Marek Ł. **GRABANIA**

INDUSTRY 4.0 ENGINEER

Abstract. The article presents the requirements set for professionals employed in industry as a result of the changes related to the implementation of the Industry 4.0 concept. The challenges and necessary new competencies of specialists are described. The current model of vocational education in Poland is referred to. Some selected offers of specialist education in universities are presented. Polish initiatives are also discussed, aimed at familiarizing and facilitating entrepreneurs to implement new technological areas that form the basic structures of Industry 4.0.

Keywords: Industry 4.0, Industry 4.0 engineer, specialized education.

1. INTRODUCTION

At the current phase of Industry 4.0 implementation [1]*, engineers are important in the task of skilful design and application of new solutions based on, among others, digital technologies in such a way as to create and implement new business models. For this reason it is so important to create a specific kind of communication between engineers, businessmen and ultimately the clients. In this aspect, engineers play a key role because they are responsible for both machine design, as well as the creation of integrated manufacturing networks, and it is their responsibility to implement and control the manufacturing process in the era of Smart Industry* [2].

The research carried out as part of the Smart Industry Polska 2019 [2] project commissioned by Siemens and the Ministry of Entrepreneurship and Technology was designed to answer the question of what the labour market is like in the context of demography and the competencies of the engineering staff. The research was conducted among Polish small and medium-sized industrial enterprises (SMEs) operating in Poland.

2. KEY SKILLS [2], [3] ,[4]

The engineering competencies of the future are mainly related to the ability to combine knowledge in the areas of automation, mechatronics, robotics and programming with skills that go beyond typical engineering competencies. Based on the research conducted, the results of which are presented in report [2], one can distinguish the most important, desirable competencies and skills of engineers - Industry specialists.

Marek Ł. **GRABANIA –** Ośrodek Badawczo-Rozwojowy Urządzeń Mechanicznych „OBRUM" sp. z o.o., Gliwice

Tier 1 Personal competencies	**Tier 2** Academic competencies	**Tier 3** Workplace competencies	**Tier 4** Technical competencies	**Tier 5** Industry-Sector Functional Areas
Interpersonal skills	Reading	Teamwork	Foundations of engineering	Competencies to be specified by industry sector representatives
Integrity	Writing	Client/stakeholder focus	Design	
Professionalism	Mathematics	Planning & organizing	Manufacturing & construction	
Initiative	Science & technology	Creative thinking	Operations & maintenance	
Adaptability & flexibility	Communication	Problem solving	Professional ethics	
Dependability & reliability	Critical & analytical thinking	Seeking & developing opportunities	Business. legal & public policy	
Lifelong learning	Computer skills	Working with tools & technology	Sustainability	
		Scheduling & coordinating	Engineering economics	
		Checking, examining & recording	Quality control & assurance	
		Business fundamentals	Safety, health & environment	

Fig. 1. Competencies defined by specialists of the industrial sector (Source: Smart Industry Polska 2019 [2])

3. MODEL OF VOCATIONAL EDUCATION [5], [6], [7]

Poland must change its model of education at all levels. We have to move from a traditional model that teaches memorization and obedience, towards building soft skills: teamwork, creativity, innovation. The contemporary employer needs someone who can solve problems. That someone does not have to remember, he/she must know where to look. He/she must be able to communicate with his/her colleague in Poland and abroad. But that is not what the Polish school teaches [5].

Awareness of the necessary changes is already reflected in the proposed structure of vocational education related to higher education. A diagram of relationships is shown in Fig. 2 [6], [7].

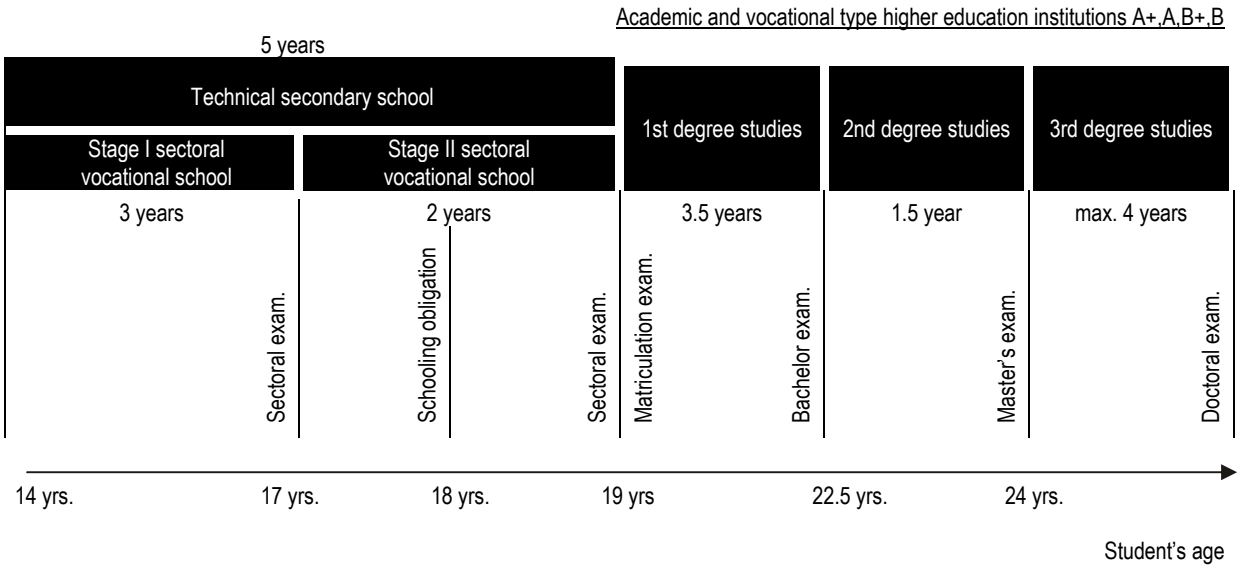

Fig. 2. The model of vocational education being implemented [6], [7]

3.1. Sectoral vocational schools [6],[7]

The elimination of lower secondary schools and ending of recruitment allow to prepare the launch of education in sectoral vocational schools formed as:

- 3-year stage I sectoral vocational schools (BS I);
- 2-year stage II sectoral vocational schools (BS II);
- 5-year technical secondary schools (T);
- 2.5-year or less post-secondary schools (SP).

The creation of sectoral vocational schools aims to more strongly involve entrepreneurs, among others through direct participation in the formulated core curricula and in defining the requirements for practical examinations. Their participation in equipping schools with the latest machinery, equipment and materials is also expected. This cooperation should allow for the defining of requirements for the staff that executes and implements the Industry 4.0 concepts on a running basis.

The problem that we face every day is the migration of graduates after getting a job. The solution may be contracts signed with the future employer during the vocational education.

3.2. Higher technical education institutions

The barriers to the development of Industry 4.0 are primarily related to the availability of adequately educated human resources. This is understandable in the face of high expectations as to the interdisciplinary competencies posed to engineers. Interdisciplinary skills are already expected from engineers. A distinctive feature of the future competence is the combining of technical skills (acquisition of which requires sound education), characterological characteristics (more difficult to practice), and soft skills, which must be learned using other strategies than in the case of exact sciences.

The changes introduced in the field of vocational education also apply to universities. "The Constitution for Science 2.0" [8], published in 2018, introduces a very important division of higher education institutions into academic type higher education institutions and vocational type higher education institutions.

Regardless of the formal changes [8], it is necessary to change education methods. The education of technical staff at all levels of education requires changes in the education methods and deeper involvement on the part of future employers who can provide access to new technologies and projects being implemented, for both research workers and students. Various solutions for "tying" research and academic institutions with the industry are sought for. The chart in Fig. 6 shows a simplified diagram of ties between research/science and the industry.

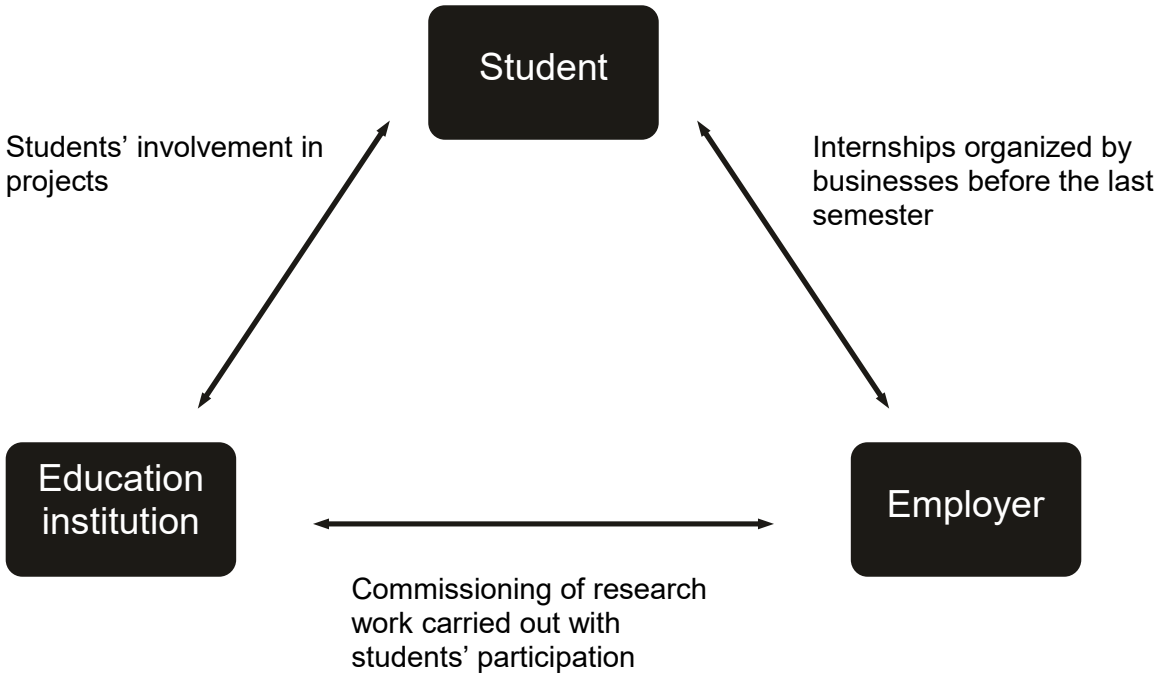

Fig. 3. Preferred model of collaboration between an education institution and the industry [7]

Universities around the world are looking for optimal forms of education that would allow its graduates to adapt their skills and knowledge to the requirements of entrepreneurs/employers. The aim is to prepare students for flexible thinking, and to teach them how to apply theoretical knowledge in various practical situations.

The CDIO system [7],[9] may be assumed as the educational model. The CDIO education system (Conceive - Design - Implement - Operate) may be considered the most effective when it comes to modern industrial training of engineers. The model was originally conceived at the Massachusetts Institute of Technology (MIT) in the 1990s.

A new vision of education was proposed at that time, consisting in:

- abandoning typical engineering sciences as a context in exchange for emphasizing the development of systems and products;
- abandoning the dissociated study of separate disciplines and implementing an integrated system which sees the problems that require for their solution many areas of knowledge, including social and management sciences;
- moving away from design as the basis for educating engineers to systemic thinking "conceive - design - construct - evaluate".

An elite organization was established: the CDIO Initiative. The founders of the CDIO Initiative included Swedish universities: Chalmers University of Technology in Göteborgu, Linköping University in Linköping, Kungliga Tekniska Högskolan in Stockholm, and the Massachusetts Institute of Technology in USA. CDIO Initiative has now nearly 70 members in 27 countries, among them world-renowned universities.

The important thing is that CDIO is based on 12 so-called gold standards, constituting a program for the implementation of a modern education system for engineers, which do not have to be accepted in their entirety by each university. A detailed, recommended curriculum recommends not only teaching traditional knowledge, but also the development of personal and professional skills and qualities [10]. This approach fits in the philosophy of educating an Industry 4.0 engineer.

So far, in Poland only the Gdansk University of Technology has joined the group of universities - members of the CDIO Initiative aspiring to implement a modern education system. Other Polish universities provide education in accordance with the requirements of the Ministry of Science and Higher Education, as made possible by the available research facilities and scientific apparatus.

4. EDUCATIONAL OPPORTUNITIES IN POLAND

The response to the current market demand are the initiatives undertaken by higher technical and economic education institutions and universities, that include postgraduate, managerial and MBA studies that would provide the necessary knowledge in the area of Industry 4.0.

Table 1 presents the educational offer of some universities selected from the current university ranking list [11].

Table 1. List of courses offered by universities

Item	University	Education/training form
1	Silesian University of Technology, Gliwice International Centre for Interdisciplinary Research	MBA Industry 4.0
2	Silesian University of Technology, Gliwice Faculty of Mechanical Engineering	Incubator of Industry 4.0 Leaders [One-term training/course]
3	Warsaw University of Technology Institute of Production Systems Organization Faculty of Production Engineering	Industry 4.0 Academy [Two-terms post-graduate studies]
4	Poznań University of Technology Department of Production Management and Engineering	IT systems in product and process management in Industry 4.0. [Two-terms post-graduate studies]
5	Wrocław University of Economics Faculty of Management, IT and Finance	INDUSTRY 4.0 [Two-terms post-graduate studies]
6	Kozminski University, Warsaw	Industry 4.0 Manager [Two-terms post-graduate studies]

Among the many educational initiatives outside universities, worth noting is the offer of ASTOR and Nowe Motywacje companies, which created the "Engineer 4.0 Competence Development Program" [12].

Numerous training courses or regular conferences devoted to Industry 4.0 are also offered throughout the country. Some current selected events are listed in Table 2.

Table 2. Conferences, lectures

Item	Organizer/date	Event type/subject matter/lecturer
1	Control Engineering Polska Sound Garden Hotel Airport, 7 April 2020, Warsaw	Conference & Exhibition – Industry 4.0 (5th edition)
2	Business School of the Warsaw University of Technology Warsaw, 14 June 2019	Lecture: Industry 4.0 and economic development. Dr Jan Filip Staniłko Director, Innovation Department Ministry of Entrepreneurship and Technology
3	AHK Polska, Regional Office, Poznań Poznań International Fair, Poznań, 5 June 2019	Conference: The Fourth Revolution in Polish factories – current status and expectations
4	Komputronik Biznes, Poznań Novotel Wrocław Centrum Wrocław, 16 May 2019	Conference: Industry 4.0
5	The Jacob of Paradies University Gorzów Wielkopolski 26 April 2019	International Scientific Conference INDUSTRY 4.0. Algorithmization of problems and digitalization of processes and devices

5. POLISH INITIATIVES IN THE FIELD OF INDUSTRY 4.0

One of the key elements of successfully reaching entrepreneurs with new trends in managing manufacturing processes is creating strong ties between science and industry. To this end, various types of organizational initiatives are undertaken, such as a foundation, cluster, competence centre, thematic platforms or individual research and development projects. These initiatives are supported by: Ministry of Entrepreneurship and Technology, Ministry of Science and Higher Education, National Centre for Research and Development, Polish Economic Development Agency, Chambers of Commerce, provincial and local self-governments.

5.1. Foundation of the Future Industry Platform [13],[14]

The aim of the Foundation of the Future Industry Platform will be to promote the growth of entrepreneurs' competitiveness and their development towards Industry 4.0. This includes support for their digital transformation in the area of processes, products and business models, using the latest achievements in the field of automation, artificial intelligence, telecommunication technologies and communication between machines and between humans and machines.

The Act [12] on the Foundation of the Future Industry Platform is the result of the implementation of the project Polish Industry 4.0 Platform, included in the Strategy for Responsible Development. It points to reindustrialization as one of the pillars of the new economic model for Poland.

5.2. Industry 4.0 National Cluster [15]

The INDUSTRY 4.0 National Cluster was created as a result of an initiative of industries located in Podkarpacie and the Central Industrial District in cooperation with the Rzeszów University of Technology as a response to the dynamic development of innovative computer support systems for manufacture, automation and computerization of manufacturing processes compliant with the INDUSTRY 4.0 concept. On the basis of the founding documents

signed on 6 October 2017, the Association was granted legal personality on 8 November 2017 and was registered as the INDUSTRY 4.0 National Cluster Association. Based mainly on the achievements of the Central Industrial District, the Cluster aims to develop innovative solutions for the Polish industry and to strengthen its international position in the area of innovative technologies. The seat of the Cluster is Rzeszów, the capital of the Podkarpacie province.

5.3. Incubator of Industry 4.0 Leaders [16]

An interesting project implemented at the Silesian University of Technology in Gliwice is the Incubator of Industry 4.0 Leaders, which is a response to the demand for staff working for the Polish Platform of the Future (PPP) and Centres of Industry 4.0 Competence (CKP4.0). The aim of the project is to prepare trained staff based on equal standards and representing a high level of technical knowledge in the area of new technologies and business models. The new staff will carry out the tasks of PPP and CKP4.0 (promoting the idea of Industry 4.0 - Industry 4.0 technologies) and their integration. The institution managing the Incubator of Industry 4.0 Leaders is the Ministry of Development, while the coordinator of the Incubator is the Silesian University of Technology.

The one-term training course project is dedicated to:

- (S) PhD students and young researchers (up to 35 years old) with a technical background;
- (N) university teachers and/or industry representatives.

5.4. Silesian Competence Centre for Industry 4.0 [17]

In 2017, the Silesian Competence Centre for Industry 4.0 (SCKP 4.0) was established by the joint initiative of the Katowice Special Economic Zone and the Silesian University of Technology. The agreement officially establishing SCKP 4.0 was signed on February 21, 2018 at the Ministry of Entrepreneurship and Technology.

The Silesian Competence Centre for Industry 4.0 operates in the "one-stop-shop" model covering knowledge and access to advanced Industry 4.0 technologies. SCKP 4.0 guides the beneficiaries (entrepreneurs and employers) through the successive stages of the digital transformation. The beneficiary or the partner of SCKP will then:

- be more aware of the benefits and risks of the digital transformation process;
- better plan and safely conduct the digital transformation process;
- effectively involve staff in the implementation of digital transformation;
- become a more dynamic organization (flexible, conscious, effective in reactions to changes).

5.4.1. Collaboration between OBRUM and SCKP

The OBRUM Management Board has decided to include Industry 4.0 in new work areas that allow employees to meet upcoming challenges. OBRUM declared its will to cooperate with the Silesian Competence Centre for Industry 4.0 by signing a Letter of Intent on May 10, 2019 (Fig. 4).

Fig. 4. Signing of the Letter of Intent (photo by OBRUM)

OBRUM, for the purposes of external communication, will be able to use the status of a "Partner of the Silesian Competence Centre for Industry 4.0".

6. SUMMARY

The challenges faced by employees of modern plants that implement modern 4.0 Industry technologies urge these employees to continuously acquire and supplement their knowledge virtually during the whole of their professional career. The transformation of manufacturing processes and changes related thereto has an impact not only on managerial staff and specialists, but also on machine operators and production line workers. *The opportunity to work with modern equipment is perceived by many people as an element of professional development (although of course one can also observe obvious opposition, often resulting from the fear of the unknown). However, it is significant that there is no simple relationship between the employee's age and his/her aspirations to adapting to Industry 4.0.* [3].

In the Smart Industry Poland 2019 report [2], the research team draws attention to the issues of education. Over half of the respondents considered the current educational system to be unsuited to the requirements of innovative industry. This is noticed especially by senior engineers, who observe that the education of young employees does not comply with the present-day needs.

Both in Poland and in other countries, there are voices saying that the competencies and skills of engineers differ from the requirements of employers, which in turn have been imposed as a result of dynamic changes brought about by the industrial revolution 4.0. This applies to both the people who are already employed as well as to graduates of the technical universities looking for their first job in their profession [3], [4], [5].

Employers also send a message to the representatives of technical universities. For years, the usual model of engineering education was a deep, but quite narrow technical specialization.

While Polish universities certainly can educate good engineers, nowadays something more is needed because the concept of an engineer evolves. Industry 4.0 will require an interdisciplinary approach spanning many university faculties, as well as combining knowledge and skills in several fields [2], [3], [4].

In spite of a number of innovative actions and undertakings that modify the national education system at secondary and higher levels, we have a long way to go to achieve Western standards. Large expenditures are still required to provide education that combines knowledge with skills. The workplace will then become a place where graduates develop and gain experience, rather than learn [7].

Industry 4.0 Engineer and Manager - these are new specialists who will be increasingly sought after in the labour market, and who will be more difficult to find due to the greater demand for these specialists.

Entrepreneurs planning to introduce new technologies, while optimizing the costs of their implementation, should take evolutionary approach to changes, by gradually preparing and adapting managerial staff and specialists to the Industry 4.0 projects.

7. REFERENCES

[1] Schwab K.: Czwarta rewolucja przemysłowa. Wydawnictwo Studio EMKA. Warszawa, 2018.

[2] Smart Industry Polska 2019. Inżynierowie w dobie czwartej rewolucji przemysłowej. Raport z badań. Ministerstwo Technologii i Przedsiębiorczości / Siemens. Warszawa, May 2019. https://www.siemens.pl/pool/files/2019_05_smart-industry-polska2019_raport.pdf [Retrieved: 12.06.2019]

[3] Piątek Z.: Kim powinien być inżynier w Przemyśle 4.0? , Automatyka B2B.Portal Branżowy, 22 August 2018, https://automatykab2b.pl/gospodarka/49961-kim-powinien-byc-inzynier-w-przemysle-4-0 [Retrieved: 12.06.2019]

[4] Inżynierowie Przemysłu 4.0. [Nie]gotowi do zmian. ASTOR WHITEPAPER 2017. ASTOR sp. z o.o., Kraków 2017 https://www.astor.com.pl/images/Industry_4.0_Przemysl_4.0/ASTOR_Inzynierowie_4.0_whitepaper.pdf [Retrieved: 25.04.2019]

[5] Bujara M.: Umarła fabryka, niech żyje fabryka. Gazeta Wyborcza. Sobota-niedziela 16 -17 September 2017. Magazyn Świąteczny.

[6] Zawłocki I., Niewiadomski K.: Kształcenie i doskonalenie kadr pracowniczych w dobie czwartej rewolucji przemysłowej. Edukacja-Technika-Informatyka. No. 3/21/2017.

[7] Panasiuk J., Kaczmarek W.: Zapewnienie ciągłości edukacji technicznej w kontekście wymagań Przemysłu 4.0. Napędy i Sterowanie. No. 6, June 2018.

[8] Act of 20 July 2018. Law on higher education and science. Dziennik Ustaw 2018, item 1668.

[9] Kształcenie inżyniera przyszłości. http://pg.gda.pl/info/cdio/ [Retrieved: 12.06.2019]

[10] Sobieszczyk S., Zieliński A.: System kształcenia inżynierów przyszłości: Conceive-Design-Implement-Operate (CDIO) https://pg.edu.pl/documents/10607/4567904/bfda0c64900375a140f7cf91ab0de34f.pdf [Retrieved: 12.06.2019]

[11] Ranking Szkół Wyższych 2019. Perspektywy. http://ranking.perspektywy.pl/RSW2019/ [Retrieved: 12.06.2019]

[12] Piątek Z. Jak rozwijać kompetencje inżyniera 4.0? http://przemysl-40.pl/index.php/2018/04/11/jak-rozwijac-kompetencje-inzyniera-4-0/ [Retrieved: 12.06.2019]

[13] Act of 17 January 2019 on the Foundation of the Future Industry Platform**.** Dziennik Ustaw 2019, item 229.

[14] Przemysł 4.0. https://www.gov.pl/web/przedsiebiorczosc-technologia/przemysl-40 [Retrieved: 13.06.2019]

[15] Krajowy Klaster Industry 4.0. http://industry40.edu.pl/o-nas/ [Retrieved: 12.06.2019]
[16] Inkubator Liderów Przemysłu 4.0. http://przemysl40.polsl.pl/ [Retrieved: 13.06.2019]
[17] Śląskie Centrum Kompetencji Przemysłu 4.0. http://www.ksse.com.pl/test-2335 [Retrieved: 13.06.2019]