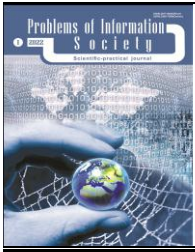

www.jpis.az

13 (1)
2022

Trends and prospects for IT education in Industry 4.0

Firudin T. Aghayev[1], Gulara A. Mammadova[2], Rena T. Melikova[3]

[1,2,3]Azerbaijan National Academy of Sciences, Institute of Information Technology, B.Vahabzada str., 9A, AZ1141, Baku, Azerbaijan

[1]agayevinfo@gmail.com; [2]gyula.ikt@gmail.com; [3]rena22@rambler.ru

ORCID: orcid.org/0000-0002-7660-1406[1]
orcid.org/0000-0002-6332-7129[2]
orcid.org/0000-0001-6589-6379[3]

ARTICLE INFO
http://doi.org/10.25045/jpis.v13.i1.12

Article history:
Received 14 September 2021
Received in revised form: 21 November 2021
Accepted 24 January 2022

Keywords:
Industry 4.0
Education 4.0
Cyber-physical systems
Internet of Things
Virtual reality
Skills and competencies of IT specialists
Technologies

ABSTACT

The fourth industrial revolution (Industry 4.0) has brought about changes in various aspects of human life. One of them is the education system. The article explores the impact of Industry 4.0 on the field of education. In this regard, the main characteristics of Industry 4.0, driven by artificial intelligence and digital physical structures are explored using distributed computing, big data, portable devices, the Internet of Things (IoT), virtual reality (VR), augmented reality (AR), etc. Moreover, the article analyzes the main technologies of Education 4.0, which play an important role in supporting Industry 4.0 and have a significant impact on the change in IT education. The article shows the main engineering competencies of Industry 4.0 specialists to be knowledge, skills and abilities necessary to successfully complete production tasks. Future engineers need to improve their professional, social, methodological and personal competencies. They need an interdisciplinary understanding of systems, manufacturing processes, automation technology and information technology. The article uses methods of comparative analysis, generalization and systematic approach to the peculiarities of using Industry 4.0 technologies in the field of e-education. The results obtained are expected to be used by specialists, managers and teachers to improve the educational performance of IT specialists in higher education institutions.

1. Introduction

Many countries are currently stepping into the stage of the Fourth Industrial Revolution, also called Industry 4.0, in which technological progress significantly changes all areas of human activity. Industry 4.0 will not only increase the efficiency consumption of resource and time, but will also change the way people work. Moreover, the development of technologies and innovations will affect not only the production sector, but also the education system.

The concept of Education 4.0 refers to the education benefiting from Industry 4.0 technologies and training qualified personnel capable of adapting to the changing "professional landscape". Due to the changes in production processes, some jobs are estimated to disappear and many new ones to emerge. The industry will face the disappearance of jobs requiring physical effort being replaced by machines [1]. In the future, workers will be more focused on creative, innovative and communicative activities rather than the routine ones, as the routine activities, including monitoring duties, will also be performed by machines [2, 3]. Therefore, the skills and qualifications of workers will be a key factor in the success of these smart enterprises.

The entire system of the national economy is being transformed into a fully digitized system. Future workers who are students today will face a more globalized, automated, virtualized and networked world [4]. As the workspace changes rapidly, new competencies are emerging. They will include essential skills for student competitiveness and employability in the near future. Taking into account the above, the article studies these new competencies and skills and presents recommendations regarding the necessary changes in higher education system.

2. Industry 4.0 and its effect on IT professionals' competencies

The key technologies defining Industry 4.0 include mobile devices, augmented reality, simulation devices, autonomous vehicles and robots, additive manufacturing, distributed cluster systems (block chain), big data analytics, mobile computing and cloud computing. These technologies make it possible to create various new business models [5].

Along with these technologies, there are social and economic factors, such as remote work, emerging platform economies, more freelance services and consultants made possible by these technologies, are also driving Industry 4.0. Furthermore, more and more people are getting used to the new flexible type of work, which also means that working relationships are becoming more interdependent [6].

Other factors associated with Industry 4.0 are also available. They may include climate change and natural resources, geopolitical instability, privacy issues, demographic processes, urbanization, and an increased influence of women on economic development [7, 8]. Fig. 1 illustrates the building blocks of Industry 4.0 leading to a paradigm shift in manufacturing.

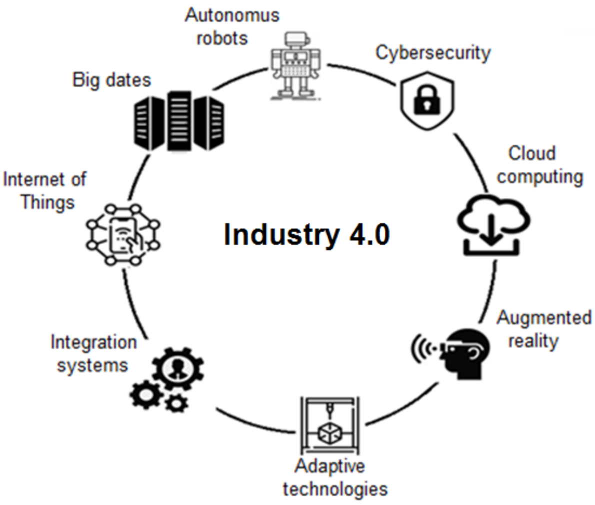

Fig. 1. Industry 4.0 components

The World Economic Forum report [9] "The Future of Jobs" lists ten key skills to be in demand by future companies. The qualifications are not categorized in this report, but most of them refer to soft skills. These skills may include finding a simple way to solve complex problems, critical and creative thinking, people management skills, teamwork coordination, emotional intelligence, service orientation, negotiation skills, and cognitive flexibility. As skills and competencies will be the key factors in Industry 4.0, organizations will seek to find the right workers with the right skills and abilities.

The demand for these skills and qualifications will no doubt be higher than at present. This will lead to the need to change and adapt existing curricula and tools used in the educational system to create a new curriculum format to equip students with the necessary skills for employment.

Analyzes and forecasts of future work activity mainly point to the impact of automation and the emergence of new types of jobs. Therefore, current students need to be prepared for professions that do not exist yet.

This means that as new challenges emerge in a changing environment, the demand for new skills and qualifications will increase. To meet the Industry 4.0qualifications and skills, educational systems must evolve and take into account several promising trends, such as the ability to study at different times and places; individual training based on the abilities of the trainee; the use of new learning devices, tools and resources; remote engineering laboratories; introduction of project and problem-based approaches to learning; the use of experiential and collaborative learning; participation of students in the development of curricula; broader approaches to mentoring [10].

Industry 4.0 offers creating intelligent manufacturing enterprises with the "consciousness" element through artificial intelligence, which provides making decisions in the production and service processes [11]. Smart factory is capable to track all manufacturing stages of each individual product of the enterprise, even in a mass production environment. "Smart factories" create "smart products", and the latter, in turn, can store data about themselves [12], "communicate" with the company and make decisions about their production process, transportation and, possibly, after-sales use through Radio Frequency Identification (RFID), sensors, actuators and mobile structures. This provides flexibility and customization of the production process. The enterprise becomes "smart" due to Cyber-Physical Systems (CPS) and the Internet of things. Cyber-physical systems create a virtual copy of the enterprise using sensors and actuators, which provides decentralized decision making. In such a cyber-physical system, interconnections allow machines, machines-human, as well as himan, to cooperate. Smart manufacturing increases the role of workers, requires a wider range of skills for decision making and thereby changes the way people work.

The role of the manufacturing worker is changing and becoming more complex as it is more about decision making and problem solving rather than manual labor.

The German Academy of Sciences and Engineering Acatech [13] claims the cyber-physical systems to comprise three types of networks:

– Internet of people;
– Internet of things;
– Internet services.

The scope of CPS is estimated to extend to almost all types of human activity, i.e., industry, agriculture, transport, energy, military, etc. (Fig. 2) [14].

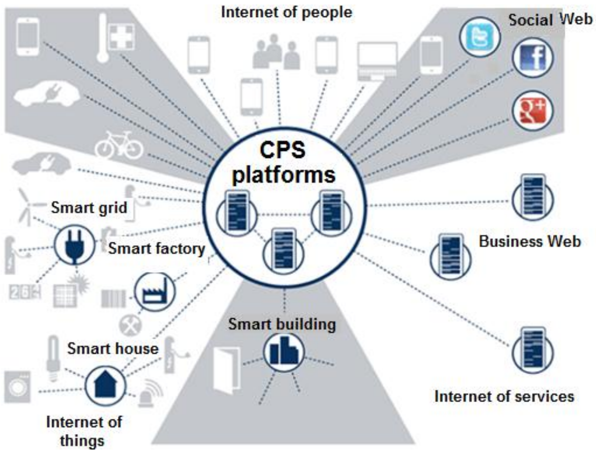

Fig. 2. Cyber-physical system architecture

The core Industry 4.0 worker skills include engineering competencies, namely knowledge, skills and abilities necessary for successful job performance.

The literature provides a list of engineering competencies in professional activities, which includes the ability to apply knowledge of mathematics, science and engineering, design and conduct experiments, analyze and interpret data, identify, formulate and solve engineering problems, apply the methods, skills and modern engineering tools required for engineering practice [15].

Many higher education institutions abroad are trying to train their students for change by emphasizing the ability to use theoretical knowledge in practice. However, the question still remains: is this theoretical knowledge enough to bring about the necessary changes and instill the necessary skills? If we take into account Industry 4.0, future engineers need to improve their professional, social, methodological and personal competencies. They need an interdisciplinary understanding of systems, manufacturing processes, automation technologies, information technology, ergonomic principles, and business processes [16]. Future professionals need not only to have a broad outlook and in-depth knowledge of complex production systems, but they also need to develop the skills to collaborate and communicate in interdisciplinary teams.

The articles devoted to the competencies and knowledge of IT specialists in Industry 4.0 primarily focus on the interaction between robots and people, as well as user interfaces [17, 18]. Knowledge related to the user interface and innovation in Industry 4.0 is related to human-machine interaction, ergonomics and interaction with other users. The authors distinguish four main groups of competencies in Industry 4.0:

– technical competencies (advanced knowledge, technical skills, media skills, programming skills, understanding of IT security);
– methodological competencies (creativity, entrepreneurial thinking, analytical skills, research skills, efficiency orientation);
– social competencies (intercultural skills, language skills, communication skills, teamwork skills, negotiation skills, ability to transfer knowledge, leadership skills);
– personal competencies (flexibility, motivation to learn, ability to work under pressure, sustainable thinking, compliance).

Table 1 illustrates the competencies of IT specialists in detail [19].

3. Introducing Industry 4.0 technologies in educational process

In different countries, the universities of the future are being formed in differently. Different levels of teaching and research activities can be observed there. To become the university of the future, an educational institution must transform, learn to apply advanced technologies, modernize and redefine the educational process. Current practice shows that most universities are at the Education 2.0 level, based on the processes of mass learning systems. Universities should avoid this practice and move to a new approach to education focusing on individualized learning.

Education 4.0, as Harkin [20] explains, is a personalization of the learning process in which the learner has complete flexibility, is the architect of own learning path, strives for personal goals, approaches and achieves them. Modern educators need to be future-oriented and able to adapt to new methods to keep up with the changes taking place in the digital era. This is where the Educator 4.0 has a role to play and to introduce innovative approaches to teaching using new technologies.

Table 1. Competencies of IT specialists in Industry 4.0

Engineering competencies	Business and management competencies	Design and innovation competencies
– Data Science and Advanced Analytics – Human-Machine Interface – Technologies for transferring digital data into physical ones (for example, 3D printing) – Advanced simulation and virtual simulation – Data transmission and automation of systems and networks – Artificial intelligence – Robotics – Programming skills – Integrated production process control//management system – Real time optimization of logistics system management	– Technology Awareness – Change management and strategy – New Ability Management Strategies – Organizational structures and knowledge – Role of manager as facilitator – Forecasting and planning of technological processes	– Understanding the Technology Impact – Interaction of Human-Robot and User Interface – Technological design of products and services – Technological ergonomic solutions and ease of use

Learning should be interactive, creative, engaging, effective, with more emphasis on developing digital era skills and less on memorization of content.

In addition, education needs new developing adaptive educational systems that could be improved through Industry 4.0 technologies and the Internet. Education taking advantages of Industry 4.0 technologies offers opportunities supporting the process of teaching and learning through the integration of e-learning and technology. The application of these technologies provides access to socio-technical innovation at the undergraduate and graduate levels, both for teaching practice and for research, tailored to the needs of individuals and organizations. Technology-assisted learning may maximize the students' academic experience in rapidly growing fields, their interest in Industry 4.0 at all levels of global education. This article presents the main technologies of Education 4.0 significantly affecting the reform of engineering education. Below are some of them.

Remote and virtual laboratories. They have become widely used in engineering education [21]. Virtual labs are a flexible practice method for engineering education, and most of them are web-based applications enabling the students to replicate the work of real labs and gain hands-on experience. Remote labs offer a virtual interface for a real physical lab. Their main advantage is that they offer an opportunity for an educational institution non-applying any high-tech equipment to conduct certain experiments while working remotely and benefit from the equipment of another manufacturer offering all the conditions to launch experiments and obtain results. Virtual labs eliminate the risks associated with the physical presence in a real lab and the use of real items or components. Actions can be performed anytime and anywhere. This allows students with very low programming knowledge to analyze different systems, change the mathematical model, or build a new model based on new requirements.

Educational robots are used in the educational process to improve and facilitate the learning activities. Some studies [22] review the applicability of robots in education, emphasizing the main advantages of their introduction. The robots designed to support the teacher's activities in the classroom and the teaching process according to the curriculum are presented in a special category. Studies show that after applying educational robots, students are more actively involved in the learning process, even in the fields of science, technology, engineering and mathematics.

Augmented and virtual reality. Augmented reality is implemented by introducing any sensors into the visual field to supplement information about the environment and change the perception of the environment. The use of augmented reality helps students to be engaged in learning, because this technology provides an additional and indirect view of the real world. Students gain a physical training experience with enhanced sensory inputs and graphical elements, as well as useful learning tools, providing powerful support for collaborative work and socialization. Through virtual reality, students explore the visual elements of real objects, effectively improving the links between learning concepts and information. This technology helps students become more deeply involved in the educational process compared to a traditional textbook.

Some studies [23] review the augmented and virtual reality as an emerging form of experience in which the real world is enhanced by computer content. To create a real perception of the world for the user, reality is enriched with the elements such as audio, video, tactile information, graphics, Global Positioning System (GPS), etc. In the learning process, these technologies help students better and easier understand the processes and memorize the information received. These technologies have many advantages as improved collaboration, a safe place to study, learning becomes more practical, and learning materials can be used anytime, anywhere. ActiveWorlds (AW) is typical virtual reality actively used for education. The owners of AW describe it as "a sandbox platform for creating anything you can think of, a universe with hundreds of worlds, millions of objects, a dedicated and friendly community inside" [24].

The Internet of things as a component of the information and educational environment. The Internet of Things (IoT) is a system of interconnected computers, digital devices (sensors), objects, animals or people provided with unique identifiers and the ability to transmit data over the network without the need for human-to-human or human-to-computer interaction.

A "thing" in the Internet of Things refers to either a physical thing (an electrical device, a robot, etc.) or an element of the information world (a program, multimedia content, etc.). It can also refer to a person or an animal with a built-in transponder biochip, a car with built-in sensors to warn a driver about the danger on the road [25]. Sensors can be assigned an IP address, based on which data is transmitted over the network.

In educational institutions, devices and sensors are built into various educational devices, technical teaching aids. Two ways of using the Internet of things in the educational process are available. The first is the use of the Internet of things in the educational process to improve the perception of the educational process. The second is the use of IoT to study the content of education. With the help of software and built-in sensors in the studied disciplines, the processes can be controlled remotely and measuring instruments can be read. In terms of ever-increasing popularity of mobile devices, this technology has a particular impact on the educational process. It facilitates establishment of rapid communication and interaction between students and teachers both in the classroom and outside it.

E-learning platforms with game and simulation tools. Game-based learning, also referred to as gamification, is the use of a game-based approach and design in a variety of situations to engage students in the learning process and to motivate and stimulate their actions. A practical experiment that presents the game mechanism [26] shows that the social gamification can be used to improve the students' results in practical activities. Gamification is a technique often used in software engineering courses as well [27]. This method is based on a game approach used in various situations. Players must explore several aspects of the game in an environment created by the teacher.

Computer simulations provide students with the opportunity to observe and experience real situations and scenarios. Based on this, they will easily assimilate new information and combine it with the knowledge they already have. As far as engineering education is concerned, computer simulations can complement, extend, and in some cases replace traditional elements. Zavalani in his work [28] describes computer simulation of a design project for an electrical engineering course.

These educational platforms have led to a new concept of learning called the flipped classroom or flipped learning [29]. The characteristics of this new way of teaching are that the teaching instructions are provided in the form of media files (video, images, text, animation) and the time spent by students in the classroom is mainly used to better comprehend the course content, discuss with the teacher and peers, solving educational problems.

Connected open and complex visualized data technologies. Due to the huge amount of data stored on public and private devices, students often have to do some pre-processing, searching and extracting the necessary data from these devices. Some studies present various ways of visualizing complex data as a method of supporting teaching, learning and assessment of knowledge [30]. The benefits of using these technologies include stimulating the user's imagination, interactivity, using real images, identifying trends, and so forth. The transformation of raw data into a graphic format helps to explain educational content in an accessible way, allows combining data with the possibility of sharing and access to digital resources, and looking for alternative approaches to solve problems.

Training factories. A growing need of universities for putting the theoretical research of students into practice has recently grown. Although seminars, business games, case studies are held at universities in this regard, where students meet with managers to solve actual problems, many researchers recommend training factories [31]. Training factories can be viewed as real factories used for education and training purposes. The objective of training in factories is to modernize the learning process and bring it closer to industrial practice. They are an important way to put technical knowledge into practice and are used for education, training and research, and offer studying the basics of Industry 4.0, such as cyber-physical systems, smart factories, robotics, artificial intelligence and the Internet of things. As technological developments accelerate, training factories are increasingly being used by higher educational institutions. For example, the Learning Factory at the W. Booth School of Engineering and Technology at McMaster University in Canada provides students with an experiential learning lab that enables its users to understand learn and apply modern manufacturing approaches such as Industry 4.0 and additive manufacturing [32].

4. Conclusion

Education of the new generation is designed to prepare students for the challenges of the modern world. Education and training for Industry 4.0 needs to be addressed at all levels of education. In Education 4.0, information becomes ubiquitous, and the teaching and learning process dynamic. As technology rapidly changes the way industries and companies interact and function, higher education institutions also have to change the way students learn and teach, preparing them for the future. Instead of focusing on theory, educational practice should emphasize the application of experiential learning. The competencies required for successful Industry 4.0 should be part of professional education. To train the graduates for the future of life and work to be achieved through Industry 4.0, the university and faculty must adapt to new realities. To transform the education system, the current teaching practice in universities should be reconsidered and the teaching process restructured to meet future needs.

Higher education institutions are strongly encouraged to respond to the changes in industry much faster. To meet the needs of Industry 4.0, higher education institutions must continue to introduce innovative methods to improve the educational process. The introduction of advanced technologies in education will play an important role for higher education institutions, increase the efficiency of the teaching and learning processes. With new technologies, students will focus on learning more. Using Industry 4.0 technologies in the learning process, educational institutions will put the student at the center of this process and better understand their needs. Numerous educational programs and methodological approaches can be created with sufficient information about students, meanwhile, each student can choose what, in his/her opinion, is more preferable and important for him/her. The use of multiple technologies in the learning process will enable students to gain more interesting experiences for their future careers.

References

1. Schwab, K. (2016). Fourth industrial revolution. Moscow. : EKSMO.
2. Balyer, A. Oz, O. (2018). Academicians Views on Digital Transformation in Education, International Online Journal of Education and Teaching, 5(4), 809–830.
3. Benešová A., Tupa J., (2017). Requirements for Education and Qualification of People in Industry 4.0, 27th International Conference on Flexible Automation and Intelligent Manufacturing, 27-30 June 2017, Modena, Italy, Procedia Manufacturing, 11, 2195–2202.
4. Abhyankar K., Ganapathy S. (2014). Technology-Enhanced Learning Analytics System Design for Engineering Education, International Journal of Information and Education Technology. 4, 345–350.
5. McQuaid, RW, Lindsay, C. (2005). The concept of employability. Urban Stud.; 42(2), 197–219.
6. Hofmann E., Ruesch M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. Computers in Industry, 89: 23–34.
7. Filho MF, Liao Y, Loures ER, Canciglieri O. (2017). Self-Aware Smart Products: Systematic Literature Review, Conceptual Design and Prototype Implementation. Procedia Manuf.; 11:1471-1480. https://doi.org/10.1016/J.PROMFG.2017.07.278
8. Lee, J., Bagheri, B., Kao, H-A. (2014), Recent Advances and Trends of Cyber-Physical Systems and Big Data Analytics in Industrial Informatics. Int Conf Ind Informatics 2014. https://doi.org/10.13140/2.1.1464.1920
9. World Economic Forum. The Future of Jobs Report 2020, October 2020. http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf
10. Chen, D., Doumeingts, G., Vernadat, F. (2008). "Architectures for Enterprise Integration and Interoperability: Past, Present and Future." Computers in Industry. 59 (7), 647–659.
11. Sackey, SM, Bester, A., Adams, D. (2017). Industry 4.0 Learning Factory Didactic Design Parameters for Industrial Engineering Education in South Africa. South African, Industrial Engineering, 28(1), 114–124.
12. Hermann M, Pentek T, Otto B. (2016). Design Principles for Industrie 4.0 Scenarios. In: 49th Hawaii International Conference on System Sciences Design. Hawaii: IEEE., 2016.
13. Rautavaara, E. (2015). Educating the Future Product Designers - Exploring the anatomy of a project-based capstone course, Aalto University, 2015, p. 88.
14. Cyber-Physical Systems (CPS), http://www.imm.dtu.dk/~jbjo/cps.html
15. Passow, H.J, Passow, C.H. (2017) What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. Journal of Engineering Education, 106(3), 475–526.
16. Laudante, E. (2017). Industry 4.0, Innovation and Design. A new approach for ergonomic analysis in manufacturing system. The Design Journal, 20, 2724–2734.
17. Lubis, A., Absah, Y., Sari, A, Lumbanraja, P. (2019). Human resource competencies 4.0 for generations, European Journal of Human Resource Management Studies. 3(1), 99–105.
18. McQuaid, RW, Lindsay, C. (2005). The concept of employability. Urban Stud.; 42(2), 197–219.
19. Universities of the Future, https://universitiesofthefuture.eu/wp-content/uploads/2019/02/State-of-Maturity_Report.pdf
20. Harkin A.M. (2008). Leapfrog Principles and Practices: Core Components of Education 3.0 and 4.0, Future Research Quality, 24(1), 19–31.
21. Heradio, R., Torre, L., Francisco, D.G., Herrera-Viedma, J.C., Dormido, S. (2016). Virtual and remote labs in education: A bibliometric analysis, Computers & Education, Elsevier, 98, 14–38.
22. Mubin, O., Steven,s C.J., Suleman S., Abdullah M., Jian-Jie, D. (2013). A review of the applicability of robots in education, Technology for Education and Learning,

http://roila.org/wp-content/uploads/2013/07/209-0015.pdf
23. Souza-Concilio, I., Pacheco, B. (2013). The Development of Augmented Reality Systems in Informatics Higher Education, International Conference on Virtual and Augmented Reality in Education, Procedia, 25, Elsevier, 179–188.
24. Active Worlds, https://www.activeworlds.com
25. Internet of Things (in Russian), https://www.sas.com/ru_ru/insights/big-data/internet-of-things.html
26. García-Cabot, A., García-López, E., Caro-Alvago, S., Gutierrez-Martinez, J., de-Marcos, L. (2020). Measuring the effects on learning performance and engagement with a gamified social platform in an MSc program, International Journal of Engineering Education, 1(28), 207–223.
27. Pieper, J., Lueth, O., Goedicke, M., Forbrig, P. (2017). A case study of software engineering methods education supported by digital game-based learning: Applying the SEMAT Essence kernel in games and course projects, IEEE Global Engineering Education Conference (EDUCON), Athens, pp. 1689–1699.
28. Zavalani, O. (2015). Computer-based simulation development of a design course project in electrical engineering, Computer Applications in Engineering Education, Wiley Online Library, 23, 4, 587–595.
29. Karabulut-Ilgu, A., Cherrez N.J., Jahren, C. (2018). A systematic review of research on the flipped learning method in engineering education, British Journal of Educational Technology, 49, 3, 398–411.
30. Ifenthaler, D. and Erlandson, B. (2016). Learning with Data: Visualization to Support Teaching, Learning, and Assessment. Technology, Knowledge and Learning. 21 (1), 1–3.
31. Souza-Concilio, I., Pacheco, B. (2013). The Development of Augmented Reality Systems in Informatics Higher Education, International Conference on Virtual and Augmented Reality in Education, Procedia, 25, Elsevier, 179–188.
32. Elbestawi M., Centea D., Singh I., & Wanyama, T. (2018). SEPT Learning factory for Industry 4.0 education and applied research. Procedia Manufacturing, 23, 249–254.