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EDUCATION AT TECHNICAL SECONDARY SCHOOLS FOR THE NEEDS OF INDUSTRY 4.0 IN POLAND WITH PARTICULAR CONSIDERATION OF THE ŚLĄSKIE VOIVODSHIP

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Purpose: The research presented here was intended to describe to what extent secondary technical education is prepared to educate staff for the needs of Industry 4.0.
Design/methodology/approach: The research was conducted by analysing the education offer of Polish and Silesian technical secondary schools while identifying professions that are important for the development of Industry 4.0 concept in production enterprises. The results obtained on a national scale were compared with those of the Śląskie voivodship.
Findings: During the research it was found that the education offer in terms of preparation of future technical staff for the needs of Industry 4.0 is not sufficient and definitely not diversified enough. Among the "professions of the future" the profession of IT technician definitely prevails and its share in the offer is several times higher than that of other professions.
Research limitations/implications: The research concerned only the offer of Polish secondary schools and not the actual number of students attending them. It is also difficult to accurately compare the values under study in the rest of the European Union due to the diversity of secondary education systems across countries.
Practical implications: The research conducted shows that there is a need for greater promotion among young people of those faculties that are relevant from the perspective of requirements of the Industry 4.0. The promotion should take place both at the level of government and local authorities with active participation of industry representatives.
Originality/value: The paper presents an analysis of Polish, and in particular Silesian technical secondary schools from the point of view of the opportunities they offer to graduates of primary schools wishing to gain a profession of a technician useful in their future careers in modern enterprises following the concept of Industry 4.0. The research results can serve as a starting point for analysis of the condition of Polish education in the context of requirements of employers wishing to employ qualified staff useful in modern production facilities in the future.

Keywords: Industry 4.0, smart factory, education, technical schools, Silesia.

Category of the paper: research paper.

1. Introduction

The global economy, the pursuit of competitive advantage, diversification and expansion of the supply chain, products customisation, increasingly widespread digitalisation of all aspects of a company's operations, and expansion of the Internet. The combination of these and other phenomena led to emergence of the concept of the fourth industrial revolution called Industry 4.0. The fourth industrial revolution does not anticipate revolutionary changes in existing manufacturing technologies and techniques, it only assumes their use in the integral world of ICT technologies, consequently creating intelligent manufacturing systems (Bendkowski, 2017; Mącik, 2016).

Meeting the demands of new, constantly evolving manufacturing concepts requires not only new technical solutions: machines, equipment, systems, but above all an army of highly qualified engineers and machine and equipment operators. In order to be successful on this battlefield, it is essential that future employees are properly prepared. The education process constantly faces new and bigger challenges. The industry needs well-educated specialists with new skills and capable of self-development (Moid, 2020; Siemieniecka, 2021). New fields of education are emerging: ICT, mechatronics, robotics or broadband radio communication. The existing ones gain new meaning: optics, electronics, computer science, automation (Zawłocki, 2017).

A qualified specialist whose qualifications will meet the requirements of the Industry 4.0 idea is not only a specialist in his or her narrow field. It is a versatile technician or engineer who is familiar with computer science, telecommunications and automation (Iwański, 2017). Thus, it seems reasonable to start such education as early as possible. The challenges of the new era are faced not only by technical universities but also by secondary schools that prepare qualified operators and technicians and above all candidates for future engineers and managers who are familiar with basic technical issues (Benešová & Tupa, 2017).

2. Literature review

The idea of the fourth industrial revolution, commonly known as Industry 4.0, came to light in 2014. Some authors saw its première at Hanover trade fairs (Olszewski, 2016; Lasi et al., 2014), but it is also believed that the concept was first announced publicly at the World Economic Forum in Davos (Iwański, 2017). The platform was created by an Advisory Committee of technical organisations and industry representatives working under the auspices of the German Academy of Technical Sciences (Olszewski, 2016).

The main, basic idea of the Industry 4.0 concept is the notion of smart factory, which is a modern and intelligent factory based on socio-technical systems (Bendkowski, 2017). In order to better understand the idea and scope of the concept we need to take a closer look at the structure of a modern company within a value chain (Fig. 1).

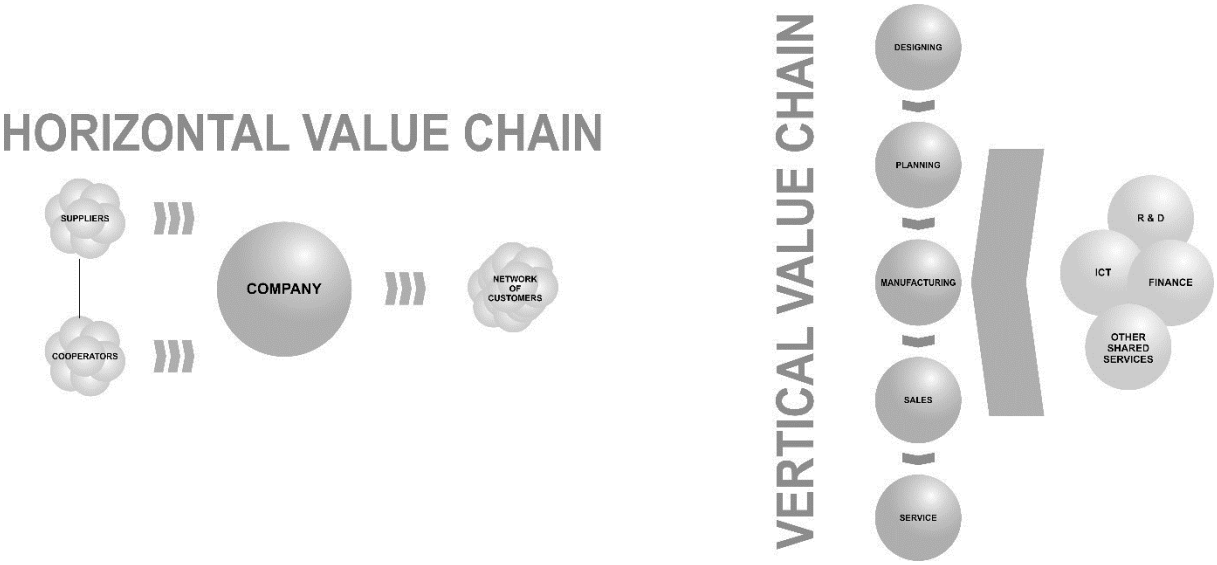

Figure 1. Value chains in Industry 4.0. Source: based on (Oesterreich, 2016; Koch et al., 2014).

Smooth functioning of the idea of Industry 4.0 assumes integration based on digital technologies (both information and communication technologies) for each participant in the horizontal value chain, i.e. cooperators, suppliers and customers, and of course the company itself. This will ensure the smooth flow of information and thus the smooth functioning of the process of the supply of raw materials, components and products (Sirine & Andadari, 2020). However, integration of the vertical value chain is also important, which will allow for smooth cooperation not only between particular departments of a company but also between individual participants of the manufacturing process and even individual machines and devices. The application of modern, coherent and proven ICT solutions will increase the level of autonomy of individual elements of the chain, minimising the probability of errors caused by employees. It is not sufficient to only "equip" the connection system between horizontal and vertical chain links with new technologies. The most essential element is to enable, through technical solutions, each link in the chain to communicate with each other autonomously (Tjahjono, 2017). Such integration is to support not only the manufacturing process but also product development and seamless customisation (Kamiński, 2018; Wang et al., 2017). In order to implement such an ambitious concept it is necessary to equip all links of the value chain with modern technological solutions, such as (Atzori et al., 2010; Baena at al., 2017; Lu et al., 2017):

- Industrial Internet of Things,
- broadband wireless communication,
- automation, robotics, cyber-physical systems, universal mechatronics,
- autonomous transport and storage systems,

- additive manufacturing,
- virtual and augmented reality,
- predictive analytics,
- optoelectronics,
- computing clouds, Big Data and more.

Smooth implementation of comprehensive, modern and even pioneer solutions poses enormous challenges for today's engineers. The proposed new technological solutions are interdisciplinary and combine several science and technology domains. This requires employees to constantly expand their knowledge or learn new things, for example mechatronics, optoelectronics or predictive analytics to name just a few. However, IT and telecommunication come to the fore due to the need to integrate all system components into a single IT network. The new working environment so formulated requires employees to have interdisciplinary knowledge and requires continuing education in innovation in their own and related domains (Gracel & Makowiec, 2017).

The new requirements for technical staff demand excellent preparation of specialised staff on different levels who are useful in the Industry 4.0 era. Jobs that involve independent product manufacturing are becoming less and less crucial while skills required to operate complex, modern machines and devices are becoming more and more important. It is becoming increasingly difficult for unskilled people, who can quickly be trained to perform simple manual work, to find their place in the labour market. In order to prepare young people for the requirements of contemporary labour market, it is necessary to start specialised education already at the stage of secondary schools – in industry and technical schools. As indicated in reports by Manpower Group (a staff recruitment company), both global and Polish industry has been facing shortage of qualified blue-collar workers (e.g. electricians, mechanics, welders, etc.), technicians, IT specialists and engineers for many years. These groups of professionals lead the ranking of sought-after employees year after year (Manpowergroup, 2020).

In 2017, as a result of Polish education system reform, an 8-year primary school was introduced. Those who graduate can continue education in a 4-year general secondary school, 5-year technical secondary school or 3-year grade I vocational school (Fig. 2) (Panasiuk & Kaczmarek, 2018).

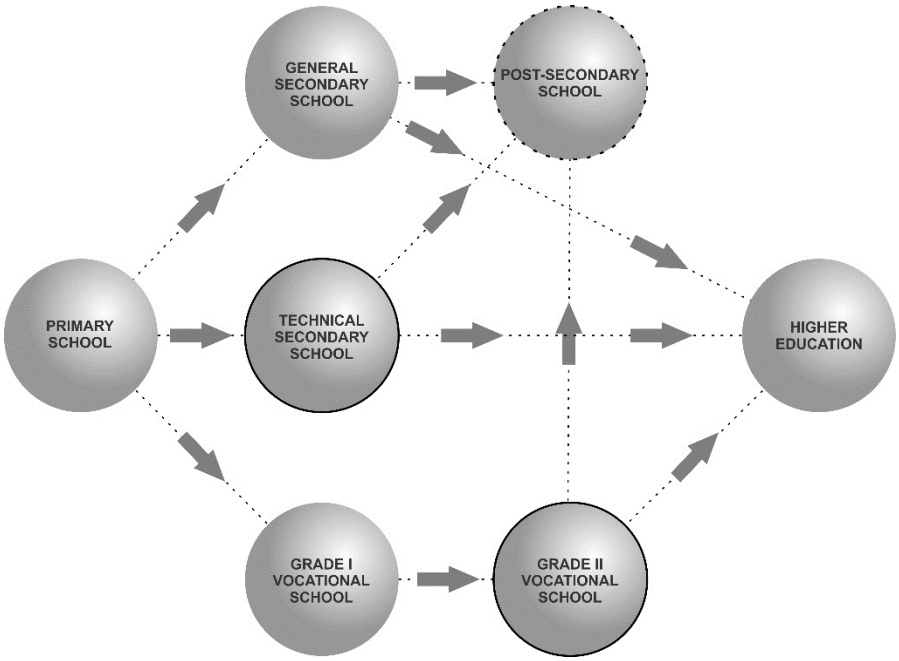

Figure 2. A fragment of Polish education system for young people. Source: on base (Zawłocki & Niewiadomski, 2017).

In order to obtain the professional title of a technician, one must either complete a technical secondary school or, after completing grade I vocational school, continue education in grade II vocational school. Graduates of general secondary schools, technical secondary schools and grade II vocational schools can continue education in post-secondary schools. This type of school offers a technician's diploma only in certain branches, such as the health care branch, the social work branch or the security and safety of persons and property branch. All graduates of secondary schools can also learn new skills in qualifying vocational courses (Zawłocki & Niewiadomski, 2017).

The best possible preparation of future employees to perform their jobs in new working environments requires not only the expansion of the educational offer to include new professions and skills, but also the development of existing curricula to include innovative elements implemented in industry on an ongoing basis. The sources of innovation in industry are mainly scientific research centres and research and development departments in companies. This is why contemporary teaching in vocational schools should have a dual nature. As many researchers point out, the measure of good employee education is, in addition to theoretical knowledge in schools, practical learning in industrial plants.

Multi-stage technical education can be a good answer to the growing demand for interdisciplinary knowledge of technical staff (Gracel, 2016). A young person who graduates from a secondary school with a professional title of technician can continue education at a university. Further studies can involve the same domain or completely new direction, thus combining the knowledge acquired in the technical secondary school with knowledge acquired during engineering studies (Zawłocki, Nieroba, Niewiadomski, 2015).

3. Methods

For the purposes of the research, faculties offered to primary school graduates were analysed in 202 technical secondary schools in Śląskie voivodship. Only state schools for young people were considered. According to current data from Statistics Poland there are 207 such schools in Śląskie voivodship (GUS, 2021). Thus, it should be assumed that more than 97% of the population was analysed.

Data obtained on a voivodship scale were compared with data on a national scale. For this purpose the "Information guide to vocational education professions" published in 2020 was used. This is currently the latest comprehensive study on vocational schools in Poland (Magnowski, 2020). Data concerning European Union were aggregated based on information from Eurostat, in particular from "Education and training" and "Regional statistics" sections.

The names of professions analysed and their assignment to specific branches are in accordance with the classification of professions of vocational education of the Ministry of Education and Science. The study includes those professions which are trained in 5-year technical secondary schools for youth or in grade II vocational schools. Professions that require post-secondary education and professional training were not included. This is why the study does not cover such professions as professions in the health care industry and the security and safety of persons and property industry.

A total of 101 professions were analysed, which fall within the following 30 industry branches:

- audiovisual industry,
- construction industry,
- ceramics and glass industry,
- chemical industry,
- wood and furniture industry,
- economic and administrative industry,
- electric energy industry,
- electronics and mechatronics industry,
- hairdressing and cosmetics industry,
- mining and drilling industry,
- commercial industry,
- tourist, hotel and catering industry,
- forestry industry,
- mechanical industry,
- precision mechanics industry,
- metallurgical industry,

- automotive industry,
- horticultural industry,
- healthcare industry,
- printing industry,
- fashion industry,
- agricultural and breeding industry,
- fisheries industry,
- forwarding and logistics industry,
- food industry,
- ICT industry,
- road transport industry,
- rail transport industry,
- air transport industry,
- water transport industry.

The classification of professions is updated on an ongoing basis by the Ministry of Education and Science. New entries are added and names (and qualifications) of existing professions change. Among the analysed professions a "robotics technician" is an example (MEN, 2020). It is not included in the 2020 list, but in 2022 there are already 6 units planned in Śląskie voivodship in which it will be possible to acquire this profession.

Based on a review of literature on the subject, those industries that may be relevant from the point of view of their usefulness for the development of the Industry 4.0 concept have been identified. They were divided into two groups. The first group includes particularly important professions: in electronics and mechatronics industry and in ICT industry. They are represented by the following professions:

- IT technician,
- mechatronics technician,
- electronics technician,
- software development technician,
- ICT technician,
- automation technician,
- telecommunications technician,
- technician in the field of IT for visually impaired people,
- broadband electronic communication technician,
- robotics technician.

The other group consists of industries that are useful for the development and functioning of the assumptions of Industry 4.0. These are: electric energy industry, mechanical industry and precision mechanics industry. The following professions are included:

- mechanic technician,
- electrical technician,
- technician of renewable energy equipment and systems,
- optician technician,
- energy technician,
- welding technician,
- lifting equipment technician.

In the research part, only industries and professions belonging to these two groups were considered.

4. Results

According to data published by Eurostat between 2013 and 2019, around 48% of all secondary school students in EU countries studied in vocational secondary schools. As there are different systems of secondary education in different Member States, it is not possible to state unequivocally what percentage of young people chooses the schools that best correspond to the Polish technical secondary school ("technikum") (Eurydice, 2022).

In order to compare how popular technical (vocational) schools are in particular countries, an average number of students of such schools per 1,000 residents was calculated. The results are presented in Figure 3.

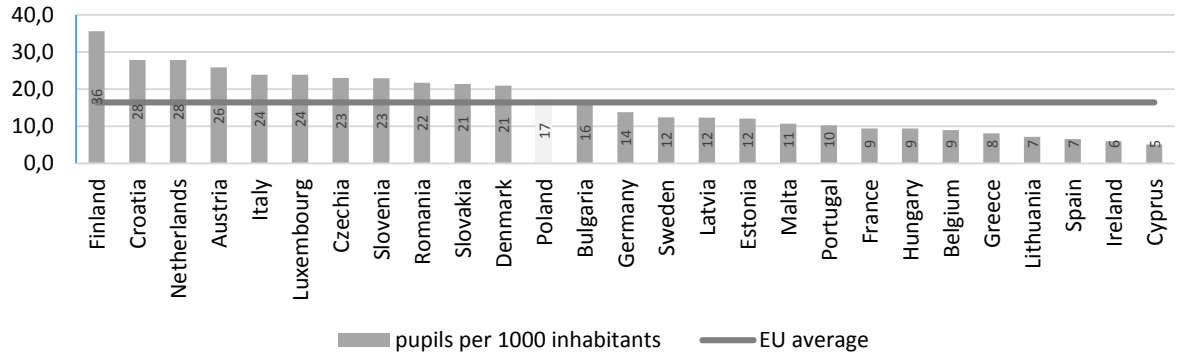

Figure 3. Number of students of vocational secondary schools in European Union.

The average in the entire EU is 16.4 students per 1,000 residents. Vocational secondary schools are most popular among young people in Finland, Croatia, the Netherlands and Austria. The fewest students choose this type of school in Lithuania, Spain, Ireland and Cyprus. In this summary, Poland is slightly above the average (17 students/1,000 residents), at the beginning of the second half of the rate (median = 13.8).

In Poland, the offer of education in technical secondary schools in 2020 consisted of 12,793 units in 96 professions, in 30 industries. Percentage share of units in particular industries is presented in Figure 4.

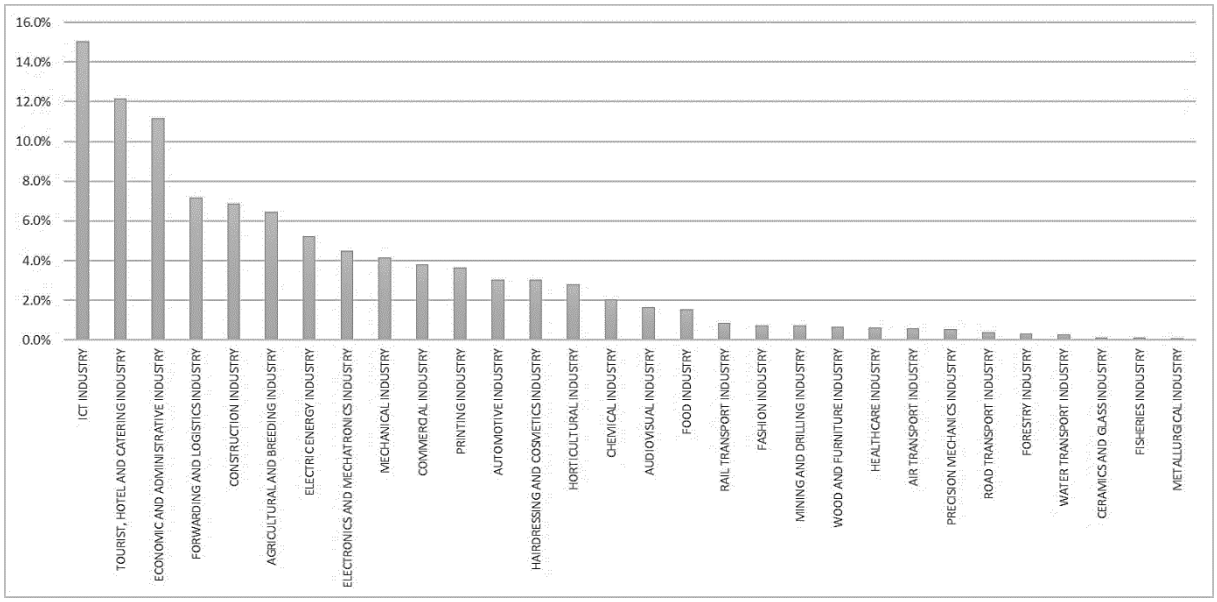

Figure 4. Percentage share of particular industries in total number of units in Poland.

Based on the collected data it can be said that industries from the first group, which are relevant for the development of Industry 4.0, constitute 19.5% of all units. Industries from the other group constitute 9.5%. Industries from the first and the other group together constitute 29% of all units in Poland in which primary school graduates could start their education.

The ICT industry is the most represented in Poland. In 2020, it included 1,924 units, which constitutes 15% of the entire education offer.

In the Śląskie voivodship in total there were 933 units from which graduates of eight grade can choose. The percentage share of particular industries of professions is presented in Figure 5.

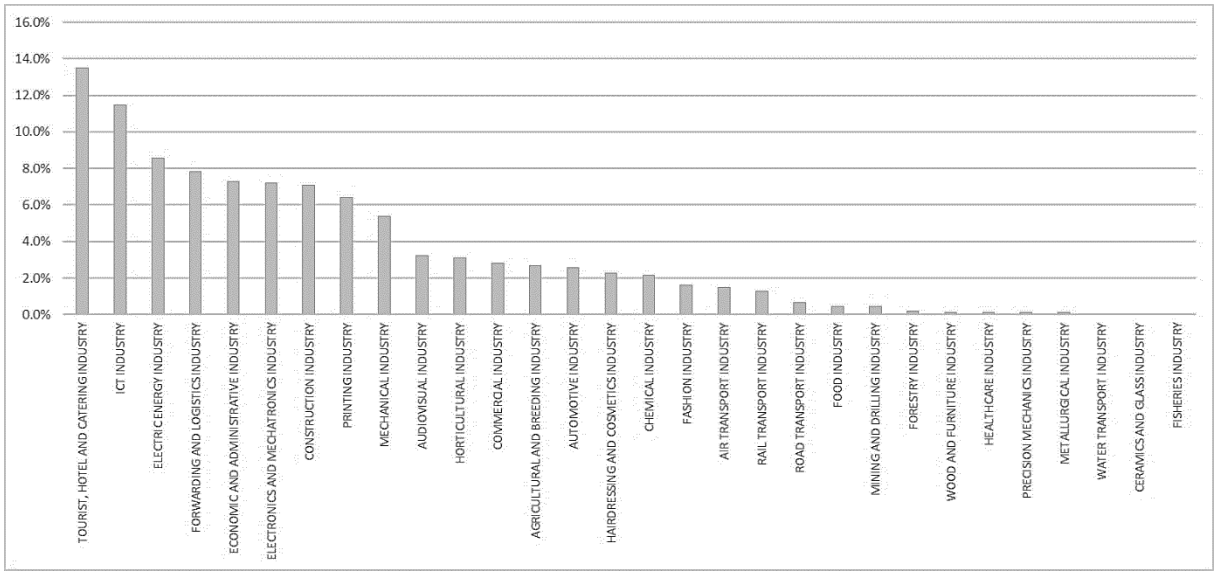

Figure 5. Percentage share of particular industries in total number of units in Śląskie voivodships.

In Śląskie voivodship, the education offer for 2022/2023 school year is represented by 27 industries. Industries in the first group constitute 18.6% of all units. Industries from the other group constitute 12.9%. The first and the other group of professions together constitute over 31.5% of all units in Śląskie voivodship.

The most numerous educational offer (in terms of potential usefulness in Industry 4.0) in Śląskie voivodship is represented by units in which young people can study professions included in the ICT industry. There are 126 such units, which is 11.5% of all units in Śląskie voivodship. Only the offer in hotel and catering industry is more numerous (13.5%).

In order to examine the professional structure of both analysed groups, Table 1 was created, which contains the number of units and their percentage share in group I and II together. Based on this, the pie charts included in Figures 6 and 7 were developed.

Table 1.
Share of professions by group in Poland

Group I – industries that are relevant for Industry 4.0			**Group II – industries that are useful for Industry 4.0**		
Profession	**Number of units**	**Percentage**	**Profession**	**Number of units**	**Percentage**
IT technician	1509	60.4%	Mechanic technician	496	40.7%
Mechatronics technician	263	10.5%	Electrical technician	329	27.0%
Electronics technician	232	9.3%	Technician of renewable energy equipment and systems	228	18.7%
Software development technician	174	7.0%	Optician technician	68	5.6%
ICT technician	167	6.7%	Energy technician	50	4.1%
Automation technician	79	3.2%	Welding technician	35	2.9%
Telecommunications technician	51	2.0%	Lifting equipment technician	12	1.0%
Technician in the field of IT for visually impaired people	12	0.5%			
Broadband electronic communication technician	11	0.4%			
Robotics technician	0	0.0%			
TOTAL	2498		TOTAL	1218	

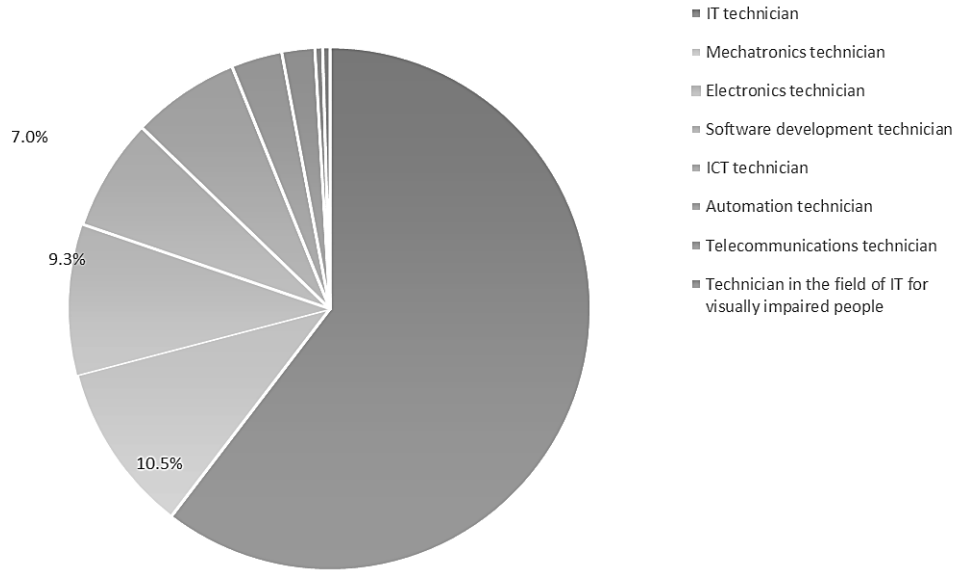

Figure 6. Percentage share of particular professions in group I in Poland.

Based on the above data (Fig. 6, Table 1) it can be noticed that the profession of IT technician constitutes over 60% of all offered professions in Poland. Disparities in the structure of the number of offered units become apparent when quartiles are analysed. In the first quarter, there are only 3% of all units that represent the following professions: telecommunications technician, technician in the field of IT for visually impaired people and broadband electronic communication technician. The second quarter constitutes 9.8% of all units in the following professions: ICT technician and automation technician. The third quarter constitutes 16.3% of units and it includes units that teach the professions of electronics technician and software development technician. The last quarter constitutes 70.9% of the entire offer and it includes professions of IT technician and mechatronics technician.

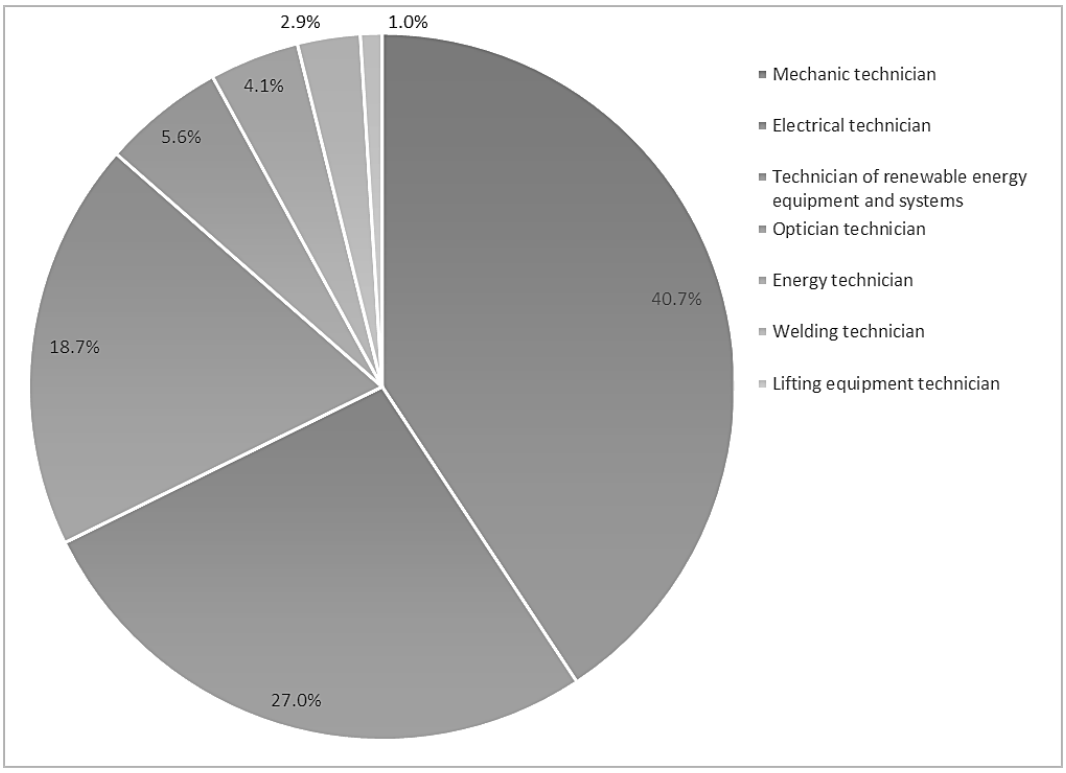

Figure 7. Percentage share of particular professions in group II in Poland.

In group II of industries useful for Industry 4.0 (Fig. 7, Table 1) it can be noticed that in the first quarter there is only 3.9% of all units representing the professions of welding technician and lifting equipment technician. The second quarter constitutes 9.7% of all units in the following professions: optician technician and energy technician. The third quarter constitutes 18.7% and it includes units that teach the profession of technician of renewable energy equipment and systems. The last quarter constitutes 67.7% of the entire offer and it includes professions of mechanic technician and electrical technician.

Next, the structure of the offer in technical secondary schools in Śląskie voivodship was analysed in a similar manner. The results are presented in Table 2 and Figures 8 and 9.

Table 2
Share of professions by group in Śląskie voivodship

Group I – industries that are relevant for Industry 4.0			Group II – industries that are useful for Industry 4.0		
Profession	**Number of units**	**Percentage**	**Profession**	**Number of units**	**Percentage**
IT technician	68	39.1%	Electrical technician	42	35.0%
Mechatronics technician	28	16.1%	Mechanic technician	38	31.7%
Software development technician	26	14.9%	Technician of renewable energy equipment and systems	20	16.7%
Electronics technician	19	10.9%	Welding technician	12	10.0%
Automation technician	14	8.0%	Energy technician	6	5.0%
ICT technician	9	5.2%	Optician technician	1	0.8%
Robotics technician	6	3.4%	Lifting equipment technician	1	0.8%
Technician in the field of IT for visually impaired people	2	1.1%			
Telecommunications technician	1	0.6%			
Broadband electronic communication technician	1	0.6%			
TOTAL	174		TOTAL	120	

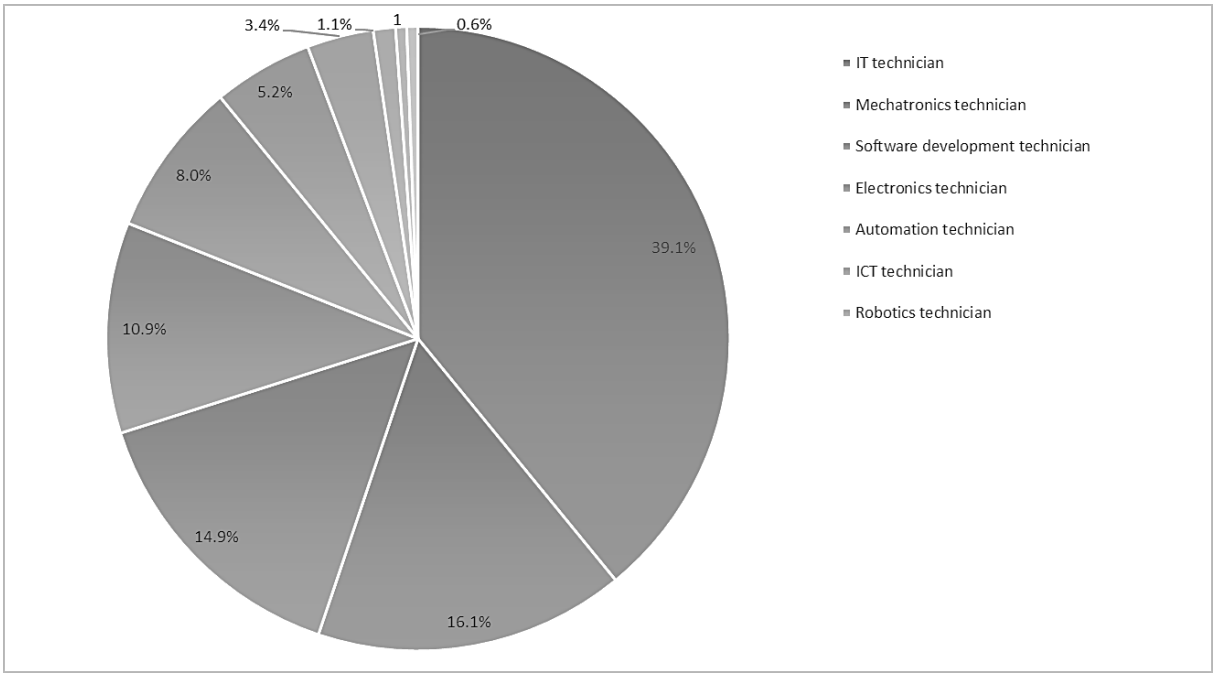

Figure 8. Percentage share of particular professions in group I in Śląskie voivodships.

The data obtained for schools in Śląskie voivodship (Fig. 8, Table 2) show that the most dominant offer among group I is the profession of IT technician (39%). After analysing the quarters it can be seen that in the first quarter there are only 2.3% of all units that represent the following professions: telecommunications technician, technician in the field of IT for visually impaired people and broadband electronic communication technician. The second quarter constitutes 8.6% of all units in the following professions: ICT technician and robotics technician. The third quarter constitutes 19% and it includes units that teach the professions of

electronics technician and automation technician. The last quarter constitutes 70.1% of the entire offer and it includes professions of IT technician, automation technician and mechatronics technician.

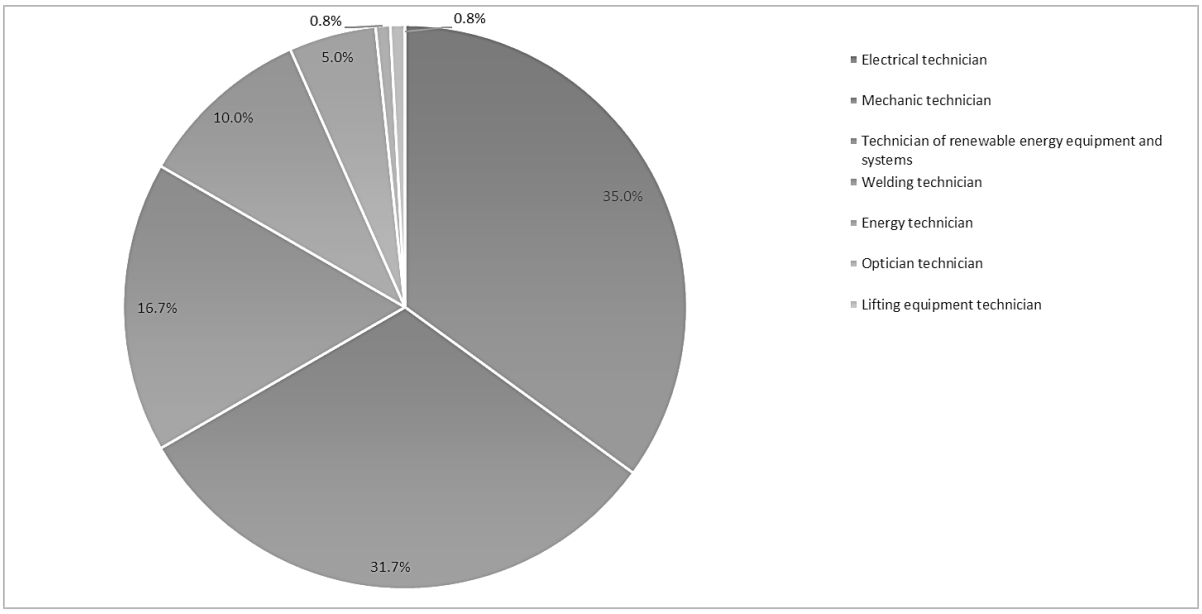

Figure 9. Percentage share of particular professions in group II in Śląskie voivodships.

In group II of industries useful for Industry 4.0 (Fig. 9, Table 2) it can be noticed that in the first quarter there is only 1.7% of all units representing the professions of welding technician and optician technician. The second quarter constitutes 15% of all units in the following professions: welding technician and energy technician. The third quarter constitutes 16.7% and it includes units that teach the profession of technician of renewable energy equipment and systems. The last quarter constitutes 66.7% of the entire offer and it includes professions of mechanic technician and electrical technician.

5. Conclusions and discussions

The research aimed at determining if Polish, and in particular Silesian, technical secondary schools are prepared to educate staff capable of meeting the challenges faced by modern enterprises in the context of the fourth industrial revolution.

The research did not take into account the qualitative aspect of Polish education in technical secondary schools, but only the quantitative dimension – thus defining the offer of the institutions addressed to graduates of primary schools.

In the countries of the European Union, approximately 48% of primary school graduates study in secondary vocational education and this figure has not changed significantly over the years. In comparison with other European Union countries, Poland is in the middle when it comes to the popularity of secondary vocational schools. In the period 2013–2019, a result of

17 students per 1,000 residents was recorded, with a European average of 16.4. The highest result was noted in Finland – over 36.5%, and the lowest in Cyprus – 5 students per 1,000 residents.

In the strategy entitled "Industrial Policy of Poland" published in 2021 by the Ministry of Economic Development, Labour and Technology the key axes are digitalisation of the Polish industry and education of staff for Industry 4.0. In light of these considerations, the share of technical secondary schools in the secondary school market in comparison with other European Union countries appears to be insufficient.

Taking into account the offer of places in units teaching professions important from the point of view of the needs of Industry 4.0, the share of units meeting these requirements in Poland is at the level of 29%, of which more than half represents the ICT industry. The situation is slightly better in Śląskie voivodship because these units constitute around 31.5%. Also, here the ICT industry has the biggest share, however its share is only over 1/3 of all professions. These figures include professions classified in the first group of professions most relevant from the perspective of Industry 4.0 requirements (19.5% at the national level and 18.6% at the voivodship level) and in the other group of professions useful from the perspective of Industry 4.0 (9.5% at the national level and 12.9% at the voivodship level).

In the first group, the profession of IT technician dominates (60% at the national level and 39% at the voivodship level). It is followed by the professions of mechatronics technician, software development technician and electronic technician and then by ICT technician, robotics technician, technician in the field of IT for visually impaired people, telecommunications technician and broadband electronic communication technician. In the other group of professions useful for the development of Industry 4.0, the professions of mechanic technician and electrical technician dominate (respectively 40.7% and 27.0% at the national level and 31.7% and 35% at the Śląskie voivodship level). In terms of number of offers they are followed by the professions of technician of renewable energy equipment and systems, optician technician, energy technician, welding technician and lifting equipment technician.

The results clearly show that IT technician is the dominating offer among all the professions of groups I and II, which also dominates among all the offers on the market. Unfortunately, other professions, such as automation technician, robotics technician or other professions in the ICT industry, are in minority. In the author's opinion, such a small diversification in educational offers is definitely insufficient in terms of educating future staff that will work in modern factories of Industry 4.0. Thus, the offer for other "professions of the future" should be expanded and education in such units should be promoted both nationally and locally, with particular emphasis on participation in these activities by representatives of industry.

Finally, it is important to stress the fact that the results relate to secondary schools offer and do not indicate the actual number of students who have used or will use it.

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