutions and working methods.

Business innovation is the ability to introduce new solutions and ideas to improve business processes, improve the quality of products or services, increase efficiency and competitiveness in the market. The introduction of innovative ideas and projects can concern many areas of the enterprise, such as technology, marketing, work organisation, production or services.

Innovative companies also strive to continuously improve their products and services in order to meet the changing needs of customers and to adapt to and even dictate changing market trends. By doing so, they are able to increase their profits, gain new customers and build and maintain their position in the market.

In modern, innovative factories, the role of the worker is changing and their tasks are becoming more complex and demanding. Operators often operate sophisticated machinery and equipment, and their work involves monitoring production processes and controlling product quality. This requires them to have high technical qualifications and the ability to operate modern IT systems. At the same time, employees must be flexible and ready to adapt quickly to changing production conditions. The ability to work as part of a team and the readiness to continuously improve their qualifications are also important.

The literature on the subject comprehensively describes the assumptions of Industry 4.0. The changes in the organisation of work, the value chain and the technologies used in modern factories and the associated requirements for future employees are well known. Both engineers, managers and technicians. However, it was found that there is a lack of research answering the question to what extent modern technical education has responded to the challenges posed by the fourth industrial revolution. This analysis, as well as the author's previous study (Zasadin, 2022), seeks to fill this research gap.

The main objective of the analysis is to answer the question to what extent the assumptions of the concept of Industry 4.0 as an intelligent factory of the future are present in Polish secondary technical education? In order to achieve the main objective, two intermediate objectives were defined:

- to identify and characterise the information on Industry 4.0 found in the core curriculum for secondary schools published by the Ministries of Education and Science, and
- to identify and characterise information on Industry 4.0 found on the websites of selected secondary technical schools.

The objectives of the study will be realised through a critical analysis of the information contained in the analysed sources.

2. Literature review

With the rapid development of technology, innovation is a key element for businesses. Companies that are able to innovate are more competitive and more likely to succeed in the market. Investment in research and development, recruitment of highly competent employees and openness to new ideas and approaches to business are important elements that enable companies to achieve innovation (Schwab, 2016).

Companies that combine innovation with the concept of Industry 4.0 are able to achieve much greater benefits than those that operate traditionally (Liao et al., 2017; Zezulka et al., 2016). The main benefits from implementing the Industry 4.0 concept are cited as:

1. Increased production efficiency, optimisation and quality - thanks to the use of automation, robotics, artificial intelligence and the Internet of Things, it is possible to detect and eliminate production errors in real time, as well as to increase production speed and precision. Continuous monitoring of production processes and data analysis to identify and eliminate the causes of failures, reduce machine downtime, make better use of raw materials and energy, and optimise logistics processes (Broy, 2010; Holub, Hammer, 2017).
2. Reduced time to react to market changes and increased production flexibility - thanks to the ability to analyse and interpret data, Industry 4.0 enables a rapid response to changing market needs and also allows innovations to be brought to market more quickly. Thanks to intelligent production systems, Industry 4.0 enables on-demand production with minimal delays and changes in production processes (Kamiński, 2018; Wang et al., 2017).
3. Increase worker safety - the use of robotisation and automation of production processes reduces the risk of occupational accidents and allows robots to perform dangerous and harmful tasks (Forcina, Falcone, 2021).
4. Optimisation of production costs - Industry 4.0 allows a better use of resources, a reduction in waste and wastage of raw materials, as well as an increase in production efficiency, which translates directly into a reduction in manufacturing costs (Rosin et al., 2020).

Innovation and Industry 4.0 are closely linked through, among other things, the use of modern technologies (Alcácer, Cruz-Machado, 2019; Gajek et al., 2022; Pereira, Romero, 2017; Wortmann, Flüchter, 2015). Among the most important revolutionary technological changes, the authors mainly mention:

- the digital integration of production systems with IT systems, which enables better control over the entire production process,
- automation of production processes, which speeds up production and reduces the risk of errors,

- personalisation of products according to individual customer needs through, for example, the use of 3D printing or digitisation of design and production processes,
- artificial intelligence and machine learning - enabling automatic analysis and processing of data, which speeds up and improves production processes,
- augmented reality - enabling the creation of interactive and integrated environments in which people and machines 'work' together,
- the Internet of Things (IoT) enabling real-time monitoring of production processes from anywhere on Earth, making it possible, for example, to react quickly to problems,
- big data technologies enabling the storage, processing and analysis of the vast amounts of data generated by production processes and IoT systems,
- ecological and sustainable production.

Industry 4.0, associated with the introduction of advanced technologies and innovative solutions, places new demands on employees (Wiśniewska-Sałek, Aneta Broniszewska, 2021). Employees must be flexible and ready to adapt to changing working conditions. Industry 4.0 is characterised by rapid technological development and dynamic production processes. Employees should therefore be open to new technologies and ready to learn new skills to function effectively in this environment (de Assis Dornelles et al., 2022). Closely related to this is also the requirement for continuous improvement. In Industry 4.0, innovation and technological advances are inherent. Employees should be open to continuous improvement of their skills, both technical and communication (Morrar et al., 2017; Wróbel-Lachowska et al., 2018). They can attend trainings, courses, conferences and gain knowledge about the latest technologies and trends in the industry. They should also be characterised by creativity and innovation. Technologies such as artificial intelligence, automation and robotics open up new possibilities that can be used to improve production processes and solve problems efficiently. Employees should be willing to think outside the box and take risks in finding new ways to increase productivity, improve quality and create innovative products. They should also have a solid understanding of modern technologies such as artificial intelligence, robotics, Internet of Things, data analytics, etc. They should be able to use these technologies in their work and realise their potential and benefits for production processes. Along with new technologies comes the ability to work with data. Industry 4.0 generates huge amounts of data, which is a valuable source of information. Employees should be able to collect, analyse and interpret data in order to make informed business decisions. Understanding data analysis and being able to use analytical tools are extremely important (Benesova, Tupa, 2017).

Additionally, employees in Industry 4.0 should be able to work in teams, as the integration of different technologies and processes requires the collaboration of many specialists. The ability to communicate, collaborate and problem-solve effectively in a group is crucial for success (Wolf et al., 2018).

It is also worth emphasising that employees in should have an awareness of sustainability and social responsibility. Industry 4.0 seeks to minimise environmental impact and promote sustainable practices. Employees should be aware of these issues and strive to implement solutions that take environmental and social aspects into account (Kamble et al., 2018; Buhr, 2015).

In Industry 4.0, technicians play a key role in maintaining, configuring, programming and operating the advanced technologies used in manufacturing processes. Their technical skills, knowledge and ability to react quickly to changing technological conditions are essential to ensure the effective functioning of modern industry (Ulewicz, Sethanan 2019). Among the most important professions, the researchers mention first and foremost maintenance technicians responsible for monitoring, maintaining and repairing machinery and equipment used in production processes. They should be specialists in diagnosing faults, carrying out preventive maintenance and repairs to ensure the continuity of the production line. No less important is the role of IT technicians who are involved in the configuration, programming and integration of the various IT systems and technologies to ensure that communication between them runs smoothly. They are responsible for the creation and configuration of interfaces, communication protocols and the integration of various devices and modules, but also for the installation, configuration and management of computer networks, ensuring the secure and reliable connection of devices, systems and sensors within the network infrastructure including IoT systems (Vermesan, Friess, 2014). Automation technicians, responsible for the design, installation, programming and maintenance of automation systems, robotics technicians, responsible for the operation, programming and maintenance of industrial robots, also play an important role in the production system. They are specialists in the calibration, motion programming, diagnosis and repair of robots, which are widely used in various stages of production processes. There is also an emerging need for new skills related, for example, to 3D printing or vision systems using image processing, pattern recognition and visual analysis to monitor and control manufacturing processes (Bhatia, 2015; Koh et al., 2017).

The above considerations show that occupations that involve making products themselves are losing ground. It is becoming increasingly difficult for unskilled people, who can be quickly trained to do simple manual work, to find a place in the labour market and, as analyses of the labour market show, they are less and less attractive to young people (Chou et al., 2018; Zawłocki et al., 2016).

In order to prepare young people for the requirements of modern industrial plants, it is necessary to start specialised education already at the secondary education stage - in trade schools and technical schools (Pfeiffer, 2015; Zawłocki, Niewiadomski, 2016). As reports of companies dealing with employee recruitment show, for many years the industry, both global and Polish, has been facing a shortage of skilled manual workers, technicians, IT specialists and engineers. These occupational groups top the ranking of sought-after employees year after year (Manpowergroup, 2020).

3. Methods

According to the Ministry of Education and Science's classification of occupations of vocational education, there are 32 vocational branches in Poland (Ministry of Education and Science, 2023). Within the individual trades, it is possible to study 215 occupations in first- and second-level trade schools, technical schools, post-secondary schools and further education courses. For the purposes of this analysis, only those occupations were selected whose acquisition is associated with the completion of a 5-year technical school (Magnowski, 2020). After taking this criterion into account, 97 professions were identified, falling into 30, the following industries:

- audiovisual industry,
- construction industry,
- ceramics and glazing industry,
- chemical industry,
- wood and furniture industry,
- the economic and administrative sector,
- the electricity industry,
- the electronics and mechatronics industry,
- the hairdressing and cosmetics industry,
- the mining and drilling industry,
- trade industry,
- the hospitality and tourism industry,
- forestry industry,
- mechanical engineering,
- the precision mechanics industry,
- the metal industry,
- the automotive industry,
- the horticulture industry,
- the healthcare industry,
- the printing industry,
- the fashion industry,
- agriculture and livestock industry,
- fishing industry,
- the shipping and logistics industry,
- food industry,
- ICT industry,
- the road transport industry,

- the rail transport industry,
- the air transport industry,
- water transport industry.

Based on the literature review, industries that are directly or indirectly useful for the functioning and development of Industry 4.0 were selected for further analysis (Panasiuk, Kaczmarek, 2018; Kuper, 2020). These are:

- electricity industry,
- electronics and mechatronics industry,
- mechanical engineering industry,
- precision mechanics industry,
- ICT industry.

Within the above-mentioned industries, 15 professions were distinguished, among which the most relevant are:

- automation technician,
- electronics technician,
- electrical technician,
- energy technician,
- IT technician,
- mechanical technician,
- mechatronics technician,
- robotics technician,
- optical technician,
- programming technician,
- broadband electronic communications technician,
- ICT technician,
- telecommunications technician.

In order to meet the first intermediate objective, the information contained in the core curricula was analysed for the above-mentioned professions. Education in the professions is based on the core curricula developed for each profession by the Ministry of Education and Science (2021). The core curricula include the following:

- learning objectives,
- vocational qualifications and the sub-qualifications contained therein,
- learning outcomes and criteria for their verification,
- training delivery conditions,
- minimum number of training hours.

All the information contained in the curricula was analysed, but the main focus was on the qualifications that technical graduates should acquire.

Industry education distinguishes between single- or dual-qualification occupations, with single-qualification occupations being primarily occupations taught in first-level industry schools. Occupations taught in technical schools are dual-qualification occupations. The first qualification usually corresponds to a qualification acquired in an upper-level trade school and provides a foundation for the second qualification. The second, higher qualification is specific to a particular profession acquired at a technical school.

Table 1 presents qualifications used to describe the analysed professions (according to the Classification of Professions in Industry Education).

Table 1.
Qualifications for selected professions

Industry	Profession	Qualification
electronics and mechatronics	automation technician	Installation, commissioning and operation of industrial automation systems
		Operation of industrial automation systems
	electronics technician	Assembling and installation of electronic systems and equipment
		Operation of electronic equipment
	mechatronics technician	Assembly, commissioning and maintenance of mechatronic devices and systems
		Operation and programming of mechatronic devices and systems
	robotics technician	Assembly, commissioning and maintenance of robotics systems
		Operation and programming of robotics systems
electricity	electrical technician	Installation, commissioning and maintenance of electrical plant, machinery and equipment
		Operation of electrical machinery, equipment and installations
	energy technician	Assembly, commissioning and operation of installations and transmission units in power systems
		Assembly, commissioning and operation of installations and generating units in energy systems
mechanical engineering	mechanical technician	Assembly and operation of machinery and equipment
		Operation of machine tools
		Making and repairing machine elements, devices and tools
		Organisation and supervision of production processes for machinery and equipment
precision mechanics	optical technician	Assembly and repair of optical components and systems
		Production and repair of visual aids
ICT	IT technician	Administration and operation of computer systems, peripheral equipment and local area networks
		Creation and administration of websites and web applications and databases
	programming technician	Creation and administration of websites and web applications and databases
		Design, programming and testing of applications
	broadband electronic communications technician	Installation and operation of in-building installations for satellite, cable and terrestrial television
		Installation and operation of non-building broadband cable networks
	ICT technician	Installation and configuration of local computer networks and administration of operating systems
		Operation and configuration and administration of wide area networks
	telecommunications technician	Installation and maintenance of telecommunications lines and subscriber equipment
		Installation and maintenance of telecommunications networks

Based on the data in Table 1, 27 professional qualifications have been identified (one of them is repeated in 2 occupations: IT technician and programming technician).

Each partial professional qualification is described by a set of expected learning outcomes, which define: knowledge, professional skills and personal and social competences. All learning outcomes are contained in the following groups:

- occupational health and safety,
- training achievements typical for the given qualification,
- vocational foreign language,
- personal and social competences,
- organisation of work of small teams.

For example, for the profession of Automation Technician we can distinguish:

- 2 qualifications in which 15 partial qualifications are included,
- 114 learning outcomes for all partial qualifications,
- 457 verification criteria for 114 training achievements.

Curriculum bases for all 15 professions included in Table 1 were analysed.

The next stage of the research was to fulfil the second intermediate objective. To establish how schools describe their educational offerings to potential candidates, i.e. primary school graduates. The focus here was on information that would identify any links to the concept of Industry 4.0. Here, information was expected on whether the proposed profession corresponds to the requirements for Industry 4.0 employees, whether it prepares graduates to work with intelligent technologies in the factories of the future.

On the basis of the data contained in the Register of Schools and Educational Establishments (Wyszukiwarka Rejestru Szkół i Placówek Oświatowych – rspo.gov.pl), 987 establishments providing education in occupations requiring education in a 5-year technical school were identified. The analysis of the information consisted in reviewing the content of educational offers contained on the websites of individual schools.

4. Results

Considering the 15 selected occupations, all 27 qualifications were analysed together with their learning outcomes and verification criteria (approximately 450 criteria per occupation). Among all criteria, the term 'Industry 4.0' occurred only once. The identified entry can be found in the core curriculum of the profession of robotics technician, in the qualification "Assembly, commissioning and operation of robotics systems". One of the learning outcomes reads: "characterises the use of robots in the context of Industry 4.0 and 5.0 and artificial intelligence".

However, it should be noted that this learning outcome is typically theoretical, as we find the following verification criteria in its qualification criteria:

- describes the elements of Industry 4.0 and 5.0,
- describes the concept of artificial intelligence,
- lists the opportunities and risks associated with the application of artificial intelligence in robotics systems.

Thus, it is not related to any practical skills of the graduate, but only approximates the student's general knowledge of the concept of Industry 4.0. Taking into account all occupations, the acquisition of which is associated with the graduation from a 5-year technical school, one occupation "robotics technician" represents only 1% of all occupations.

It is noteworthy that the profession of robotics technician is a relatively recent addition to the educational space, as it was not established until 2021, despite the fact that the world has already been in the so-called phase III of robotisation since around 1979, characterised by a rapid development of robotisation, an increase in the number of manufacturers, customers, new models and applications (Żurek, 2004).

In the remaining core curricula for the other analysed professions in which education is provided in 5-year technical schools, there is no mention of the idea of Industry 4.0.

Analysis of the Register of schools and educational establishments maintained by the Ministry of Education and Science showed that only about 85% of the 987 establishments running schools based on 5-year technical schools have websites notified to the database and functioning. 429 pages, or about 43%, were analysed, focusing on the description of the professions offered in the schools' educational offers. As a result of this work, only one entry was found in the description of a mechatronic technical school, stating that graduates are prepared to work in factories based on the concept of Industry 4.0. In the remaining cases, there were no references to the concept of Industry 4.0 in the description of professions.

5. Conclusions and discussions

The modern world is developing and changing at an alarming rate. Technological advances, global social and environmental challenges and the unpredictability of the labour market are creating new challenges for young people. This is why it is so important to encourage them to choose the professions of the future. Only those who are well-prepared and possess skills related to new technologies will be confident in the labour market of the future. Occupations related to new technologies and innovation often offer attractive working conditions, great career opportunities and higher salaries. Encouraging young people to enter these professions allows them to build a stable and rewarding career path (Blanco et al., 2019).

With these technological advances, companies in various sectors are increasingly relying on professionals with knowledge and skills in these fields. It is therefore important that vocational education responds appropriately to these changes and prepares young people for the industries of the future.

The main research objective was to answer the question to what extent the assumptions of the Industry 4.0 concept are present in Polish secondary technical education. It was realised through two intermediate objectives: to identify and characterise information on Industry 4.0 found in the core curriculum for secondary schools and to identify and characterise information on Industry 4.0 found on the websites of selected secondary technical schools.

Many technical schools offer subjects related to programming, electronics, automation or computer networks. However, there is a need to continually update these programmes to reflect the latest trends and technologies. It is particularly important to introduce subjects related to artificial intelligence, data analytics and IoT, which are increasingly important in industry and services.

Analysing the curricula, it is noticeable that there are virtually no references to the idea of Industry 4.0. The concept of the latest industrial revolution is absent from the current curricula of secondary technical schools. With one exception (robotics technician), students are not taught about the concept of Industry 4.0. No links are shown between the competences acquired in the course of education and the requirements placed on workers by modern factories.

It is also worth emphasising the importance of promoting the professions of the future to young people. Informing and educating students about the career prospects associated with modern technologies can induce them to choose a career path in line with the needs of the future labour market. Information campaigns, educational fairs and mentoring programmes can help young people to make an informed decision about their future career.

Analysing the websites of secondary technical schools, it is noticeable that references to the fourth industrial revolution are not encountered in the areas concerning educational offerings. Technical schools do not promote their fields of study in relation to the idea of Industry 4.0. Candidates reading the educational offer will not learn that the professions they plan to choose will give them the opportunity to be employed in the factories of the future, and that their competences will meet the requirements of Industry 4.0 employees.

Based on the observations resulting from the analysis of the information contained in the curricula and on the websites, the following necessary recommendations can be made:

- ongoing updating of existing curricula so that they provide a viable response to the changing labour market and advances in manufacturing technologies and work organisation,
- promoting on the websites of schools those curricula which educate in the professions expected by modern industry with a particular focus on the concept of Industry 4.0,

- use of websites of educational institutions not only as an information medium, but above all as a form of promotion of modern, innovative professions, corresponding to contemporary requirements of modern industry.

Choosing professions related to new technologies, innovation, global social and environmental challenges and the growing needs of society will allow young people to be flexible, innovative and competitive in the labour market of the future. Encouraging them to enter such professions will provide them with career satisfaction, stability and growth prospects. It is therefore worth investing in education, career orientation and the promotion of the professions of the future in order to provide young people with the best possible opportunities for development in a dynamic and unpredictable world of work.

Acknowledgements

This research was funded by Silesian University of Technology, Poland, grant number 13/010/BK_22/0065.

References

1. Alcácer, V., Cruz-Machado, V. (2019). Scanning the industry 4.0: A literature review on technologies for manufacturing systems. *Engineering science and technology, an international journal, 22(3),* 899-919.
2. Benesova, A., Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manufacturing, 11*, 2195-2202, 10.1016/j.promfg.2017.07.366.
3. Bhatia, U. (2015). 3D printing technology. *International Journal of Engineering and Technology Research, 3(2),* 327-330.
4. Blanco, E., Schirmbeck, F., Costa, C. (2019). Vocational Education for the Industrial Revolution. *Smart Industry & Smart Education: Proceedings of the 15th International Conference on Remote Engineering and Virtual Instrumentation, 15,* 649-658.
5. Broy, M. (2010). *Cyber-Phisical Systems. Innovation Durch Software-Intensive Eingebettete Systeme*. Monachium: Springer.
6. Buhr, D. (2015). *Social Innovation Policy for Industry 4.0*. Tübingen: Eberhard Karls University of Tübingen.
7. Chou, C. M., Shen, C.H., Hsiao, H.C., Shen, T.C. (2018). Industry 4.0 manpower and its teaching connotation in technical and vocational education: Adjust 107 curriculum reform. *International Journal of Psychology and Educational Studies, 5(1),* 9-14.

8. de Assis Dornelles, J., Ayala, N.F., Frank, A.G. (2022). Smart Working in Industry 4.0: How digital technologies enhance manufacturing workers' activities. *Computers & Industrial Engineering, 163*, 107804.
9. Forcina, A., Falcone, D. (2021). The role of Industry 4.0 enabling technologies for safety management: A systematic literature review. *Procedia computer science, 180*, 436-445.
10. Gajek, A., Fabiano, B., Laurent, A., Jensen, N. (2022). Process safety education of future employee 4.0 in Industry 4.0. *Journal of Loss Prevention in the Process Industries, 75*, 104691.
11. Holub, O., Hammer, M. (2017). Diagnostics and maintenance of machine tool spindles – new views. *MM Science Journal, 11*, 2094-2099.
12. Kamble, S.S., Gunasekaran, A., Gawankar, S.A. (2018). Sustainable Industry 4.0 Framework: A Systematic Literature Review Identifying the Current Trends and Future Perspectives. *Process Safety and Environmental Protection, 117*, 408-425, 10.1016/j.psep.2018.05.009.
13. Kamiński, A. (2018). „Inteligentna fabryka" – nowe trendy w rozwoju systemów informatycznych dla przemysłu. *Zarządzanie i Finanse – Journal of Management and Finance, 16, 3(2),* 113-122.
14. Koh, L., Orzes, G., Jia, F.(J). (2019). The Fourth Industrial Revolution (Industry 4.0): Technologies Disruption on Operations and Supply Chain Management. *International Journal of Operations & Production Management, 39, 6/7/8,* 817-828, 10.1108/IJOPM-08-2019-788.
15. Kuper, H. (2020). Industry 4.0: changes in work organization and qualification requirements – challenges for academic and vocational education. *Entrepreneurship Education, 3,* 119-131.
16. Liao, Y., Deschamps, F., Loures, E.D.F.R., Ramos, L.F.P. (2017). Past, Present and Future of Industry 4.0 – A Systematic Literature Review and Research Agenda Proposal. *International Journal of Production Research, 55(12),* 3609-3629, 10.1080/00207543. 2017.1308576.
17. Magnowski, T. (2020). *Informator o zawodach szkolnictwa branżowego*. Warszawa: Ośrodek Rozwoju Edukacji.
18. Manpowergroup (2020). *Niedobór talentów 2020*. Retrieved from: https://www.manpowergroup.pl/wp-content/uploads/2020/02/Rozwiazanie_problemu_ niedoboru_talentow_PL-1.pdf, 10.10.2021.
19. Ministerstwo Edukacji i Nauki (2021). *Rozporządzenie Ministra Edukacji i Nauki z dnia 28 maja 2021 r. zmieniające rozporządzenie w sprawie podstaw programowych kształcenia w zawodach szkolnictwa branżowego oraz dodatkowych umiejętności zawodowych w zakresie wybranych zawodów szkolnictwa branżowego*. Dz.U. 2021, poz. 1087.

20. Ministerstwo Edukacji i Nauki (2023). *Rozporządzenie Ministra Edukacji i Nauki z dnia 18 stycznia 2023 r. zmieniające rozporządzenie w sprawie ogólnych celów i zadań kształcenia w zawodach szkolnictwa branżowego oraz klasyfikacji zawodów szkolnictwa branżowego*. Dz.U. 2023, poz. 183.
21. Morrar, R., Arman, H., Mousa, S. (2017). The Fourth Industrial Revolution (Industry 4.0): A Social Innovation Perspective. *Technology Innovation Management Review*, *7*, 12-20.
22. Panasiuk, J., Kaczmarek, W. (2018). Zapewnienie ciągłości edukacji technicznej w kontekście wymagań Przemysłu 4.0. *Napęd i Sterowanie*, *6*, 80-85.
23. Pereira, A.C., Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*, *13*, 1206-1214.
24. Pfeiffer, S. (2015). *Effects of Industry 4.0 on vocational education and training*. Vienna: Institute of Technology Assessment.
25. Rosin, F., Forget, P., Lamouri, S., Pellerin, R. (2020). Impacts of Industry 4.0 technologies on Lean principles. *International Journal of Production Research, 58(6),* 1644-1661.
26. Schwab, K. (2016). *The Fourth Industrial Revolution*. World Economic Forum.
27. Ulewicz, R., Sethanan, K. (2019). *Quality of Educational Services – Industry 4.0 Requirements.* 20th International Symposium on Quality Kvaliteta–Jučer, Danas, Sutra/Quality – Yesterday, Today, Tomorrow. Hrvatska, Pula, 137-149, 10.11222/020.01.011.19.
28. Vermesan, O., Friess, P. (2014). *Internet of Things. From Research and Innovation to Market Deployment*. Denmark: River Publishers.
29. Wang, Y., Ma, H.-S., Yang, J.-H., Wang, K.-S. (2017). Industry 4.0: a way from mass customization to mass personalization production. *Advances in Manufacturing*, *5*, 311-320.
30. Wiśniewska-Sałek, A., Broniszewska, A. (2021). Przemysł 4.0 – analiza potencjału pracodawcy. In: A. Woźny, R. Dwornicka (eds.), *Multidyscyplinarne aspekty zarządzania produkcją i usługami* (pp. 59-71). Kraków: Wydawnictwo PK.
31. Wolf, M., Kleindienst, M., Ramsauer, C., Zierler, C., Winter, E. (2018). Current and future industrial challenges: demographic change and measures for elderly workers in industry 4.0. *Annals of the Faculty of Engineering Hunedoara, 16(1),* 67-76.
32. Wortmann, F., Flüchter, K. (2015). Internet of things: technology and value added. *Business & Information Systems Engineering*, *57*, 221-224.
33. Wróbel-Lachowska, M., Wiśniewski, Z., Polak-Sopinska, A. (2018). The role of the lifelong learning in logistics 4.0. *Advances in Human Factors in Training, Education, and Learning Sciences: Proceedings of the AHFE 2017 International Conference on Human Factors in Training, Education, and Learning Sciences*, July 17-21, 2017. Los Angeles: Springer International Publishing, 402-409.
34. *Wyszukiwarka Rejestru Szkół i Placówek Oświatowych*. Retrieved from: https://rspo.gov.pl/, 21.02.2022.

35. Zasadzień, M. (2022). Education at technical secondary schools for the needs of Industry 4.0 in Poland with particular consideration of the Śląskie voivodship. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, 161*, 349-364. https://doi.org/10.29119/1641-3466.2022.161.23.
36. Zawłocki, I., Nieroba, E., Niewiadomski, K. (2015). Preferowane modele kształcenia zawodowego w średnim i wyższym szkolnictwie w Polsce. *Edukacja – Technika – Informatyka, 1(11),* 136-141.
37. Zawłocki, I., Niewiadomski, K. (2016). Optymalne ścieżki kształcenia prowadzące do uzyskania pełnych kompetencji zawodowych. *Edukacja – Technika – Informatyka, 4(18),* 164-167.
38. Zezulka, F., Marcon, P., Vesely, I., Sajdl, O. (2016). Industry 4.0 – An Introduction in the phenomenon. *IFAC-PapersOnLine, 49, 25*, 8-12.
39. Żurek, J. (2004). *Podstawy robotyzacji*. Poznań: Wydawnictwo Politechniki Poznańskiej.