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## **INTRODUCTION**

In the face of current economic changes, far-reaching changes in business are necessary. The sources of success are seen in building a knowledge-based economy. It is assumed that in conditions of continuous uncertainty only knowledge can constitute a competitive advantage of enterprises, and the organization's success lies in the unique way of acquiring, processing and creating knowledge (Beyer, 2012; Davenport, 2007; Drucker, 2010; Sveiby, 1997; Toffler 2006). Changing the operating conditions of modern enterprises requires adaptation, among others in the field of human resources (Appelo 2016; BRICS 2016; Hollinger 2016; Stoch, Gracel 2017). The emergence of new advanced technologies will significantly transform the nature of employment (Gartner 2017). In the era of the fourth industrial revolution, robots are increasingly taking over manual and repetitive work. However, people are required to operate them as well as control the implementation of processes in the enterprise. The increase in digitization creates new opportunities and at the same time generates unrecognized threats. What constitutes human advantage over a machine today are soft competences, e.g. creativity (Gracel and Makowiec, 2017; Palti, 2017).

According to the report of the Organization for Economic Cooperation and Development (OECD) entitled OECD Employment Outlook 2019 (The Future of Work) OECD predicted that almost 46% of existing jobs will be subject to a comprehensive change (of which 14% in the next 15-20 years may cease to exist as a result of automation, and another 32% is likely to be affected by the

specter of radical transformation, because individual tasks will be automated). Newly created jobs will increasingly require transversal competences and high qualifications in advanced technologies. Report of the World Economic Forum (WEF) entitled The Future of Jobs Report 2018 on the future of jobs (World Economic Forum 2018) indicates that by 2022 as much as 54% of employees will require a significant increase in their competences. Large-scale enterprises will be forced to take action to increase skills and/or retrain the workforce.

The role of engineers in the knowledge-based economy is different than it used to be in the traditional manufacturing environment. The engineer, in addition to consistently important technical competences, must be aware of the importance of soft competences and the ability to skillfully integrate them. Should demonstrate the ability to associate issues in the field of specialized technologies and industrial processes with elements of management and entrepreneurship (Łapuńska et al., 2020).

It is a great challenge for engineering programs to prepare graduates for what the future job market will require. Lining up engineering educational objectives and outcomes with industry needs is a great challenge. An ongoing survey of industry needs is essential in determining the importance of competences needed in engineering practice. By assessing in the same survey, the level of preparation of engineering graduates allows to determine the discrepancy and areas where corrective action in the curriculum is required.

The aim of the study is to analyze of industry expectations related to engineering graduates in Poland and the United States (USA). According to The Global Competitiveness Report (Schwab, 2018) and International Institute for Management Development (IMD) World Competitiveness Yearbook Ranking (2019), the USA is one of the best countries in the world in terms of economic competitiveness. In view of that, the experience of USA enterprises can be used as a background for considerations for Polish industry expectations related to engineering competences as well as the possible direction of change in Poland in this area.

## **THEORETICAL BACKGROUND**

Engineering programs are preparing graduate for multiple variety of carriers: government careers, academic careers and work in industry (Choe NH and Borrego M., 2020). In the traditional system of training, students mostly acquire theoretical competences. University is guided by the requirements of educational standards and qualification requirements, related to engineering specialty. Engineering specialist must have a certain set of knowledge and skills (Dubovikova, 2019). Dubovikova (2019) noticed also a gap: "young specialists lack developed independence, sense of self-identity and creativity within their profession".

University aims at development of general and professional competences, corresponding to the characteristic of the future professional activities of graduates (Dubovikova, 2019). Competence contains aspects of knowledge,

skills and abilities or personality characteristics (Syahmaidi et al., 2019). Engineering competencies include the following: theoretical knowledge, skills and ability, practical experience, method of training and method of implementation, activity, attitude and soft skills. Dubovikova (2019) divides competences gained by a engineering student by: universal competences (general scientific, social, personal, non-technical) and professional competences (general professional and major-specific).

Gorshkova (2019) focused on teaching engineering students to conduct research. This can be done by incorporating research in the educational process of the university. It provides valuable attitude to research, ability to identify information insufficiency and knowledge for solving research engineering problems.

Nowaday believe we need interdisciplinary, competence and practice-oriented approach to the education (Fedoseeva et al., 2019; Srgeeva et al., 2019). Ghonim and Eweda (2019), confirm that based international study. Results "considered new deliverables, such as writing, theory, built projects, and creative products, which extend beyond the scope of architectural design". Highlights also, necessity of live projects, which should be provided in education. Interdisciplinary approach in education involves various methods of implementing the system of training highly skilled engineers (Fedoseeva et al., 2019). The process of educating engineers should cover many aspects like: research carried out using the developed practice-oriented techniques, independent work, special forms and extracurricular activities, information technology, system of tasks, complex and end-to-end research projects, interactive forms and methods, self-control and self-assessment of students in the learning process (Gorshkova, 2019).

It is necessary to take into account the level of readiness of the teaching faculty to improve curricula and methods (Gorshkova, 2019; Smirnova et al., 2019; Srgeeva et al., 2019). Syahmaidi, et al. (2019) indicated that key factor for engineereng education is pedagogical competences of teaching staff.

Highly skilled engineers – what those that means? One of the aspects is corresponding to market needs. Balve and Ebert (2019) conducted research in Germany, aimed at answering the questions of how the competence profile required by the industry from the graduates' perspective looked like. They took into account the wide range of graduate competences divided into four groups: professional competences (e.g. knowledge of IT, knowledge of engineering methods), methodical competences (problem-solving ability, analytical skills), social competences (communication ability, oral expressiveness), self-competences (decision-making ability, adopt to changing circumstances). The results confirmed that the industry value the most so-called soft skills: self-competences and methodological competences.

Soft skills become crucial for engineers. For example, Fedoseeva et al. (2019) focused on development of teamwork skills of students. The team-building competence could be formed during instruction time and extracurricular time: in

research, internships, sports and other activities at university. Interesting is also concept of "humanization" of the modern higher education. Sabirova et al. (2019) focused on five parameters: traditional, national and universal humanistic and democratic values; service to the Fatherland and its protection; attitude to physical and psychological health; the adoption of traditional values of family life and the implementation of their own life plans and attitude to professional activities.

## LEGAL BACKGROUND

In Poland to create a new academic program, at baccalaureate or master's degree level, permission is required from the State Department of Education (Minister of Education). The university applies for permission to establish academic program in a specific field, level and specialty. The application to create a program shall be submitted no later than six months before the planned commencement of studies. The minister issues a permit after consulting the following (Rozporządzenie Ministra Nauki...):

- PKA (Polish Accreditation Commission) on meeting the conditions for conducting studies at a specific field, level and specialty as well as the alignment of the program with the university's strategic plan;
- Minister supervising the university.

The university assigns the proposed program to at least one discipline. If a proposed program is assigned to more than one discipline, the leading discipline shall be indicated in which more than half of the learning outcomes will be obtained.

Studies can be conducted in the form of (Rozporządzenie Ministra Nauki...):

- Full-time studies (At least half of the ECTS credits covered by the program curriculum are obtained as part of classes with direct participation of academic faculty or other teachers and students);
- Extramural studies indicated in the resolution of the Senate (less than half of the ECTS credits covered by the program curriculum can be obtained with the direct participation of academic faculty or other teachers conducting classes and students).

Academic programs are offered at the listed below levels (Rozporządzenie Ministra Nauki...):

- First degree level (baccalaureate degree);
- Second degree level (master's degree);
- Combined first and second-degree level (baccalaureate degree and master's degree combined).

First- degree full-time studies last at least 6 semesters, and if the study program includes learning outcomes enabling engineering competences at least 7 semesters. Second-degree full-time studies last from 3 to 5 semesters. The combined first and second-degree programs (full-time) usually last from 9 to 12 semesters.

The study program is subject to systematic evaluation and improvement. Changes to improve the program are allowed. The changes can affect the program outcomes as well as the curricular content provided those changes in the program outcomes do not exceed 30% of the original outcomes when the program was established. Any curricular changes are implemented for the new cycle of education (They are affecting only incoming students and do not affect students already in the program).

Some minor changes can be implemented during the education cycle, but they are limited to the following (Rozporządzenie Ministra Nauki...):

- Changes in the content of the courses resulting from changes in the economy and society (scientific discovery, new technology, changes in professional practice, etc.);
- Changes necessary for:
  - Complying with the requirements and recommendation of the accreditation agency (Polish Accreditation Commission);
  - Compliance of the program with the new rules and regulations implemented by the government or professional requirements.

Changes in study programs introduced during the education cycle are made available in BIP on the university's website at least one month before the beginning of the semester to which they relate.

The systems of higher education in Poland and the USA are different. Most Engineering programs in the USA are being accredited by the Accreditation Board for Engineering and Technology (ABET). Accreditation criteria requires every engineering program to have a continuous quality improvement (CQI) process in place to make sure that the program is responsive to the continuous changing requirements of industry. Every engineering program needs to have clearly stated program educational objectives and student outcomes. Program educational objectives need to be reviewed periodically (usually every three years) to assure that the program educational objectives reflect and coincide with industry needs. Industry needs and expectations in the knowledge-based economy are changing. The program educational objectives need to adapt, so that the graduates can be fully employable. Most engineering programs do ongoing surveys of the former graduates as well as surveys of the companies hiring program graduates.

The propose of the survey is to identify the following:

- Level of importance to industry of different competences that industry expects of engineering graduates;
- Discrepancies between the level of preparation of engineering graduates and industry expectations.

The feedback received from former graduates of the engineering program as well as the industries hiring those graduates allows the programs to close the loop of continuous quality improvement. Every year some minor curricular changes are being implemented while some major changes take place at a three-year interval.

## METHODOLOGY OF RESEARCH

The research was carried out in 2019 and 2020. The survey was conducted in 92 companies operating in the USA and 86 from Poland. The stages of research are presented in Figure 1.



Fig. 1 Stages of the research

The criteria for selecting enterprises were based on the following:

- Diversity criterion (enterprises represent various industries);
- Willingness of the company to participate (not all want to participate in the study);
- Compatibility criterion (research focused on companies hiring engineering graduates).

## RESULTS OF THE INDUSTRY SURVEY IN THE USA AND POLAND

The results of the industry survey in the USA and in Poland is shown in Table 1. The data was collected in ninety-two companies and USA and in eighty-six companies in Poland hiring engineering graduates. In the USA, the companies are mostly medium-size companies with 50-500 employees. However, some companies are larger with 500-1,500 employees. In Poland, the research sample was very diverse. Small, medium and large companies that represented many industries were examined. All of them belonged to the group of manufacturing enterprises. The survey focused on engineering supervisors working with graduates from an engineering program.

The individuals taking the survey were assessed on a scale 1-5 related to the importance of different competences in engineering practice. They were also assessing the level of mastery of those skills and attributes by graduates of an engineering program. In Table 1 arithmetic mean was used.



### Results of the industry survey in Poland

Employers are expecting a diversity of skills (Table1). The most important skills are listed below:

- Computers and related technologies (4.95);
- Using computers and information technology (4.91);
- Works with others (4.84);
- Engineering design and analysis (4.80);
- Practical skills necessary to obtain employment (4.77);
- Articulating yourself orally (4.74);
- Knowledge of science, mathematics and engineering principles (4.65);
- Problem solver (4.65);
- Communications (4.61);
- Professional work-related skills (4.60);
- Design of processes, systems or devices (4.55);
- Solving real-world problems (4.55);
- Using quantitative analysis to solve problems (4.54);
- Lifelong learning (4.53);
- Teamwork (4.52).

The collected data indicated that technical skills as well as the soft skills like teamwork, etc. are important to prospective employers hiring engineering graduates. The skills related to information technology (IT) and usage of the computer network are also highly rated.

It is interesting that all skills except art were rated above 4 points. This may mean that employers are increasingly expecting versatility, creativity and an open attitude, which is consistent with the idea of knowledge-based economy. Graduates often do not meet all the expectations of employers. The Engineering programs do not always keep up with changes in the economy. Sometimes they focus only on selected areas or do not focus on the development of an innovativeness attitude. The largest discrepancies between the employer's expectations and the actual skills of graduates relate to:

- Developing personal ethics and values (1.43);
- Works with others (1.29);
- Has practical skills necessary to obtain employment (1.25);
- Is a problem solver (1.22);
- Can define the problem (1.07);
- Solving real-world problems (1.03);
- Using quantitative analysis to solve problems (0.90);
- Articulating yourself orally (0.69);
- Engineering design and analysis (0.68);
- Teamwork (0.67).

It is interesting that in the range of skills listed below, graduates exceed the expectations of employers in the following:

- Broad general subject knowledge (-0.31);
- Global and societal aspects (-0.21)



- Humanities (-0,03).

### **Results of the industry survey in the USA**

Based on the data collected from industry (Table 1), it was a relatively easy task to identify the most important and valuable competences in engineering practice (which have the highest rating of 5) are as follows:

- Teamwork;
- Communication;
- Lifelong learning;
- Articulating yourself in writing;
- Articulating yourself in speaking;
- Working well with others;
- Personal ethics and values;
- Ability to define a problem;
- Ability to be a problem-solver;
- Understands environmental concerns.

It was surprising that non-technical soft skills were considered the ones that employers valued most. An explanation could be that most engineering programs are focusing too much on technical and scientific subjects and neglect the development of the soft skills needed by industry. Engineers work in teams and need to be team-players working well and communicating well with others. This is especially important in the knowledge-based economy. The engineering profession is being considered ethical. Engineers need to conduct themselves according to the code of engineering ethics. Understanding the global aspect of the economy, especially when engineers work on environment related projects. The knowledge-based economy requires engineers to define problems that others do not see and solve those problems. This was also listed as a high priority attribute.

The biggest discrepancy between the importance of competences and the preparation of engineering graduates in those areas are as follows:

- Defining and the problem (2.05);
- Working with others (1.95);
- Personal ethics and values (1.95);
- Understands global concerns (1.95);
- Understands environmental concerns (1.65).

Many engineering programs are focusing too much on the technical aspect of the education and do not emphasize enough the humanities, social and behavioral sciences and arts components of the curriculum. Most engineering programs require the following:

- Two courses in social and behavioral sciences (combined ninety hours of lecture);
- Two courses in humanities (combined ninety hours of lecture);
- Two courses in arts (combined ninety hours of lecture);
- One course in verbal communication (forty-five hours of lecture);

- One course in technical writing (forty-five hours of lecture).

Regardless of those courses, there is a gap between the level of preparation of the engineering graduates and the level of the importance of those topics.

## CONCLUSIONS

The environment of education and sociocultural trends of the modern educational system undergone transformations (Castro-Bedrin et al., 202; Haidi and Rabiman, 2019; Sabirova et al., 2019; Racero et al., 2020; Zamaletdinova et al., 2019). Research (including Gartner, OECD, WEF) indicates that in the coming decade many new job categories will appear, partly or completely replacing existing jobs. The skill required for both old and new professions will change radically in most industries changing entirely the employment pattern, (Łapuńska et al., 2020). This means that curricula must be adjusted to the expectations of the modern world.

The conducted research among Polish and American entrepreneurs focused on the competences of graduates of Engineering programs which are expected by future employers. The approach of entrepreneurs to graduates of engineering studies in Poland and the USA is different.

In the USA entrepreneurs have higher expectations, and the importance of individual competences is also different. Up to 22 criteria rated above 4.5 on the Linkert scale. In Polish enterprises, there were 15 criteria. In the USA, entrepreneurs pay special attention to soft skills, such as teamwork, communication, lifelong learning, articulating yourself in writing and speaking, etc. In Polish enterprises, mainly technical skills are expected, e.g. computers and related technologies, using computers and IT, engineering design and analysis. In both countries the employed engineer should have the skills to work with others, that is to work in project teams. Entrepreneurs from both Poland and the USA signaled discrepancies between expected and real qualifications in terms of criteria: works with others, developing personal ethics and values and can define the problem. In America, discrepancies also apply to understands global and environmental concerns. In Poland, however, the differences were additionally demonstrated in solving real-world problems and using quantitative analysis to solve problems.

After obtaining such interesting information, it should be applied while revising curriculum in existing programs or developing new ones. The changes in the economy and market requirements should directly influence program educational objectives and academic content of the courses. Entrepreneurs create jobs for future graduates and their feedback during the development of academic programs is essential. An ongoing working relationship between universities and business cannot be overemphasized.

The main research limitations include the small research sample, due to the availability of data. The enterprises came from specific regions of given countries. In the future, consideration should be given to the randomness of the sample and its increase. It would also be interesting to relate the research

results to the time necessary to introduce an employee-graduate to a new job, or to examine the relationship of qualifications of an engineering graduate to a professional career or company results.

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**Abstract:** The paper contains a comparative analysis of the competences needed to practice engineering in Poland and the United States (USA). Surveys of industries were conducted in Poland and the USA. Legal background of curricula was discussed. The surveys were done for the purpose of assessing the importance of competences as well as level of mastery those skills and attributes by engineering graduates. The results confirm differences in approach of entrepreneurs to graduates of engineering studies in Poland and the USA. In the USA entrepreneurs have higher expectations and the importance of individual competences is also different. The comparative analysis was done to identify the weaknesses in the engineering curricula and identifying the best practices.

**Keywords:** engineering education, graduate's competences