FACTA UNIVERSITATIS
Series: **Automatic Control and Robotics** Vol. 20, Nº 3, 2021, pp. 189 - 201
https://doi.org/10.22190/FUACR210908015M

Education Paper

SYSTEMATIC APPROACH TO THE EDUCATION IN THE FIELD OF SMART PRODUCTS AND SERVICES ENGINEERING

UDC ((378:316.663)+616-004)

Vojislav Miltenović[1], Zoran Nikolić[2], Marko Milojković[2], Staniša Perić[2]

[1]University of Niš, Faculty of Mechanical Engineering, Republic of Serbia
[2]University of Niš, Faculty of Electronic Engineering, Republic of Serbia

Abstract. *Industry 4.0 has a huge impact on the entire social system. The speed, scope and impact of the changes it brings have an exponential trend. The biggest impact is related to the industry and industrial development. Full digitalization and automation of production is expected, i.e. networking of smart digital devices with products, machines, tools, robots and people. For the realization of such complex tasks, it is necessary to have adequate human resources. In the changes brought by I4.0, the engineering of smart products and services, i.e. the education of development engineers, has a very important role.*
The social and industrial transformations dictated by the fourth industrial revolution also define new trends in the education of development engineers. Development engineers are expected to be comprehensively educated and trained to work in interdisciplinary project teams, in order to create new intelligent and networked products through creativity, innovation and fascinating technique.
The paper presents the development of education through the epochs of industrial development and presents trends and challenges related to the education 4.0. Special attention is paid to the education of development engineers and the relevant competencies they need to have in order to meet the tasks and expectations in modern conditions.

Key words: *Engineering education, development engineers, Industry 4.0, smart engineering, smart products, higher education*

1. INTRODUCTION

Thanks to the rapid progress of information and communication technologies (ICT), there have been incredibly fast changes in science, education, application of new technologies, production. People today are more informed about the range of products offered on the

Received September 08, 2021 / Accepted October 08, 2021
Corresponding author: Staniša Perić
University of Niš, Faculty of Electronic Engineering, Department of Control Systems, Aleksandra Medvedeva 14, 18000 Niš, Republic of Serbia
E-mail: stanisa.peric@elfak.ni.ac.rs

market and more demanding when choosing and buying products. They are looking for products with performances that will fully meet their specific needs. As a result, companies are forced to produce personalized product options that are available on customer's demand. Therefore, companies need flexible and innovative technology that can be enabled by the application of I4.0. Industry I4.0 can be defined as the integration of information and communication technologies with industrial progress aimed at developing intelligent factories that will lead to the more efficient and customized production processes. This should enable the application of new innovative technologies, with higher productivity and the possibility of producing personalized product profiles, which fully meet the requirements of the consumers. In order to be able to successfully use this potential, industrial companies are facing a great process of transformation, i.e. radical changes, where they have to overcome many challenges [1]. It is necessary to apply methods, processes and IT tools for interdisciplinary system-oriented development of innovative, intelligent and networked products, production facilities and infrastructure. All this must be accompanied by appropriate human resources, primarily development engineers with relevant competencies and skills.

2. Overview of Stages of Industrial Development and Education

Until the middle of the 18th century, production was largely based on the use of human and animal power. The main activity was agricultural production, which required a large engagement of human resources. The majority of the population was poor and could not access education. With the arrival of the first industrial revolution, the partial transition happened from manual to machine production with the use of a steam engine and water turbines. Significant human resources were freed from hard physical work and there emerged a need for educated people, especially in the field of technology. A larger number of polytechnic schools opened with an increase in the number of engineers and technicians. In 1794, the "École polytechnique" was founded in France. The main progress in engineering came after 1848, thanks to the development of the railway. Public education was launched that was accessible to the poor. There were a lot of changes in education related to the specializations, the establishment of vocational schools and the development of universities, i.e. it was a time of a significant flourishing of engineering sciences [2].

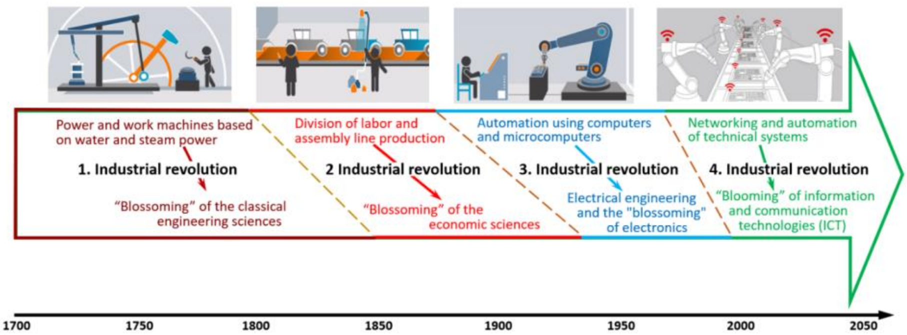

Fig. 1 Stages of industrial development [3] [4]

The indications of the second industrial revolution date back to 1850, but the main ones originated between 1870 and 1914 (Fig. 1). The greatest momentum of the second industrial revolution was gained by the application of electricity, which enabled serial and mass production in industry. Mass production contributed to the accelerated development of the railway, and consequently to the further development of mass production [5]. The revolution is characterized by significant innovations in chemistry and mass production of steel. At the same time, significant changes in education occurred. The system of science, technology, engineering and mathematics (STEM) was introduced in the industry, which led to the great progress in education, which is significantly related to both economic sciences and a new approach to management [2]. The rapid development of the industry required a large number of skilled labors, which educational institutions of that time could not offer. Due to that problem, in some countries a certain decline of industry and economy happened. The main task of educational institutions became to educate people with technical competencies, knowledge and skills of a higher level, who are able to lead the industrial development of their countries. Thus, there occurred a multi-level system of training for industry, standardization in the field of education and significant favoring of engineering education.

The beginning of the third industrial revolution dates between 1950 and 1970 and is called the information age. It is often also called the digital revolution, because there has been a transition from analog and mechanical systems to the digital ones. The main drivers of the third industrial revolution were electronics and electrical engineering, which led to the automation of technical systems into automated production (Table 1). The third industrial revolution was and still is a direct consequence of the great development and application of computers as well as information and communication technologies. This has led to significant changes in education, characterized by easier access to education,

Table 1 The main drivers and impact of industrial revolutions on education

Industrial revolution	The main driver	Characteristic	Education
1	Engineering sciences (classical)	Propulsion and working machines (increase of productivity)	Opening of polytechnic schools; Education accessible to wider sections of society; Increase of the number of engineers and technicians; Encouragement to the university development.
2	Economic sciences Management, Taylorism, Fordism	Division of labor and assembly line (mass production)	STEM education system; Education with higher level technical skills; Multilevel education system; Standardization of education; The prestige of engineering education.
3	Electronics (and electrical engineering)	Automatization of technical systems	Expansion and diversification of higher education; Interdisciplinary curricula; Integration and globalization of education; Academic mobility; International educational standards.
4	Information and communication technologies (ICT), including Informatics, Artificial Intelligence...	Networking and automatization of technical systems	New model of education: 4.0; Personalization of education; Importance of advanced technologies; EduTech - educational technologies; Digital Learning Resources; Online studies.

expansion and diversification of higher education, multidisciplinarity, globalization of academic research. ICT have made it easier to access world-class research results, search quickly and efficiently, and provide immediate and free access to information. STEM education was reformed, with an emphasis on interdisciplinary curricula [2]. In engineering education, there was an integration and globalization of education, the development of academic mobility, the transition to international educational standards and increased training for specialists in specific fields.

3. Education 4.0

Industry I4.0 has a huge impact on education. Practically, a new model of education is sought, in the professional literature called Education 4.0 (or Academia 4.0) [6]. It is believed that education should include virtual resources in addition to the physical ones. The goal is the personalized education, where the process of education is not structured and fixed, but takes place permanently using all the resources provided by the existing environment, i.e. modern innovative tools [7]. Students create their own curriculum.

The modern approach to the education includes the use of relevant technologies. The advantage of educational technologies (EduTech) is the provision of distance education, adaptation of assessment to the learning style as well as easier access to and updating of learning materials. Introduction to the advanced technologies is also an integral part of the education of development engineers. An important role is played by Digital Learning Resources (DLRs), which refers to digital resources such as applications, software, programs or websites that engage students in learning activities and support student learning goals.

3.1. Industry 4.0

The fourth industrial revolution arose in the correlation between the existing traditional industry and innovations in the field of the Internet, i.e., in the field of information and communication technologies (ICT). The most important components of Industry 4.0 [8] (Fig. 2) are: Cyber-Physical Systems CPS, Internet of Things IoT, Internet of Services IoS and Smart Factories.

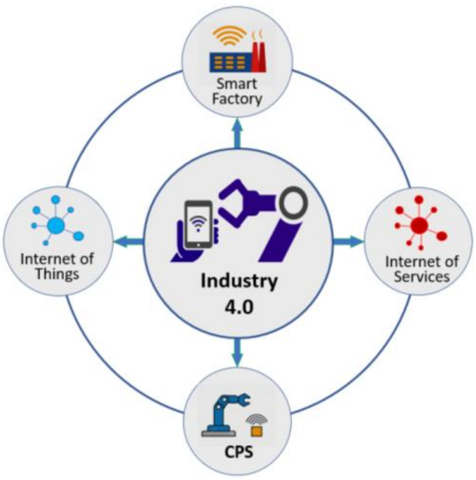

Fig. 2 Components of the Industry 4.0

Industry 4.0 is a collective term for technologies and concepts of value chain organization. Within Industry 4.0 modularly structured smart factory, CPS monitors physical processes, creates a virtual copy of the physical world, and makes decentralized decisions. Through IoT, CPSs communicate and collaborate with each other and people in real time [9]. Through IoS, value chain participants offer and use internal and inter-organizational services. The ultimate goal of this approach is to produce more personalized products and services so that people, products and machines can continuously communicate across all value chains.

The speed, scope and impact of changes brought by I4.0 on the entire social system are extremely high. The development of Industry 4.0 has an exponential trend. As a result, there have been enormous changes in science, technology, engineering and innovation.

3.2. Range of I4.0 technologies

The development of I4.0 is based on the perfect integration of components related to technology (information) and people. The range of technologies that support I4.0 is quite wide. These include Artificial Intelligence (AI), Internet of Things (IoT), virtualization technologies (digital twins), cloud and cloud computing, 5G Network, horizontal and vertical integration system, Big data and analytics, Robots & Cobots, additive manufacturing. A brief description of these technologies will be presented below.

3.2.1. Artificial Intelligence (AI)

Artificial intelligence can be defined as a science that studies how a computer can surpass man in solving problems in all related intellectual activities [10]. Thus, it refers to systems or machines that mimic human intelligence to perform tasks and which can be iteratively improved based on the information they collect.

The most important characteristic of artificial intelligence is its ability to rationalize and take optimal actions to achieve a given goal. A subspecies of artificial intelligence is machine learning, which refers to the concept that computer programs can automatically learn and adapt to new data, without the help of humans. Deep learning is a function of AI that mimics the work of the human brain in data processing and creating patterns for use in decision making. Deep learning is a subset of machine learning in AI that has networks capable of unattended learning based on unstructured data. It is also known as the deep neural learning or the deep neural network.

3.2.2. Inernet of Things (IoT)

Internet of Things (Internet of Intelligent Devices) describes a network of physical objects in which sensors, software and other technologies are embedded in order to connect and exchange data with other devices and systems via the Internet. In this way, data can be collected and shared, that is, digital systems can record, monitor and adjust any interaction between related items. The physical world is in contact with the digital world - and they are collaborating.

Industrial IoT (IIoT) refers to the application of IoT technology in industrial environments, especially in terms of instrumentation and control of sensors and devices that include cloud technologies. The interaction between objects in a certain environment tends to be such that there is an immediate reaction if there is a change.

3.2.3. Virtualization technologies (digital twins)

Virtualization is a term that refers to different techniques, methods or approaches to creating a virtual version of something, which exists as real. One of the most important virtualization techniques is digital twins.

The Digital Twin model arose from the idea that every system consists of a physical system that has always existed and a new, corresponding virtual system that contains all the information about the physical system. A virtual system is a mirror image of a real system. These two systems are interconnected throughout the entire life cycle. A virtual system can be defined as a digital representation of a physical object, process, or service. It is basically a computer program that uses real-world data to create simulations that can predict how a product or process will behave. These programs can integrate the Internet of Things, artificial intelligence, and software analytics [11].

The Digital Twin can be considered a virtual copy of the real world. It integrates all data, models and other structured information about the product, plant, infrastructure system or production process. This data can be generated during design, engineering, production, commissioning, operation or service. The rapid adoption of the Digital Twin concept is based on advances in simulation methods, computing capacity, IoT data availability, and artificial intelligence. The two key elements of Digital Twin are that it is holistic and dynamic.

Holistic approach implies that all information is integrated and consistently applied at different stages of the life cycle and interconnected digitally.

Dynamic approach means that the Digital Twin grows throughout the life cycle, completing the description of the system and adding higher levels of detail when they become available and updating the basic models based on the actual use of the product.

Digital twins are designed to model complex means or processes that work in a complex environment and communicate with it in many ways. They can be designed in a wide range of contexts to serve different purposes.

3.2.4. Cloud and cloud computing

Cloud is an abstract virtualized IT resource (like data storage, computing capacities, applications or services) managed by service providers. Access is enabled via a network, usually the Internet. The term "cloud" means that the actual physical location of the infrastructure for these services often cannot be tracked to users, but resources can be pulled "as from the cloud". Cloud Computing is the use of IT resources from the cloud, i.e. storage and processing of data on other people's computers in a data center via a network, which gives companies the ability to store huge amounts of data and process them almost in real time.

In the context of I4.0, this technology can improve process efficiency, offer valuable information that can be easily shared with different partners, reduce costs and improve system performance.

Cloud service providers such as Amazon, Google, and Microsoft allow companies to host all vital IT infrastructure in their cloud rather than within an organization's digital boundaries, reducing the overall cost of maintaining and working with individual systems, software, and data.

3.2.5. 5G Network

5G is the fifth generation of the mobile network. It is a new global wireless standard that enables a new type of network that should connect almost everyone, including machines, objects and devices.

5G wireless technology is designed to provide higher maximum data rates, ultra low latency, higher reliability, huge network capacity, increased availability and a more uniform user experience for a larger number of users. Higher performance and improved efficiency empower new user experiences and connect new industries.

5G network is considered a key technology in the provision of smart services because it needs to meet the high demands for network capacity in mass networking of everyday objects on the Internet of Things. Moreover, this network will necessarily lead to further advances in applied technologies, for example through the evolution of IoT to NB-IoT (Narrowband Internet of Things) [12], given that IoT applications which require more frequent communications will be better served by NB-IoT.

3.2.6. Horizontal and vertical system integration

Horizontal integration is integration within the functional/organizational level of the hierarchy across system boundaries. So, it refers to combining different independent production chains so that companies with related products become more efficient.

Vertical integration represents integration within the system at several levels of the functional/organizational hierarchy and is achieved by connecting all value subsystems of one company.

Through the application of horizontal and vertical integration, the entire business network works autonomously, making processes optimal, reducing costs and producing better products [13]. System integration is a condition for the application of I4.0, because it enables the included production elements to function and communicate in real time. This integration is based on the application of IoT, wireless sensor networks, Big Data, cloud-based services, embedded systems, and mobile internet.

3.2.7. Big data and analytics

Products, components and machines are equipped with sensors and actuators, intelligently networked with each other. The digital connection of products and machines enables continuous data collection outside the factory, so that a large amount of data is obtained. Big data is analyzed, interpreted, linked and supplemented and thus transformed into smart data. This data can be used to control, maintain and improve smart products and services. After proper storage, analysis and interpretation of smart data, this database is the starting point for the development of innovative services. These services are based on data, they supplement or replace a number of physical products and thus allow individual adaptation to the specific expectations of users.

The main characteristics of big data are related to volume, speed, diversity, truthfulness and value. Therefore, advanced techniques are needed to analyze this information in order to make the best use of them. Big data can help companies improve system performance, and enable successful ongoing monitoring of health and safety.

3.2.8. Robots & Cobots

Autonomous robots can be defined as intelligent machines that can understand and react to their environment and autonomously perform routine or complex tasks. They can learn and make their own decisions by temporarily collecting and analyzing large amounts of data. Autonomous robots enable the industry to increase productivity, reliable operation, perform high-risk tasks and more efficient production processes.

The latest generation of robotic systems designed to work with humans is known as cobot (or collaborative robots). Cobot can help employees in a job that could be dangerous, tiring or monotonous, thus creating a safer and more efficient workplace. Thanks to sensors and other design features such as lightweight materials and rounded edges, they can communicate directly and securely with people. In addition, cobots are generally easier to program than industrial robots because they can "learn" while doing work.

3.2.9. Additive Layer Manufacturing

Additive manufacturing are technologies that enable the creation of a three-dimensional object from a digital 3D computer aided design (CAD) model. The construction of the model is based on digitally "cut" horizontal layers of the model, which are glued layer by layer into the final shape in physical space. The name Rapid Prototyping is often used for these technologies as a group of techniques used to quickly fabricate a scale model of a physical part or assembly.

Types of Additive Manufacturing technologies depend on the type of material: for Photopolymers: Stereolithography (SLA) and Polyjet; for Thermoplastics: Fused Deposition Modelling (FDM); for Metals: Selective laser melting (SLM), Direct Metal Laser Sintering (DMLS), Direct Energy Deposition (DED) and Electron Beam Melting (EBM); for Powdered materials: Material Jetting (MJ, Binder Jetting (BJ) and Selective laser sintering (SLS).

The most common 3D printing process is FDM technology. Although FDM technology was found after the other two most popular technologies, stereolithography (SLA) and selective laser sintering (SLS), today it is the most popular technology since it is the cheapest and safest technology.

3.3. Smart Engineering

The central place in Industry 4.0 belongs to smart products and services. For the successful development of smart products, in accordance with the aspects of Industry 4.0, it is necessary to meet a number of requirements. Smart product designers must therefore quickly and flexibly integrate new trends and standards into their solutions. They can only use their past experiences to a limited extent, so they have to learn and find constructive solutions at the same time. The basic precondition for them to be successful is the use and application of new development methods that guide them towards creative solutions [5]. Therefore, it is necessary to apply modern engineering of smart products. The term engineering can be defined as the creative application of scientific knowledge and mathematical methods for the development and production of technical products.

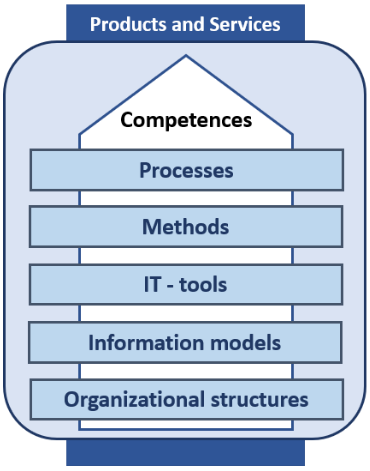

Fig. 3 Components of the holistic engineering [14]

Smart product engineering is also called "Smart Engineering", which describes methods, processes and IT tools for interdisciplinary, system-oriented development of innovative, intelligent and networked products, production facilities and infrastructure.

It is expedient to consider a holistic approach in engineering, where, in addition to the development of products and services, their complete life cycle is also taken into account. The components of holistic engineering are the methods used in the development process, IT tools, information models and organizational structures. All this is combined by human resources with appropriate competencies (Fig. 3).

Engineering processes are primarily information processes that, in addition to product development, follow other phases of the physical life cycle of products, production, procurement, logistics, product use and the end of working life - liquidation. Therefore, comprehensive communication between all actors and systems involved in the product development process is necessary, from product planning to its production. This approach enables obtaining reliable, high-quality and market-competitive products.

For early and efficient development and production of smart products, it is necessary to virtually model the process of physical production, including their production facilities. During production, virtual models are continuously compared with actual data on the behavior of objects ("digital twin") in order to identify the actual state of the process and prevent the occurrence of errors in reality.

Smart engineering implies the integration of product development, production planning and control for rapid market-ready implementation of innovative product ideas, and thus added value through a digitally designed development process. It is necessary to develop a product lifecycle management concept for digital recording and complete product lifecycle control, thus increasing productivity, quality and reliability in all process segments.

4. Education of Development Engineers

In accordance with the changes brought by I4.0, the education of development engineers is changing drastically. An integral part of their education is also advanced technologies, which change very quickly and require their permanent monitoring. Requirements related to product life cycle, environmental protection, product recycling, safety and reliability, etc. are also changing. In that sense, development engineers must have far more knowledge and skills to meet the demands that lie ahead of them.

Engineers must also have knowledge of advanced analytics. In addition to basic knowledge, skills and competencies related to innovation, analysis and problem solving also play an important role. This will allow them to analyze large data sets from many sources, optimize available resources, and make real-time decisions.

Therefore, development engineers with new profiles are required, who will have to successfully cope with the new, more complex conditions. They must have the knowledge and ability to use adequate methods, models and IT tools to solve problems in a high-tech interdisciplinary environment, which is constantly changing. Thus, development engineers must be prepared for lifelong learning, leadership, communication, flexibility, adaptability, teamwork, and decision making.

I4.0 is still being developed, which requires permanent monitoring of the I4.0 environment, determination of trends and, accordingly, making adequate changes in the educational process. In that sense, development engineers should also be the initiators of the transformation of education in this area.

I4.0 forces universities to update/modify existing curricula in order to educate students to perform activities expected in the near future. The content and competencies need to be harmonized with the range of advanced technologies (see 3.2).

A very important role in the development of human resources is played by competencies, i.e. skills, abilities and knowledge that a person must possess in order to efficiently perform a certain task. The notion of competencies is primarily related to education, but also to the acquisition of knowledge and skills during a professional career. Understanding, identifying and correct insight in competencies has a very significant impact on the successful execution of work tasks.

The task of the teams in the field of product development is to reach multiple agreements, exchange information, discuss, resolve conflicts and make formal decisions. In doing so, personal competencies should be established, which are very important for the successful work of the team. Also important is the actual competence, which the team members have in relation to the upcoming task, in order to successfully solve it. After extensive research in this direction, the following relevant competencies of development engineers have been clearly defined: professional competence, methodological competence, social competence, creative potential and ability to elaborate. Furthermore, the above-mentioned competencies will be defined in more detail [15].

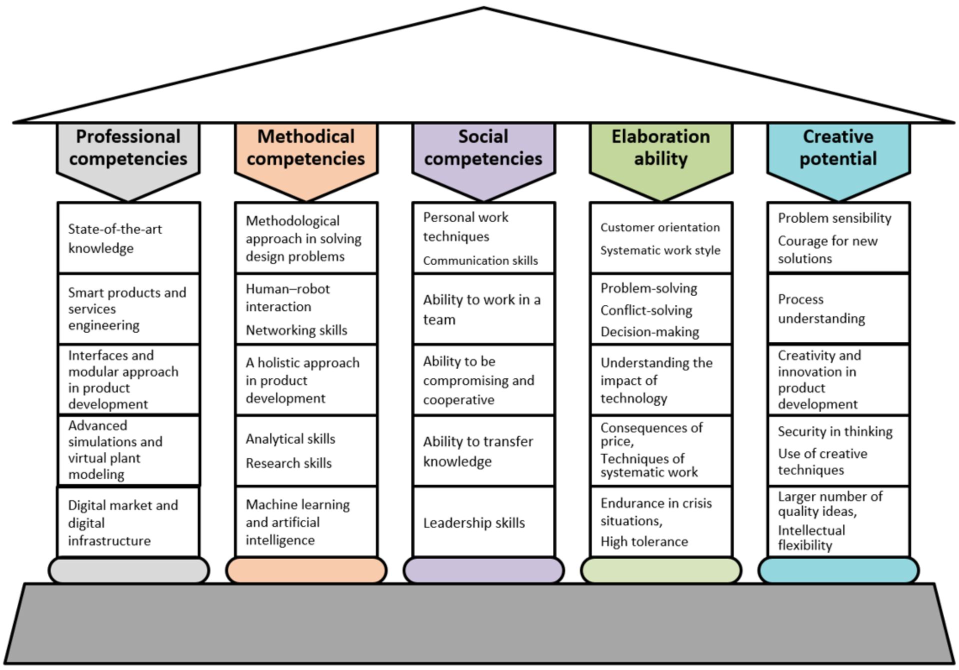

Fig. 4 Relevant competencies of development engineers [16]

The term professional competence implies practical knowledge and professional experience, as well as theoretical knowledge, which the engineer constantly applies in his work. It can be defined as "Readiness and ability to orient tasks and problems towards the goal, on the basis of professional knowledge and skills, to solve them correctly, methodically and independently and to adequately evaluate the obtained results".

Methodological competence includes methods, models and IT tools used by development engineers in solving known and partially unknown problems. For the acquisition of methodological competencies, there is a practical application of a number of methods for solving problems in product development, the ability to synthesize technical solutions, as well as the successful application of innovations.

Social competencies are focused on communication and articulation, the ability to work in a team and lead, as well as the ability to solve problems on one's own initiative.

Competencies related to the ability to elaborate are also very important. These competencies are expressed through skills for systematic work style, integration of professional and methodological knowledge as well as coping in crisis situations.

Competencies related to creative potential include acquiring the ability to apply creative techniques, gaining safety at work and the application of innovative solutions, as well as intellectual flexibility.

The relevant competencies of development engineers are shown in Fig. 4.

According to the education model I4.0, the following challenges should be kept in mind when educating development engineers [13]:

1. The education and resources used must be consistent with the learning style of each individual.
2. Development engineers independently define plans and programs in accordance with their intellectual abilities and interests, i.e. they go for personalization of education.
3. Continuing education and monitoring the course of development of advanced technologies is a necessary precondition for successful integration into the course of changes dictated by I4.0.
4. The process of education is not fixed, but takes place permanently in accordance with modern trends and using all the resources provided by the existing environment.
5. Intensive use of Digital Learning Resources (DLRs).

The fourth industrial revolution led to an increase in the number of online studies and the automation of many tasks. This trend has both positive and negative impacts on education. The positive ones are reflected in the fact that in this way it is possible to spread education to a larger number of people, reduce the costs of education, and internationalize education. However, the negative impact is quite pronounced, especially in the education of development engineers. In addition to the reduction of human contacts and socialization, the negative impact is reflected in the reduction of opportunities for gaining laboratory and practical experience, developing thinking skills, direct exchange of opinions, adequate teamwork, innovative activities. So, online education can only be a supplement to the acquired engineering education.

5. CONCLUSION

The fourth industrial revolution led to great changes in all spheres of society. The biggest changes have occurred in the industry, which means a complete transformation of the existing situation to a new higher level. The changes are largely dictated by the emergence of new advanced technologies that blur the boundaries between the digital, physical and biological spheres and greatly affect the future global transformation of industry and the economy. The evolution of global industries in the era of the fourth industrial revolution is happening very fast, bringing numerous challenges.

Accordingly, there are major changes in the field of education, so educational organizations need to design and adequately adjust their education strategies. Universities need to update their curricula and develop programs that should provide students with the knowledge and skills needed to perform effectively in the new environment. It is necessary to develop adequate content and competencies that will be balanced with new advanced technologies, while monitoring the pace that dictates the development of advanced technologies in I4.0.

The main activity in the era of the fourth industrial revolution is the development of smart products and services. In order for that to be realized, it is necessary to have adequate human resources. Development engineers have the most important role in that, so special attention is paid to their education. Trends in the education of development engineers are related to the individualization and virtualization of education, strengthening the project and multidisciplinary nature of education, as well as the interaction of educational resources. The competencies of development engineers include lifelong learning, leadership, communication, flexibility, adaptability, teamwork, and decision making.

Multidisciplinary areas that include mechanical engineering, electronics, sophisticated technologies (artificial intelligence, biotechnology and nanotechnology), ICT, etc. have a significant share in the education of development engineers. Accordingly, education should be organized as interdisciplinary studies with the participation of professors of appropriate profiles.

Acknowledgement: *This paper is a product of work that has been fully supported by the Jean Monnet Module Smart Products and Services Engineering (SPaSE), project no. 101047566-ERASMUS-JMO-2021-MODULE. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

REFERENCES

[1] Miltenović, V., Đorđević, V.: *Excellence, Relevance and Efficient Application of Research Results at University and Institutes from the Standpoint of Economy Developing***.** International Symposium MACHINE AND INDUSTRIAL DESIGN IN MECHANICAL ENGINEERING KOD 2018. 6 - 8 June 2018, Novi Sad, Serbia. IOP Conf. Series: Materials Science and Engineering **393** (2018) 012004 doi:10.1088/1757-899X/393/1/012004.

[2] Fomunyam, G., K.: *Education and the fourth industrial revolution: challenges and possibilities for engineering education.* International Journal of Mechanical Engineering and Technology (IJMET). http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=8. 2019.

[3] https://mensch-maschine-fortschritt.de/reportage/arbeit-4-0-im-zentrum-steht- der-mensch/

[4] https://www.imk.engineering/industrie-4.0.html

[5] Miltenović, V., Marjanović, N.: *Development of Innovative and Smart Products - opportunities and challenges.* Proceedings of the 9th International Scientific Conference „Research and Development of Mechanical Elements and Systems". 5th & 7th September, 2019, Kragujevac. Plenary Session S. 11-21.

[6] Penprase, B., and Nardin, T.: "*Common Curriculum at Yale-NUS.*" Yale-NUS College Centre for Teaching and Learning. July 1. Accessed December 3, 2017. https://indd.adobe.com/view/b8748bf2-c7a6-4cef-a1e6-9a30c36bfe80. 2017.

[7] Coskun, S., Kayıkcı, Y., Gençay, E.: *Adapting engineering education to Industry 4.0 vision.* Technologies **7**, 1–10, 2019.

[8] Hermann, M., Tobias, O.: *Design principles for Industrie 4.0. Scenarios: A Literature review*. TU Dortmund. https://www.researchgate.net/publication/307864150_Design_Princ-iples_for_Industrie_40_Scenarios_A_Literature_Review
[9] Plattform Industrie 4.0: *Referenzarchitekturmodell Industrie 4.0 (RAMI 4.0).* Online: https://www.plattform-i40.de/I40/Redaktion/DE/Downloads/Publi-kation/rami40-eine-einfuehrung.pdf?__blob=publicationFi le&v=10 (Stand: 3.5.2018).
[10] Rich, E., Knight, K., & Nair, S. B.: *Artificial intelligence third edition*. 2009.
[11] https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-twin
[12] 3GPP Low Power Wide Area Technologies - GSMA White Paper, 2016.
[13] Menendez, M., Díaz, C., Menendez, R.: *Engineering education for smart 4.0 technology: a review*. International Journal on Interactive Design and Manufacturing (IJIDeM). https://doi.org/10.1007/s12008-020-00672-x. 2020.
[14] Abramovici, M.: *Engineering smarter Produkte und Services Plattform Industrie 4.0*. STUDIE. Deutsche Akademie der Technikwissenschaften. München, 2018.
[15] Miltenović, A., Banić. M., Miltenović, V.: *Importance and Role of Competence in Professional Career of Product Develop Engineers*. The 7th International Conference on Manufacturing Science and Education - MSE 2015 - June 3-6, 2015 Sibiu, Romania.
[16] Miltenović, V., Antić. D.: *Smart Products and Services Engineering (in Serbian),* University of Niš, Niš, Serbia, 2020. p. 202.