

Production engineering curriculum in the context of Industry 4.0 – current state of art and necessary changes in AP of Vojvodina and Republic of Srpska

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Abstract: Industry 4.0 (I4.0) provides the framework for a new industrial revolution based on digitalization and networking. This production concept is based on the intelligent connection of mechanical engineering, electronics and software. The development of the I4.0 concept has directly contributed to the development of new technologies and business models as well as new ways of working and thinking. The implementation of Industry 4.0 technologies in the education of engineers is a basic prerequisite for the development of the economy and society. For this reason, university education of production engineers must constantly change and adapt to modern production technologies and systems. The widespread application of new technologies in production practise requires a rapid response from the university community, which is reflected in the introduction of innovations in the traditional education of production engineers. The paper analyses the current curriculum of production engineering studies at the Faculty of Technical Sciences in Novi Sad (Republic of Serbia, AP of Vojvodina) and the Faculty of Mechanical Engineering in Banja Luka (Bosnia and Herzegovina, Republic of Srpska) in terms of the requirements and needs of Industry 4.0. Based on the analysis, proposals and guidelines for their innovation were given.

Keywords: PRODUCTION ENGINEERING CURRICULUM, INDUSTRY 4.0, STATE OF ART, NECESSARY CHANGES

1. Introduction

By implementing the concept of Industry 4.0 in production, employers will demand new skills and abilities from their employees. The implementation of this concept in manufacturing will have a positive impact on companies in Serbia and Bosnia and Herzegovina by enabling: an increase in the competitiveness of companies, greater flexibility in production, an increase in productivity and ultimately an increase in their profitability. The impact of the I4.0 concept on occupational health and safety and the environment should not be neglected either. For this reason, teaching and training techniques must be changed, especially at universities that train production engineers.

In the last decade, a large number of papers have been published on the topic of education in the context of Industry 4.0. In these papers, the focus is on different areas, such as: new qualification requirements, new subject areas that should be included in curriculum, the transformation of education itself (Education 4.0), and the development of new laboratory concepts that would bring students closer to the Industry 4.0 production environment.

The general conclusion is that the new industrial practice reminds us every day that education as we know it today must significantly change its character. The workforce of the future will have to work with big data. They will need to be able to quickly find the information they need and then put it into practice. Communication technologies are bringing rapid change, so the answer to the question of how and in what way to educate the engineers of the future is by no means easy or simple. The main objective of this work is to determine the current state of art of production engineering curricula at the University of Novi Sad and the University of Banja Luka, in order to identify the areas on which the content of engineering education should be focused in the future with regard to the concept of Industry 4.0 (I4.0).

The University of Novi Sad, i.e. the Faculty of Technical Sciences (acronym: UNS-FTS), is the engine of industrial development in AP Vojvodina and the Republic of Serbia. On the other hand, the University of Banja Luka and its Faculty of Mechanical Engineering (acronym: UBL-FME) are the carriers of the development of the Republic of Srpska and Bosnia and Herzegovina. AP Vojvodina and Republika Srpska have a very well developed cultural, educational and scientific cooperation. This paper is the result of joint research by colleagues from these two universities within the project entitled: "The impact of the Industry 4.0 concept on the transformation of modern university engineering education in AP of Vojvodina and Republic of Srpska", and has

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2. Competencies and skills for Industry 4.0

The term Industry 4.0 can be explained by different concepts, such as smart factory, cyber-physical systems, self-organization and adaptation to human needs [1]. The final goal of the I4.0 concept is the creation of smart factories, where there will be autonomous systems with the possibility of self-configuration and self-monitoring. The new production processes will be based on collaboration between humans and machines. This collaboration will not be possible without the application and integration of the following technologies in practice, Fig. 1: Robotics, IoT, Additive Manufacturing, Virtual (VR) and Augmented Reality (AR), Simulation, Systems Integration, Big Data, Artificial Intelligence, Industrial Security, CPSs, Mobile and Wearable devices, and Cloud Computing. The Industry 4.0 model promotes the connection of physical components such as sensors, devices and machines, both to each other and to the Internet.

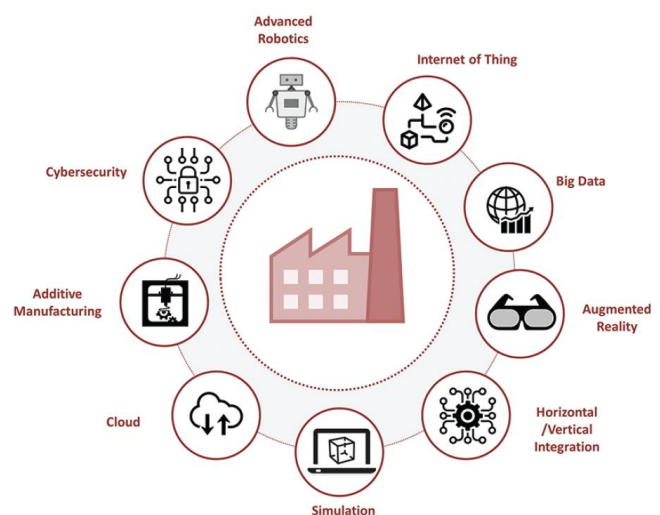


Fig. 1 Industry 4.0 technologies [2]

Figure 2 shows the new skills and competencies that Industry 4.0 requires from workers, as well as their integration and importance depending on. These skills can be divided into: **technical, methodological, social and personal**. Each of these skills has a corresponding importance, depending on the employee's role in the company. It is obvious that, for example, technical workforce must have a good knowledge of equipment, process and production technologies. Production engineers and managers of production

facilities, of course, must have the necessary knowledge for a methodological approach, creativity, problem solving, decision making, and analysis and research skills. Their social and personal skills (communication, cooperation, leadership, autonomy, flexibility and responsibility) are no less important than technical and methodological skills. The new technological world will require people who can make quick decisions based on the information available to them. The amount of intangible work will increase with digitization, robotization, artificial intelligence, and the Internet of

Things, so the human skills of sharing ideas and thinking critically will become increasingly important. Based on the above facts, the current educational system should be transformed in the following main directions: incorporating technical multidisciplinary into the curriculum, incorporating non-technical courses into the curriculum, offering problem-based learning, updating teacher skills, promoting innovation in teaching, organizing collective training programs and apprenticeships, accepting the concept of lifelong learning [4].

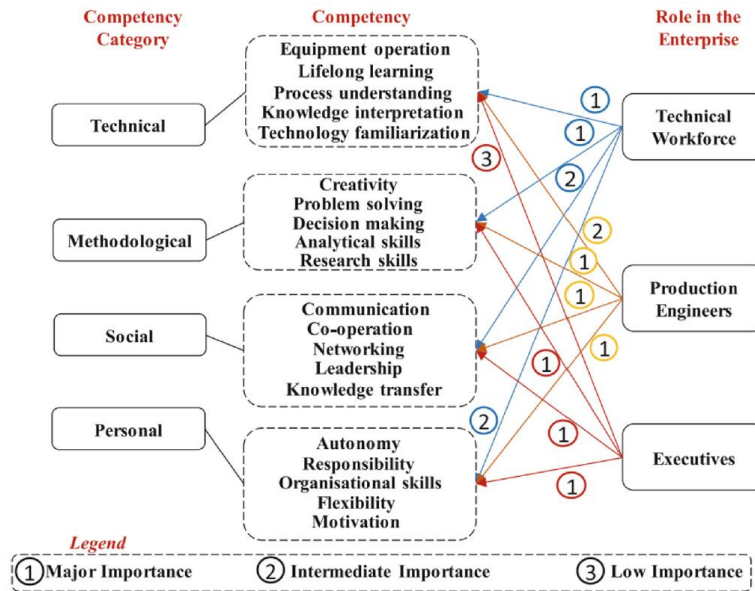


Fig. 2 Industry 4.0 competencies and their importance for performing roles in the company [3]

Technical competencies in the context Industry 4.0

The European Union - funded project entitled "The Universities of the Future" has identified the technical competencies that the engineers of the future should possess. These competencies are listed in the Table 1, and divided into the areas of engineering, business and design [6].

Table 1: Mechanical Engineering, Business and Design Elements of I4.0

| Engineering Competencies | Business Competencies | Design Competencies |
|---|--|--|
| Data Science and advanced (Big Data) analysis | Technology awareness | Understanding the impact of technology |
| Novel human-machine interfaces | Change management and strategy | Human-robot interaction and user interfaces |
| Digital-to-physical transfer, technologies, such as 3D printing | Novel talent management strategies | Tech-enabled product and service design |
| Advanced simulation and virtual plant modeling | Organizational structures and knowledge | Tech-enabled ergonomic solutions and user experience |
| Data communication and networks and system automation | The role of managers as facilitators | |
| Artificial Intelligence | Tech-enabled processes: Forecasting and planning metrics, scheduling | |
| Robotics | | |
| Programming skills | | |
| Closed-loop integrated product and process quality control/management systems | | |
| Real-time inventory | | |

| | | |
|------------------------------------|--|--|
| and logistics optimization systems | | |
|------------------------------------|--|--|

Advanced manufacturing technologies are an important factor that will lead society to higher industrial competitiveness, sustainable growth and job creation. The number of high-skilled manufacturing jobs will increase in the near future. The growing demand for higher-skilled workers includes those with traditional engineering profiles - process engineers, quality control engineers, mechanical or mechatronics engineers. At the same time, there will also be demand for newer skills - particularly designers, industrial data scientists, 'Big Data' statisticians/mathematicians and data security analysts. The most in-demand profile is likely to involve a combination of engineering and information and communications skills.

3. Production engineer profile in Industry 4.0

The production engineer is a professional capable of performing a range of activities within industrial manufacturing methods and production lines, as well as other related services. These activities include coordination, planning, feasibility studies, technical services, audits, research and teaching, budget preparation, and quality monitoring. However, with the advent of Industry 4.0 and the associated digitalization, these definitions need to be revised and updated. The classic profile of engineers' work will increasingly have to dive into the world of information and communication technology to deal with the modelling of processes and complex systems [7]. It is fair to ask whether the production engineers graduating today will be able to perform the tasks that Industry 4.0 and the new digital environment will demand of them. Classical teaching methods based only on lectures will not be sufficient to develop the necessary skills for future production environments. Numerous publications on the topic of education in the context of Industry 4.0 propose the development of new laboratory concepts

that enable students to experience a production environment like that of Industry 4.0 [8].

In Industry 4.0 tasks will be complex and require collaboration with machines [9]. Production engineers will be tasked with the following in Industry 4.0 [4]: **pre-production & planning** (research & development and product design; resource planning & procurement; staff augmentation & management), **production & logistics** (machining, production & assembly; supply chain management; warehousing & transportation), **monitoring & control** (operations, maintenance & continuous improvement; quality, risk & compliance; health, safety & environment), **new paradigms** (cybersecurity; product service systems; sustainability & circular economy). Industry involvement in education and training is seen as a key element in ensuring that production engineers are trained for the skills required by Industry 4.0.

The new profile of a production engineer in Industry 4.0 should be based on the following five pillars [4] : **basic technical knowledge** in the field of production engineering; **methodological skills** such as process-related and systemic thinking; **basic cross-disciplinary knowledge** in the fields of mechanical engineering, electrical engineering and electronics, as well as data science for computer science; **contextual knowledge**, i.e. knowledge of the conditions, requirements and perspectives in other fields and disciplines; and **interdisciplinary skills**, in particular the ability to work in a team, independence, motivation, problem-solving skills, the ability to learn and adapt, openness and communication skills.

Figure 3 shows the pillars on which the new profile of a production engineer is based and the tasks that this engineer will perform in Industry 4.0.

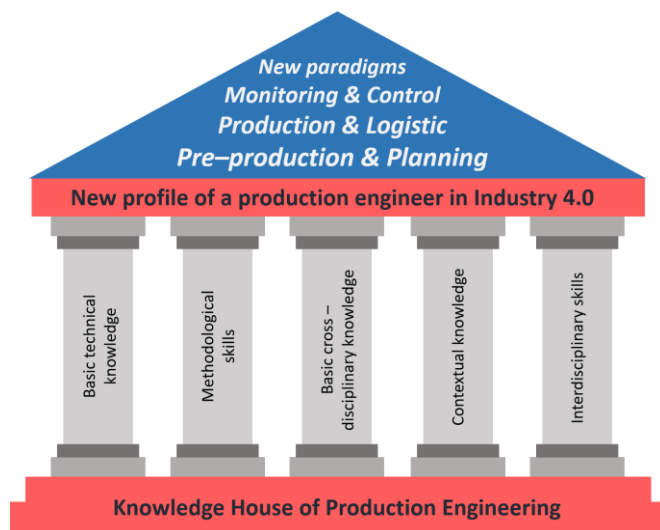


Fig. 3 Knowledge house of production engineering in Industry 4.0

4. Current state of art in production engineering curricula at UNS-FTS and UBL-FME

In the past, the university education system has often been slow to embrace innovation. Educational institutions are reluctant to introduce systemic changes and wait years, if not decades, to change. Innovations in the education system are difficult to spread because they disrupt established routines. This can also be explained by specific barriers that prevent change in education, which relate to the following:

- Professors are very often suspicious of brought about changes and have very little tolerance for something new and unknown,
- Lack of trust in professors when proposing innovations,
- Professors have little incentive to develop and introduce innovations in education,

- Introducing innovations often requires tremendous effort and commitment from many stakeholders,
- Lack of modern equipment and infrastructure, the acquisition of which would require large investments.

Currently, in the Republic of Serbia and Bosnia and Herzegovina, there are no national curriculum guidelines for the education of production engineers in the context of Industry 4.0. For this reason, analyzing the compliance of current production engineering curricula with the requirements of Industry 4.0 is a very complex task. In this analysis, it is important to keep in mind that the results of numerous studies show that companies are increasingly demanding soft skills, especially communication skills, over and above technical expertise. In addition to reading and writing skills, foreign language skills are also part of these communication skills and are in high demand by companies [10].

Table 2 shows when production engineering curricula were last accredited at UNS-FTS and UBL-FME. Both faculties have organized academic studies (Bachelor and Master) according to the principles of the Bologna Declaration based on the 4+1 system. The programmes consist of compulsory and elective courses.

Table 2: Latest revisions of the curricula of production engineering courses

| University - Faculty | Latest revision of the curriculum of the production engineering course | Study model |
|----------------------|--|-------------|
| UNS-FTS | 2020 (there were no changes compared to the accreditation 2013) | 4+1 |
| UBL-FME | 2016 (study model 3+2 replaced by study model 4+1) | 4+1 |

The analysis of the compliance of current production engineering curricula with the requirements of Industry 4.0 was carried out by comparing the knowledge offered by these programs with the tasks that production engineers (tasks are shown at the top of Figure 3) will have to perform in the context of Industry 4.0. The results of the analysis are presented in Table 3.

Table 3: Major university disciplines that could encompass skills and competencies of Industry 4.0

| The main task | Subtasks | Disciplines | UNS-FTS | UBL-FME |
|---------------------------|---|--|----------------------------|---------|
| Pre-production & planning | Research & Development and product design | Science in the context of production engineering (mathematics, physics, mechanics, thermodynamics, fluid mechanics, materials) | + | + |
| | | Basic cross-disciplinary knowledge (electrical engineering, mechatronics) | +/- | + |
| | | Computer programming | - | + |
| | | Applied programming and computer science | - | - |
| | | Engineering graphics communications | + | + |
| | | Fundamentals of design | + | + |
| | | CAD techniques and rapid prototyping | + | + |
| | | Reversible engineering | + | - |
| | | Virtual, augmented or mixed reality (VR/AR/MR) | + | - |
| | | Resource Planning & Sourcing | Probability and statistics | + |

| | | | | |
|---------------------------------|--|--|---|---|
| | | Applied engineering statistics and time series analysis (Big Date analysis) | - | - |
| | | Database of production processes | + | - |
| | | Production systems | + | + |
| | | Modelling, optimisation and simulation of production systems by artificial intelligence methods | - | - |
| Staff augmentation & Management | | Organization of production | + | + |
| | | Automation in production engineering – numerical control machines and systems | + | + |
| Production & logistic | Machining, Production & Assembly | Manufacturing technologies (machining, metal forming, welding, etc.), machine tools, tools and fixture | + | + |
| | | Additive manufacturing | + | - |
| | | CAD/CAE/CAM and CIM systems | + | + |
| | | Process planning and CAPP systems | + | + |
| | | Modern industrial metrology | + | + |
| | | Assembly technologies | + | + |
| | | Digital factories | - | - |
| | Supply chain management | Optimization and logistics in production | + | - |
| | Warehousing & Transportation | Robotics | - | + |
| | | Autonomous vehicles within warehouses | - | - |
| Monitoring & control | Operations, Maintenance & Continuous Improvement | Contemporary Maintenance Techniques | - | + |
| | Quality, Risk & Compliance | Quality control | + | + |
| | Health, Safety & Environment | Basics of work safety on processing machines | + | - |
| | | Ecological technologies and systems | + | - |
| New paradigms | Cybersecurity | Cybersecurity in manufacturing | - | - |
| | Product-Service Systems | PLM systems | - | + |
| | Sustainability & Circular Economy | Circular manufacturing systems | - | - |

5. Discussion of results

When analyzing the disciplines studied in production engineering curricula at the University of Novi Sad and the University of Banja Luka, it is clear that these disciplines most often deal with traditional production processes and technologies. The current curricula still do not fully include the skills and competences in the context of Industry 4.0, although these curricula were revised in 2020 and 2016, respectively.

The majority of disciplines in production engineering subjects focus on production processes and technologies, while very few

disciplines deal with computer science, applied programming, applied engineering statistics, time series analysis (Big Data analysis), and artificial intelligence, and these disciplines are the pillars on which Industry 4.0 rests. In addition, it is necessary to include disciplines related to digital factories, cybersecurity in manufacturing, and circular manufacturing systems in both study programs. The study program of production engineering at UNS-FTS should be enriched with additional knowledge in the areas of mechatronics, robotics, autonomous vehicles within warehouses, contemporary maintenance techniques and PLM systems.

The production engineering study program at UBL-FME, on the other hand, should be additionally enriched with knowledge in the area of virtual, augmented or mixed reality, database of production processes, additive manufacturing, autonomous vehicles within warehouses, optimization and logistics in production, basics of work safety on processing machines, ecological technologies and systems.

6. Conclusion

Digitalization will bring new challenges and change the skills required for successful production engineering. The aim of this study was to investigate the impact of Industry 4.0 on the development of production engineering curricula at two universities in AP Vojvodina and the Republic of Srpska. It is evident that the curricula and study programs that currently exist in production engineering programs at UNS-FTS and UBL-FME should be redesigned to include the skills and competencies required by Industry 4.0.

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