

COMPARATIVE ANALYSIS OF THE CURRICULUM OF MECHANICAL ENGINEERING PROGRAM IN POLAND AND THE UNITED STATES

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Purpose: The aim of this paper is comparison of the Curriculum of Mechanical Engineering Program in Poland and the United States. One of the institutions is The Pennsylvania State University (PSU), in the United States (USA). The other institution is Politechnika Opolska (PO), in Poland.

Design/methodology/approach: Desk Research Method is used. Paper is based on Politechnika Opolska' documents and The Pennsylvania State University' documents.

Findings: The paper addresses the similarities and differences in both curricula. It also addresses the positive and negative aspects of both curricula. The strengths and weaknesses from the perspective of the future career development of graduates is also being addressed. Both Mechanical Engineering programs are striving for excellence in preparing students for engineering jobs in industry, but the philosophy of those programs is very different. The Mechanical Engineering program at PSU is providing the student with a stronger theoretical background. Graduates from the PO program are well-trained in application-focus current industry practices. They are not going to require on-the-job training after entering industry. There are also suggestions and recommendations for both programs from the perspective of identifying the best practices.

Originality/value: The article contains a comparative analysis of the curricula of the Mechanical Engineering program at The Pennsylvania State University USA and Politechnika Opolska, Poland. The comparison of the curricula was done using the most recent catalogs of both programs. The authors of the article have had experience as faculty at their respective programs. The comparative analysis was done for the purpose of identifying the best practices and subsequent follow-up. The article addresses the similarities and differences as well as the strengths and weaknesses of both programs. The article also contains suggestions and recommendations for both programs.

Keywords: Curriculum development, engineering curriculum, mechanical Engineering.

Category of the paper: Research paper.

1. Introduction

Higher education is a crucial sector for transfer of knowledge and innovation. The education process, innovation in teaching and the graduates' integration into the labor market are important for regional economic development and contribute towards building dynamic environment for innovation. The learning environment is continuously changing. This requires a constant revision of the teaching methodology and analysis of the curriculum (Epure, 2017; Duever, 2019; Rampersad, 2015).

The aim of this paper is comparison of the curriculum of the Mechanical Engineering program in Poland and the United States. Statistical data from Organisation for Economic Cooperation and Development (OECD) confirm that, indicators like: mathematical performance (measures the mathematical literacy of a 15 year-old to formulate, employ and interpret mathematics in a variety of contexts to describe, predict and explain phenomena, recognizing the role that mathematics plays in the world), reading performance (measures the capacity to understand, use and reflect on written texts in order to achieve goals, develop knowledge and potential, and participate in society) and scientific performance (use of scientific knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues) – are higher value for Poland than for USA (OECD). On the other hand, according to The Global Competitiveness Report 2018 published by The World Economic Forum, assessing the competitiveness of economies, the USA is a pioneer (overall score), Poland – rank 37 (Schwab, 2018). It is necessary to find a way to improve this situation. One of possibility could be higher education adjusting curriculum to changes in the environment.

Engineering is an application-focused discipline. It used to be very practical. Before the Engineering programs at the university-level were created, engineers were trained in a trade-apprenticeship program. Designing, analyzing and building an invention was done by the same person or team under the supervision of the master. By the 1970's, engineering programs in the USA were coming very scientific and theoretical. While the engineering programs were becoming very theoretical, there was a need in industry for practically trained professionals. To satisfy this need, many educational institutions started Engineering Technology programs for the purpose of training hands-on engineers. Many educational institutions in the USA offer simultaneously Engineering and Engineering Technology programs targeting two different job markets. There is a significant overlap between the Engineering and Engineering Technology curricula.

Desk Research Method is used. Paper is based on Politechnika Opolska' documents (Study Plans...) and The Pennsylvania State University' documents (Program description...).

2. Theoretical background

The learning environment is continuously changing and causes modifications on every level of education (Martínez-Medina, and Arrebola, 2019; Saraiva et al., 2019). Martínez-Prado et al. (2018) noticed “technological changes require a new and different set of skills every time a novel technique raises; this involves updating the academic curricula every few years”. For example, emerging technologies referred to as ‘fourth industrial revolution’ have prompted many to develop student's socio-technical skills (Trevelyan, 2019). Demand from employers for graduates’ skills are also modified. This requires a constant revision of the textbooks, tools (software and hardware), courses teaching methodology (Bennedsen et. al. 2018; Litster et. al., 2020) and analysis of the curriculum (Epure, 2017; Rampersad, 2015). For example, Martínez-Prado et. al. (2018) focused on using a robot motion controller for an undergraduate laboratory study program. Stammes et al. (2020) highlight design practices in education. It is a way to engage students in “applying science concepts, in developing soft skills, and in applying or developing research practices”. White et all (2020), emphasized “training undergraduates in experimental design and data analysis/presentation skills especially as it applies to living systems”. Cameron and Birkett (2020) proposed Process Systems Engineering concepts, as approaches for updating higher education curricula.

Nowadays engineering curricula should contains many aspects of business reality, such as ethical, ecological, cultural, safety, etc. Bairaktarova and Pilotte (2019) noticed that “engineering practice is meant to advance the human condition, yet curricula do not appear to fully promote the human-centered philosophy of engineering in implementation”. Hoven (2019) noted aspect of comprehensive engineering. “Comprehensive engineering implies ethical coherence, consilience of scientific disciplines, and cooperation between parties” (Hoven, 2019; Taebi, and Kastenber, 2019). Jordan et al. (2019) focused on cultural aspects connected with engineering work. They indicated the necessity to develop culturally responsive engineering curriculum. Gunasekera et al. (2020) focused at safety in engineering education. Safety is an one of important area and the nowadays the trends in environmental safety promote this. It is extremely important in engineering work for example identify hazards connected with equipment design due to specification of this equipment, its type, process conditions, substances involved et al.

Sustainability has emerged as a new area of interest. Sustainability concentrates on the interactions between nature and society (Sánchez-Carracedo et al., 2019; Salovaara, Soini, and Pietikäine, 2019). For example, Durrans et al. (2020) noticed "there is an urgent need for educational institutions to produce graduates with appropriate skills to meet the growing global demand for professionals in the sustainable energy industry”. Research results (Vargas et al., 2019) suggested that policy frameworks for sustainable development implementation should include "collaboration, partnership, education, outreach, teaching and learning, staff

development, curriculum review, research, campus operations and policy". It requires developing the fields of management, research and development, teacher evaluation as well as changing academic programs (Tejedor et al., 2019; Weng, Liu, and Chuang, 2019).

Peña and Ballesteros (2016) brings attention to "the gulf that exists between the academic system and the needs of businesses" and highlight "the lack of a genuine climate of cooperation as identified as one of the causes". Litster et al. (2020) highlight the cooperation between both academia and industry to achieve a significantly higher percentage of engineers trained in engineering science. Working knowledge and practicality of engineering design prepares students for embracing the challenges of the future. To support students in developing these capabilities, teachers are tasked with the responsibility of facilitating science instruction that integrates science and engineering practices (Brand, 2020). Brand (2020) focused on factors that motivated teachers to reform their instructional practices. His results indicate, it is necessary the need to shift teaching philosophies related to teacher's learning environments and their instructional practices.

3. Results

3.1. Comparative analysis of the foundation courses

Foundation courses for Engineering programs are Mathematics, Physics and Chemistry. The comparison of the curricula requirements in those areas for the two curricula are shown in Table 1. To compare the courses, it was necessary to adapt the same method for calculating the number of credit hours that students are granted for the course. The method used in the USA is based on the number of hours spent in the classroom according to the policy as follows:

- 15 hours of lecture is equivalent to 1 credit,
- 30 hours of lab is equivalent to 1 credit.

No credits are given in the USA for consultation time or the work that the student does on their own time. Credits are given only for the time of direct contact. European credits (ECTS) include the time that the student is spending after class time. Course outlines for Politechnika Opolska (PO) list the number of hours for direct contact. It was relatively easy to calculate the number of credit hours used by the system at The Pennsylvania State University (PSU). The PSU Admissions Office is doing this if the student transfers from European to a USA university.

Comparing the requirements in the foundation courses (Mathematics, Physics and Chemistry), it is obvious that the Mechanical Engineering program at PSU is more theoretical than the Mechanical Engineering program at PO. The Mechanical Engineering program at PO is more application focused and equivalent to the Mechanical Engineering Technology

program in the PSU system. This will be discussed in greater detail when a comparison is made of the technical courses.

Table 1.
Curricula requirements in foundation courses

| The Pennsylvania State University United States | | Politechnika Opolska Poland | |
|--|---------|--------------------------------|---------|
| Mathematics | | Mathematics | |
| Course | Credits | Course | Credits |
| Calculus I MATH 140 | 4 | Pre-calculus MATH 1 | 3 |
| Calculus II MATH 141 | 4 | Calculus I MATH 2 | 1.5 |
| Differential Equations MATH 251 | 4 | Calculus II MATH | 1.5 |
| Calculus of Several Variables MATH 231 | 2 | | |
| Matrices MATH 220 | 2 | | |
| Physics | | Physics | |
| Mechanics PHYS 211 | 4 | General Physics PHYS | 1.5 |
| Electricity and Magnetism PHYS 212 | 4 | | |
| Quantum Mechanics PHYS 214 | 2 | | |
| Chemistry | | Chemistry | |
| General Chemistry CHEM 110 | 3 | General Chemistry CHEM | 1.5 |
| Chemistry Lab CHEM 111 | 1 | | |
| Organic Chemistry CHEM 112 | 3 | | |

3.2. Comparative analysis of common technical courses

Technical courses in both programs have their equivalency as shown in Table 2.

Table 2.
Equivalent courses in the Mechanical Engineering programs of The Pennsylvania State University and Politechnika Opolska

| The Pennsylvania State University (Technical Courses/Credits) | | Politechnika Opolska (Technical Courses/Credits) | |
|--|---------|---|---------|
| Course | Credits | Course | Credits |
| Computer Science SMPSC 200 | 3 | Information Technology | 2 |
| Statistics E MCH 211 | 3 | Numerical Methods | 2 |
| Dynamics E MCH 212 | 3 | Mechanics | 1.5 |
| Strength of Materials E MCH 213 | 3 | Mechanics | 3 |
| Engineering Design and Graphics EDSGN 100 | 3 | Strength of Materials | 3 |

Cont table 2.

| | | | |
|--|-----|--|-----|
| Engineering Thermodynamics ME 300 | 3 | Descriptive Geometry of Engineering Graphics | 3 |
| Product Design and Manufacturing Processes IE 312 | 3 | Thermodynamics | 3.5 |
| Properties and Processes of Engineering Materials MATSE 259 | 3 | Machining Processes | 3 |
| Computational Tools ME 300 | 3 | Material Science | 1.5 |
| Circuit Analysis, Instrumentation, Statistics ME 348 | 3 | Elements of Information and Computer Technology | 3 |
| Academics and Career Development ME 390 | 0.5 | Electrical Engineering | 1.5 |
| Mechatronics ME 454 | 3 | Industrial Practice | 0.5 |
| Mechanical Engineering Design ME 340 | 3 | Selected Measuring Technology | 3 |
| Mechanical Design ME 360 | 3 | Technological Process Design | 4 |
| Fluid Mechanics ME 320 | 3 | Mechanical Engineering Design | 4 |
| Professional Development of Mechanical Engineers ME 490 | 0.5 | Fluid Mechanics | 3 |
| | | Protecting Intellectual Properties | 1 |
| | | Materials Engineering | 2 |
| | | Automation Robotics | 3 |
| | | Engineering Graphics with CAD | 2 |
| Final Project | | Final Project | |

Many courses offered in the Mechanical Engineering program at PO do not have any equivalent or similar courses at PSU. Those courses are listed in Table 3.

Table 3.

Courses offered at Politechnika Opolska not having equivalency to The Pennsylvania State University System

| Courses | Credits |
|-------------------------------------|---------|
| CAD I | 0.5 |
| CAD II | 0.5 |
| CAD III | 0.5 |
| CAD IV | 0.5 |
| CAD V | 0.5 |
| CAD | 2 |
| Ergonomics and Industrial Safety | 1 |
| Techniques for Generating Energy | 2 |
| Technology of Industrial Operations | 2 |
| Technical Metrology | 1 |
| Basics of Ecology | 1 |
| Machines | 2 |
| Combustion Engines | 3 |

Cont table 2.

| | |
|--|-----|
| Machine Reliability or Quality Control | 2 |
| Material Shaping | 3 |
| Technological Machines | 2.5 |
| Machine Propulsion | 2.5 |
| Machine Control Techniques or CNC Programming | 2.5 |
| Maintenance of Vehicles and Machines | 2 |
| Techniques of Welding | 3 |
| Unconventional Manufacturing Techniques | 3 |
| Preparing Technical Documentation | 2.5 |
| Final Element Analysis | 3 |
| or | 2 |
| Technical Instrumentation | 3 |
| Production Management | 2 |
| Vehicle and Mobile Machines | 3 |
| Construction and Maintenance of Individual Apparatus | 3 |
| Diagnostic of Machines | 3 |
| Construction of Refrigeration Systems | 2.5 |
| or | |
| Technology of Machines and Equipment Repair | 3 |
| Apparatus Manufacturing and Technology | 3 |
| Theory of Mechanisms and Machines | 2.5 |
| Computer-Aided Chipless Technologies | 2.5 |

As shown in Table 3, the Mechanical Engineering program at PO requires students to take many very detailed specialized courses. The purpose is to better prepare students to enter a diverse job market in industry. This allows graduate to rapidly meet the demands of industry after finding employment. This characteristic is very typical of Mechanical Engineering Technology programs preparing graduates to enter the job market without the need for additional on-the-job training. The Mechanical Engineering program at PSU also offers some courses which do not have any equivalency to the Mechanical Engineering program at PO as shown in Table 4.

Table 4.

Courses offered by The Pennsylvania State University not having equivalency in the Politechnika Opolska system

| Courses | Credits |
|---|----------------|
| Vibration of Mechanical Systems ME 370 | 3 |
| Heat Transfer ME 410 | 3 |
| Modeling of Dynamic Systems ME 450 | 3 |
| Engineering Technical Elective TE | 14 |

The courses like Vibration in Mechanical Systems or Modeling of Dynamic Systems as well as fourteen credits in technical electives are very theoretical and mathematically oriented. In general, the courses offered in the Mechanical Engineering program at PSU are more theoretical and more general in nature. Graduates from that program get a stronger theoretical preparation and have a much weaker preparation in application-focused concepts. As a result, graduates from the Mechanical Engineering program at PSU will require one-to-two years of on-the-job training after entering a position in industry. By having a stronger theoretical background, however, they can be more diverse and adaptable to the constantly changing demands of knowledge-based industries.

3.3. Comparative of general education courses

General Education courses support the technical courses and provide students with the soft skills needed to work in the engineering profession. Both engineering programs offer general education courses as shown in Table 5.

Table 5.

Comparison of the general education requirements The Pennsylvania State University and Politechnika Opolska

| The Pennsylvania State University United States (USA) | | Politechnika Opolska Poland | |
|--|---------|--------------------------------|---------|
| Course | Credits | Course | Credits |
| Rhetoric and Composition ENGL 15 | 3 | N/A | |
| Technical Writing ENGL 202C | 3 | N/A | |
| Speech Communication CAS 100 | 3 | N/A | |
| Humanities Electives | 6 | Humanities/Social Science* | 5 |
| Social Science Electives | 3 | * | |
| Freshman Seminar | 1 | N/A | |
| Physical Education | 3 | Physical Education | 1 |
| Foreign Language | N/A | Foreign Language | 4 |

Notes:

* Students may take a combination of Humanities and/or Social Science electives for a total of 5 credits.

N/A: Not applicable.

The Mechanical Engineering program at PSU requires more courses in the General Education category. Rhetoric and Composition in English as well as Technical Writing and Communication are required at PSU. Those courses are normally assessed as very important by former graduates and their employers. Every engineering student is also required to take an Economics course, either Microeconomics or Macroeconomics. Those skills are needed to communicate effectively with the business world either in applying for grants or justifying investments. Students are also required to take two arts courses, two humanities courses and one social science course. Those graduates make the graduates well-rounded individuals who understand the non-technical aspects of the world better. Every student at PO is also required

to take humanities, social science and foreign language courses. However, there are no courses in technical writing as well as oral and written communication.

3.4. Comparative analysis of technical electives

The Mechanical Engineering program at PSU has fourteen credits (average five courses) of technical elective requirements as shown in Table 3. Those technical electives allow students to pursue their own interests and to specialize in the area of the student's interest. If the students know their employment goals, they may take technical electives which will help them to meet those goals.

The Mechanical Engineering program at PO has two tracks. Elective courses are based on the track chosen by the student. After the track was chosen, the student has limited choices in course selection. The strength of that approach is that every graduate will have the same training and background. The weakness of that approach is the lack of flexibility in customizing the students' educational background.

4. Summary – similarities and differences

Both Mechanical Engineering programs offered at PSU and PO are striving for excellence in preparing students for engineering jobs in industry. The philosophy of those programs is very different. The Mechanical Engineering program at PSU is providing the student with a stronger theoretical background in Mathematics, Physics, Chemistry and fundamental engineering courses. The PSU program does not have significant application components reflecting industrial practices. The application-focused component will be learned during the first years of employment. Graduates will learn precisely what they need to know to handle the responsibilities of the job for which they were hired.

The Mechanical Engineering program at PO is more like the Mechanical Engineering Technology at PSU. Graduates from the PO program are well-trained, focusing on current industry practices. They are not going to require on-the-job training after entering industry. These are different philosophies of those two programs.

5. Discussion

The aim of this paper is comparison of the Curriculum of Mechanical Engineering Program in Poland and the United States. Both Mechanical Engineering programs represent different approaches to engineering education. Some industries prefer to hire Engineering Technology

graduates because of their application-focused background. Often there are voices in industry that feel that this is the better approach to engineering education. Some industries prefer to hire Engineering graduates because they have a more theoretical background and have a higher diversity of skills. Many people in industry believe that a stronger theoretical background is more valuable in the knowledge-based economy because a theoretical background never becomes obsolete. Industrial processes can change and quickly become obsolete. Presently there are jobs for graduates from both programs. It is important to collect feedback from industry and constantly adjust program educational objectives based on the demands of industry.

The next step of the research could be a more complex analysis of lecture content (e.g. ethical, ecological, safety, cultural aspects) and results of education (e.g. knowledge, soft skills, competence).

The comparative analysis will require a study of internal and external environment in both countries. It is necessary to pay attention to the differences e.g. financing the education, model of university-industry cooperation, political, economic, social, technological and ecological factors (Czerwińska et. al., 2019). Due to the length of the article, these differences were not provided.

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