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THE USE OF EDUCATION 4.0 TOOLS IN TERTIARY EDUCATION SYSTEM IN SLOVAKIA

Abstract. This paper examines the use of digital learning tools in a technological higher education institution in Slovakia in the context of Industry 4.0 development. Based on a literature review and empirical findings from interviews with education professionals at higher education institutions, this article discusses the critical issues and challenges in the application of some of the Education 4.0 digital learning tools, namely Building Information Modeling (BIM) technology, augmented reality and digital game environment. In this paper, the use of digital learning tools and the collaboration of teachers and researchers are presented as a promising practice of the Slovak University of Technology in Bratislava. This higher education institution reflects current innovative trends in the Education 4.0 concept, e.g. Building Information Modeling technology and augmented reality methods are used as part of a modular learning system, using sensors in manufacturing, preventive maintenance, simulation, design, and 3D printing. Data collection was realized by web pages analysis including webpages of the faculties and by interviews in a sample of educational professionals.

The key challenge for the Slovak education system is the improvement of the interconnection between the education system and the industry.The current effort of the scientists and teachers is to identify future trends, techniques, experiences, and skills needed to succeed in the education associated with the requirements of the Industry 4.0 environment. The paper discusses augmented reality with its benefits in time efficiency, ergonomics, and ecological issues. Specific challenges in Education 4.0 learning tools are analysed considering students' age, attitude towards digital technologies, previous experiences, and situation awareness. The paper stresses the importance of strategical support of Education 4.0 digital learning tools application in the educational process in Slovakia.

Keywords: digital learning tools; Education 4.0; higher education institution; technological education; digital competences; augmented reality.

1. INTRODUCTION

Problem statement. The Slovak government, like governments in other countries, focuses on the adoption of digital technologies in the education system to increase its quality, to improve the graduates' chances on the labour market, and to equip them with competencies necessary for the digital era [1]. However, Slovakia belongs to a group of countries with low digital performance. In 2018 Slovakia ranked in *The Digital Economy and Society Index*

(DESI) as 20th out of 28 EU Member States [2]. Currently, the increasing importance of digital performance is being addressed in terms of differences in competencies acquired through education in Slovakia and identified expectations of practice [3].

Even though the education strategies are ambitious, critical opinions about the unsatisfactory quality of education are heard from employers, managers, HR professionals, experts in the economy, and the labour market.

According to OECD Survey Adult Study, 4.2% of people have reached the third degree of ability to solve problems in a technically advanced environment in Slovakia, which is the lowest result among all participating countries. The average proportion of people at this level in the participating OECD countries is 5.8% of adults. The largest share of the population at this level is in Sweden (8.8%) and Finland (8.4%) [4]. The level of problem-solving competence in a technically advanced environment is, besides reading and mathematical literacy, related to the level of education achieved to a lesser degree. At all monitored levels of education, including higher education institution students and graduates, it is possible to observe a low level of ability to solve problems in a technically advanced environment and low levels of preparation for the effective use of the information and communication technology.

The emerging information type of society requires, besides the achievement of a certain formal qualification, acquisition of the key competencies in line with the European Union strategy in this area. Today's defined strategic competencies are also digital competencies. According to experts, digital skills are not only part of key competencies, but also a set of necessary job qualifications [5]. While the content of the most required competencies can change, expand, and enrich over a lifetime, digital competencies as such are slowly becoming a solid and dynamic part of human capital due to the overlap between online and offline sociability [6].

Digital learning tools, that are being analysed in this article, reflect the development of innovative ways of production and manufacturing within the development of Industry 4.0. Innovative tools discussed in education within the Education 4.0 concept include augmented reality, simulation, RFID, the use of artificial intelligence methods in predictive analysis, transmission and processing of large amounts of data in real time and prediction using processed data, 3D data visualization in design, control, and monitoring trends, mapping and visualization of processes utilizing sensors, application of the Internet of Things, concept design and implementation of complex networks.

After the analysis of the key Education 4.0 tools, the paper examines the data collected on a sample of educational professionals of the Slovak University of Technology and data from web pages of selected faculties of the Slovak University of Technology. Challenges of the adoption of Education 4.0 tools in Slovakia are discussed in the final part of the paper.

The purpose of the study is to analyse the adoption of Education 4.0 tools in tertiary education as a case study of the Faculty of Civil Engineering and the Faculty of Materials Science and Technology in Trnava of the Slovak University of Technology (STU).

2. RESEARCH METHODS

Based on current literature analysis in the examined field, the paper discusses the challenges of Education 4.0 and identifies the techniques, experiences, and skills required for succeeding in education for the Industry 4.0 environment. It aims to contribute to the objectives of the research project VEGA No. 2/0077/19 “Work competencies in the context of Industry 4.0 development.”

To answer the question about the adoption of Education 4.0 tools in the case of the examined STU faculties, a descriptive case study design was adopted for the study [7]. Data collection was performed by the web pages analysis and by the interviews in a sample of chosen educational professionals.

Web pages of two faculties of STU were analysed to obtain data in new fields of study that reflect the adoption of Education 4.0 tools in STU and to reflect the adoption of new educational tools within existing study fields. Quantitative data collection was accompanied by eight interviews with education professionals at the Faculty of Materials Science and Technology in Trnava of STU and 15 online interviews at the Faculty of Civil Engineering of STU to capture the real-life situation in adopting Education 4.0.

The analysis of Strategic materials of the Ministry of Education, Science, Research, and Sports and Ministry of Economy of Slovak Republic (Strategy of the Digital Transformation of Slovakia 2030, National Action Plan of the Industry in the Slovak Republic) has been conducted on the subject of the support level of Education 4.0 development regarding tertiary education. The report examines the case of adoption of Education 4.0 tools in the above-mentioned tertiary education institution.

3. THE THEORETICAL BACKGROUND

Changes in human capital development, aimed at preparation for Human-robot collaboration, are reflected in the Education 4.0 concept. Even if the progress towards more user-friendly technologies may bring more convenient ways of human-robot communication in the future, recently, the qualification of employees, including readiness to work within a human-robot collaboration, is a challenge within Industry 4.0 implementation [8].

Within virtual learning environments, e.g. using virtual glasses, the combination of the information from real and virtual world can be attained as a part of Education 4.0, as well as the adaptation of the human workers to new work conditions in a mixed-reality work environmentas stated by [9]. “By doing so, virtual reality environment can introduce dynamic forms of learning by creating artifacts in the virtual environment with activities triggered by learners’ interaction that “enables simulation of various situations that might not be attainable otherwise due to danger or high costs, while such situation can be simulated multiple times.Trainees can learn while doing the task and by using records of the performance afterward” [9, p. 254]. Thus, virtual reality offers the highest interactivity and increases the motivation of learners resulting from the reactive response and gaming influence during learning [10]. Virtual reality, as well as the innovative technologies, such as IoT and Cloud Technology, need to be also integrated into education, supporting advanced life-long training of the skilled workforce [11], [12], [13]. Integration of Industry 4.0 requirements into education and training lies in the core of Education 4.0 development.

The concept of Education 4.0 considers, on the one hand, the exploitation of the developed technologies to facilitate the learning process, and on the other hand, preparing new methods of education for their future involvement in the factories [11].

Within Education 4.0., the concepts of Learning Factory (LF) and Teaching Factory (TF) are offered. The concept of LF emphasizes the importance of experimental learning, learning by working in companies, while the concept of TF incorporates industries in the education experience, adapting the industrial project into the context of academic practice [11]. This concept can be particularly beneficial for small and medium-sized enterprises (SMEs), which can test and simulate processes, innovations and various scenarios of the innovation testing while saving costs and time and minimizing risks in comparison with the testing during the production process. Within the cooperation between companies and the academic environment, a synergistic effect arises when the LF and TF paradigms can improve SMEs by their introduction into new technologies of the industry 4.0 environment through the transfer of product knowledge.

Virtual reality can become a substantial part of learning, e.g. in sectors such as engineering, machinery, health, aerial transportation and information and communications technology (ICT), in training robot remote control, production, simulating surgical interventions, in pilots' training, etc. [9], [14]. It is possible to consider the recommendation of the application of Virtual Reality in the context of engineering and ICT education to develop the digital pedagogical ethos of children and digital skills in primary and secondary education.

Although the strategic concepts of the Ministry of Education of the Slovak Republic reflect the need for the application of ICT in education (Action Plans), relatively little emphasis is placed on the use of ICT at higher educational levels. The need to make ICT elements accessible to higher education in line with Industry 4.0's needs is a specific area that deserves special attention. We propose to develop an Education 4.0 strategy focused on higher education, to promote the use of Virtual Reality, Augmented reality, Mixed Reality, Teaching factory, Big Data analysis, and other tools to connect the virtual and real-world, academy and industry.

Augmented reality and Mixed reality are for some scientists interchangeable. It is difficult to define the boundary between them. These terms are usually used either interchangeably, or Augmented reality refers to Mixed reality. Mixed Reality, in this case, refers to any combination of real and virtual reality, including things that are defined as Augmented Reality. In comparison, Mixed reality offers more options. Mixed reality, unlike augmented reality, offers interactivity with both real and added virtual objects, the ability to digitally manipulate in an arbitrary environment, create new objects using artificial elements or adapt them, change their shape, and move them around.

Augmented reality is expected to combine real and virtual activities interactively and to help eliminate design errors [15]. Machine Learning technologies and artificial intelligence in the construction industry make it possible to create a predictive model with high accuracy of predictions, support the streamlining of the process of preparation and construction of various objects and support the optimization of financial costs.

Within the Industry 4.0 concept, the attention is being focused on augmented reality with its benefits in time efficiency, ergonomic, and ecological benefits. Depending on information exchange in human-robot collaboration and robot-robot collaboration, these innovative tools bring intuitive and easy to see applications to communicate and to integrate a real image of the world with artificial objects. In the context of Industry 4.0, the benefits of its use are calculated mainly in logistics services [16] and in the field of providing information on production processes in real-time to improve work processes and make decisions about ongoing production [17].

However, specific limits of using virtual reality tools are being tested, too. Even if the implementation of augmented reality in the industry is one of the most desired technologies in the context of Industry 4.0, its implementation is still a challenge, as there are no specified standards. Specific challenges are identified in the impact of differences of personalities concerning augmented reality usage [18]. Also, the analyses of the work in virtual and hybrid teams confirm that trust, patience, and the ability to communicate effectively can be included among the basic preconditions for successful human-machine collaboration. The findings confirm the impact of age factors and previous online gaming experience environments on spatial orientation in virtual reality [19]. Situation awareness, which covers the ability to perceive and extract information from a surrounding and could be examined in the frame of virtual environments, is confirmed to be concerning the previous experiences and the age [20].

Implementation of augmented reality in the education process creates the need for innovative ideas in the academic sphere and education of future engineers. In the Industry 4.0

concept, visualization technology, especially virtual reality, has been emphasized as essential for sustainable education of students.

According to strategic documents in Industry 4.0 development in the Slovak Republic (National Action Plan of the Industry in the Slovak Republic, Smart Industry Action Plan), the school system of the Slovak Republic should reflect the needs of the development of work competencies 4.0, and emphasize e.g. creating virtual platforms for the adaptation of the intelligent industry.

The new content of education should address highly specialized skills: robotics, Internet of Things (IoT) deployment, open data, programming, artificial intelligence, privacy protection and security, digital skills, creative design skills, processing and analysis of data and information, statistical knowledge, organizational and process knowledge, ability to communicate within human-robot and robot-robot cooperation. The highest priority should be given to soft skills, such as time and personal management competencies, adaptability, the ability to work in a team, social and communication skills.

4. THE USE OF DIGITAL LEARNING TOOLS IN SLOVAKIA – THE CASE OF TERTIARY EDUCATION

"We are currently preparing students for jobs that don't yet exist, using technologies that haven't been invented, in order to solve problems we don't even know are problems yet." Most of us have come across this famous insight of former Secretary of Education Richard Riley about the state of education made as early as in 2014.

Nowadays, one expects from higher education institutions the enhancement of many competencies, including digital literacy. According to [21], the key competencies in the field of digital literacy include the ability to work with virtual reality and designing within virtual reality as the basis for solving problems in virtual reality. As stated in [21, p. 28], "not only work but also preparation for work in education or training - should exploit the opportunities and potential offered by mixed reality, combining sensory experience and information gain from the digital environment".

The examples, given by the authors in this area, also offer empirical findings on the benefits of digital educational tools in the tertiary education system environment. The authors present examples of forming Education 4.0, that take benefit of the innovative application of digital technologies as learning tools. These can be used not only in a repetitive and consolidating way but with the potential to learn and develop work skills in an innovative way.

Experience has shown that the digital environments, such as Minecraft, represent the innovative way how to support the development of the desirable working competencies in technologically demanding environments. Working with learning environments,which were inspired by existing virtual gaming worlds, can also support the formation of a digital pedagogical ethos that promotes a positive attitude towards working with digital technologies in hybrid human-machine work teams.

In the case of tertiary education, university students acquire not only new knowledge and competencies by using real objects of industrial automation augmented reality (AR). The modularity and versatility of the tool allow its application in teaching especially engineering subjects. Educational objects are represented by the A-Frame using virtual models, which are transmitted by AR technology and intertwined with a real image of a physical technological object. By using the technology of hybrid AR markers, the information about the examined object, such as its position and orientation, is transmitted to the observer. The interactive scene, based on a real view, provides all the necessary information obtained from the database part of the education system. By adding real-time process information from process-level controls to selected subsystems of the comprehensive AFB Factory production line from Festo Didactics, the results of the changes in the control configuration and virtual part are reflected [21].

Engineering is focused on the improvement of competences in predictive maintenance of production systems in the context of Industry 4.0, including manufacturing machines and tools, for the improvement of the production process quality [22]. Students in study program Production Equipment and Systems already use virtual reality. During the study process, the students scan technical components by using smart technologies. In the area of Production Management and Industrial Engineering, the issues with an application of simulation, RFID, Internet of Things are handled [23].

As was already mentioned, new trends in the automation and application of ICT enable research and development in a wide range of communication and management of automated software tools and knowledge systems, including a higher level of archiving and distribution.

4.1. The Slovak University of Technology as a predictor of Education 4.0 possibilities in Slovakia

STU has been for a long time a leader in technological education in Slovakia and ranks first among Slovak universities according to its graduates' employment. As the most popular and biggest research-oriented technological university in Slovakia, STU's mission is *"to achieve new knowledge through scientific research, application and dissemination of new information through engineering and other creative work, as well as to educate and enlighten the young generation in the spirit of the principles of humanism and benevolence. Thus, STU ambition is to contribute to the development of education, science, culture, and health for the good of society as a whole and, in so doing, contribute to the development of a knowledge-based society."* [24].

According to the data obtained from the faculties of the Slovak University of Technology, the trend of choosing the study of computer science has had an increasing tendency in the recent three years (Fig. 1). The data were obtained from the following faculties: The Faculty of Mechanical Engineering, The Faculty of Electrical Engineering and Information Technology, The Faculty of Informatics and Information Technologies, The Faculty of Materials Science and Technology in Trnava, and The Faculty of Chemical and Food Technology. Informatics is a sought-after study program at higher education institutions. One of the reasons is that after graduating or during this program, the graduates and students are most desirable and the highest-paid employees in the Slovakian labour market. This demand might emphasize the requirement of Industry 4.0 competencies improvement.

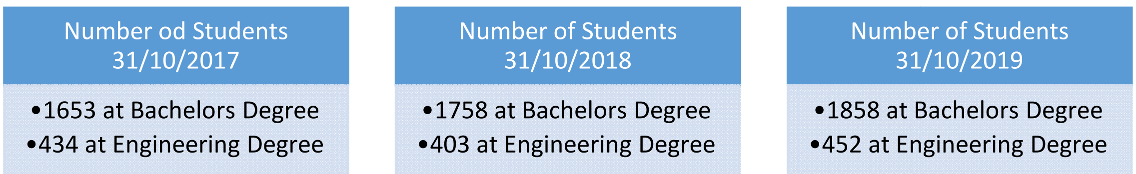

Figure 1. Number of students enrolled at STU study programs in computer science and automation by 31st October over the recent 3 years

The education system at STU offers an application of digital learning tools and promotion of the use of digital technologies in construction, engineering, technologies, and management. At the Faculty of Civil Engineering, several possibilities of digital technology have been created for smart design and construction in the context of Building Information Modelling (BIM) technology. New opportunities for the industry expansion, both on the education and the practice level, offered by the development of Industry 4.0, include the creation of a person's digital twin (by 3D scanning) and by using virtual or mixed reality illustrating and visualizing non-existing things and situations or visualizing the person around a non-existing building, simulation of construction processes, simulation of the control over the construction process by using machines controlled remotely via GPS, simulation of automated monitoring and control of the building elements by the Radio-Frequency Identification (RFID) systems. The RFID systems can be used in transportation, supply, and installation of the building elements into the construction.The advantages of the virtual or mixed reality can be used up to the final production of the virtually prepared buildings by using the 3D printing system [25]. The use of drones, autonomous vehicles, and other technological options is an opportunity for innovation, of course, with due respect for the demands of security and the necessary level of digital skills in collaboration with IT professionals.

New fields of study at the Faculty of Civil Engineering of Slovak University of Technology, that are being marked as "Construction Revolution 4.0", offer the possibility to study Augmented Reality to visualize buildings and bridges in 3D environments with the ability to virtually walk around the building.

Programming and simulation of production lines including design, 3D printing, CPS, big data processing, calculation, modelling, and simulation are integrated into the education of students at all study levels at the Faculty of Materials Science and Technology in Trnava (further MTF) at STU. Students are also educated in the Internet of Things Security issues and several issues of augmented reality, virtual reality, learning factory, and teaching factory. The information systems theory has been represented in the educational process for quite a long time and it has concentrated on these areas over time.

According to the feedback from PhD students of the Faculty of Civil engineering, most of them have used BIM technology and several statistics programs during their studies. According to one PhD student: *"I came across the term BIM technology for the first time when I was in my first year of engineering... At that time, together with two classmates, I entered an international competition focused on BIM (4D modelling) … the main theme of the competition was to bring a new idea to improve BIM-oriented software. We managed to connect the sensors for measuring the strength of a panel with a 3D model and afterward we managed to synchronize it with a schedule. Finally, we combined all these aspects into one software. As part of this project, we also used virtual reality, when we created a 3D model of the concrete reinforcement, which we tested directly on the construction site"*. The students were not familiar with the term Education 4.0 at that time. Since the term Education 4.0 is relatively new, it may be difficult to recognize digital tools as part of Education 4.0 tools, even if they are used in practice.

Big Data analysis and innovative technologies application, as one of the Industry 4.0 issues, is used at the MTF in the Advanced Technologies Research Institute (ATRI) laboratories, which are part of the 1st University Research Park in Slovakia. The ATRI consists of two main laboratories: The Scientific Centre of Materials Research and The Research Centre of Automation and ICT Implementation in Production Processes. As Figure 2 illustrates, the Scientific Centre of Materials Research consists of several laboratories of ion beam technologies, plasmatic modification and deposition, analytical methods, and computational modelling. The Research Centre of Automation and ICT Implementation in Production Processes and related laboratories comprise the Laboratories of Control Systems, ICIM, and Laboratory of Information Integration and Control Systems [26]. Research Centre of Automation and ICT Implementation in Production Processes provides simulation and optimization of processes and systems, Big Data and knowledge discovery from production databases in the hierarchical process, ICIM, information integration and control systems, artificial intelligence, bioengineering, medicine/healthcare, etc.

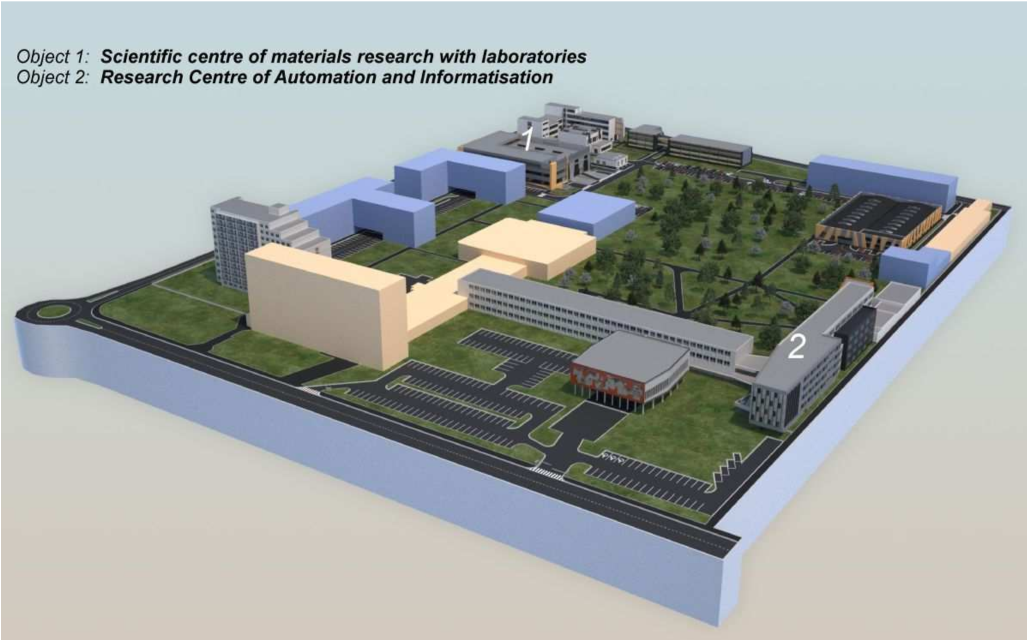

Figure 2. The 1st University Scientific (Research) Park in Slovakia [28]

The research on automation and ICT implementation in production processes and the relevant labs is being carried out at research centres. University Teachers and Ph.D. students also support the transfer of progressive technologies, collaboration in knowledge triangle (research-education-innovation) to improve know-how, innovations, and knowledge. They also provide support for start-up and spin-off activities [27].

Possibilities of how to optimize production, predict and minimize errors from the production line are investigated. To make the production more efficient, the analysis of data from pressure and error sensors is used. The analyses are performed using artificial intelligence algorithms. University teachers and Ph.D. students cooperate with companies such as Volkswagen Slovakia, PSA Peugeot Citroën Slovakia, Schaeffler, or PredictiveDataSciences.r.o.

"As Fig. 3 shows, the main aim of the projects is focused on the production process control and the deviation identification by the usage of the artificial intelligence methods in predictive analytics,transfer, transformation, adjustment, and processing in real-time; designing sensors, creating the concept, and implementing the complex networks appropriate for IoT and data visualization" [28]

An example of successful collaboration with business is a project carried out by the STU and the management of the company: "*The Slovak University of Technology in Bratislava provides our company with valuable expert advice, it brings new trends and procedures for Industry 4.0,and educates our new colleagues who are equipped with the knowledge directly applicable to the addressed problem areas*" [28].

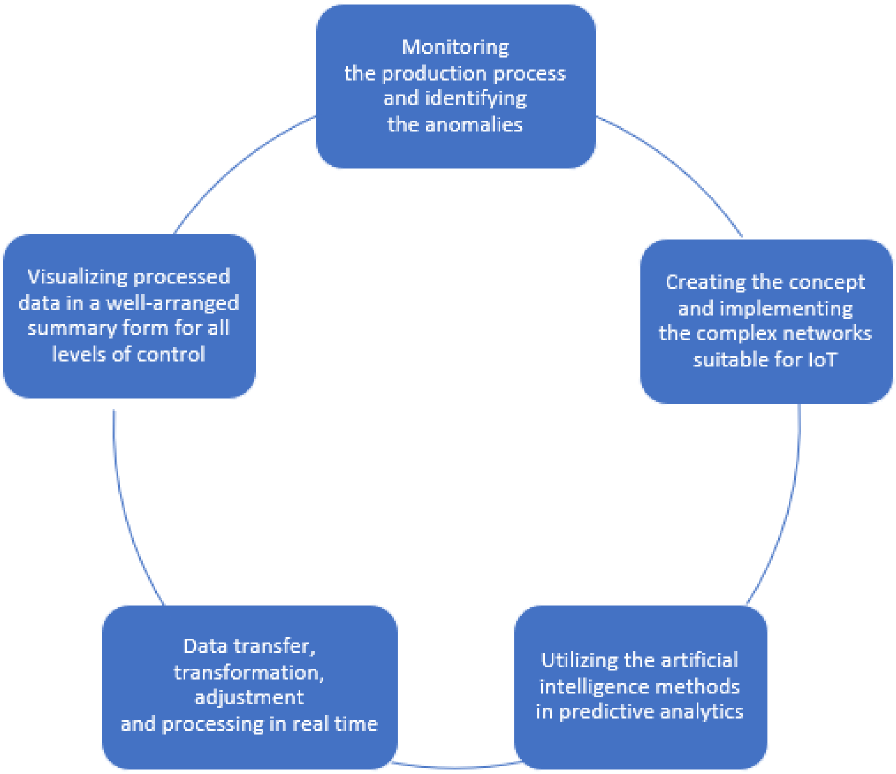

Figure 3. The key issues between MTF and its industry partners. Drawn by the authors according to [28]

Another successful project supervised by the Ministry of Education of the Slovak Republic was performed at MTF. This project focused on the implementation and use of the Industry 4.0 concept to modernize the study subject Technical Means of Automated Control, by applying the latest trends in automation and information technology. Application of the technological concept of CPS (Cyber-Physical Systems) improved the teaching process not only within the Technical Means of Automated Control subject but also other subjects thanks to the created database. The system helps the teacher to improve the effectiveness of the education process and, at the same time, students are taught new competencies, e.g. independence and analytical thinking [22]. However, according to the conducted interviews, differences in perceiving the terms Education 4.0 and Industry 4.0 are visible. A number of the interviewed respondents actively deal with the topic [22] and participate in a research project aimed at the application of Industry 4.0 concept in the frame of modernization of teaching subjects at the MTF faculty.

However, two of the interviewed teachers declared a sceptical opinion about Industry 4.0 concept and lacked accurate information about the content of the Education 4.0 term. As stated by one of them: *"The term Industry 4.0" is perceived as a buzzword with not too much deep content. Unfortunately, this is often the case. I have not found the exact definition, yet. Education 4.0 is a new concept for me - what are the elements/means? (maybe they are used, but we don't know they are part of Education 4.0)".*

4.2 New challenges in the crisis time

New challenges for education professionals are to provide education without students' physical attendance at the university during the COVID-19 quarantine. The specifics of teaching in these conditions are multidimensional. On the one hand, we initiate innovative tools and methods in the education process, and on the other hand, we try to utilize these changes to think more socially and sustainably.

During the quarantine period in the spring and summer 2020, university students have been taught by online tools such as GSuite Meet, Google Classroom, Google Drive, Zoom, Cisco Webex, and MEGASync. Students and university teachers at STU have been using the above-mentioned platforms, which can be considered also as elements of Education 4.0., on daily basis for consulting the graduation theses, online testing, online lectures, project work, chats, and consultations within teams. This platform enables Peer-to-peer learning improving metacognitive skills.

One of the programs taught at STU is MATLAB. STU is the first university in Slovakia and the Czech Republic, where students and teachers have access to the full version Total Academic Headcount (TAH) MATLAB, a great tool for engineering calculations and comprehensive research. Using the MATLAB program, the presentation of interactive tasks, as an interactive tool for extensive mathematical and statistical calculations, programming, or computer simulations is enabled. MATLAB offers more than 80 different tools, the most used are tools for development and research of control algorithms, for programming and optimization of systems in automobiles, engines, machines, robots or production lines, tools for computer simulations and verification, tools for statistics, and machine learning, tools for working with artificial intelligence or for processing large amounts of data [29].

The latest project, beneficial for the public, is the 3D printing of 300 protective shields for people in health care. This project started with the collaboration of teachers and students at MTF STU, using their obtained knowledge and professional skills. Similar projects form the new generation of engineers with both technological and digital skills which are also in line with the social engagement [30].

5. THE RESULTS AND DISCUSSION

Challenges that lie before the whole education system deal with the intensive effort to reach effective use of digital learning aids, personalized adaptive learning, project-based learning in collaboration with researchers and companies, and implementation of innovative tools and methods in the education process.

According to our findings, The Slovak University of Technology in Bratislava offers several examples of implementation of the Education 4.0 tools within existing study fields or new study fields in the examined faculties, including augmented reality, simulation, RFID, utilizing the artificial intelligence methods in predictive analytics, data transfer, distribution, transformation, adjustment and processing in real-time, prediction, sensors designing, creation of the complex networks for Internet of Things and 3D data visualization. The STU Faculty of Civil Engineering currently offers 8 bachelor and 13 master study specializations with the success rate of graduates up to 97%.

Based on the interviews conducted with Ph.D. students and teachers, Education 4.0 is a relatively new term within the education practice in Slovakia. However, the tools, included in Education 4.0 concept as its key elements, are more familiar to students when they are specified. The creation of strategic materials on the Education 4.0 development strategy could support the awareness of the term as well as the empirical analysis of the use of Education 4.0 tools.

The current challenge lies also in the emphasis on mutual collaboration of students on joint projects to develop the possibilities of creating a common set of knowledge and developing skills important for the 21stcentury. Below are the results of the survey carried out at STU between April 3rd and 9th 2020 with a sample size of 3 083 respondents.

Responsiveness was at a high level, 31% of the total current number of full-time STU students (9 877) who were invited to take part in the survey. Up to 57 % of the respondents from all 3 degrees of higher education declared their interest in online education. They want the lectures to be given in the form of online video conferences broadcast live (e.g. via Google Meet or another teleconferencing application). As a mode of practicing the acquired knowledge, almost half of the respondents (48 %) prefer video conferencing. This response is followed by the opportunity to solve online tasks with e-learning support, which is preferred by 32.63 % of respondents[31].

Also, we would like to emphasize the need for cooperation of IT professionals and pedagogical experts in the development and adoption of digital educational applications of a creative character. According to the content analysis of digital educational applications [30], more of the digital educational applications were found to be focused on an individual user base rather than on collaboration.

We suppose that Education 4.0 tools could support the innovative and interactive character of digital learning tools, offering possibilities for space and object simulations, creative-oriented learning applications [32]. Though, "usability issues, caused by the difficulty of handling AR systems are identified as a main limiting factor for learning experiences" [33, p.2], according to the respondents´ experiences, also financial issues affect the usability of AR, especially in business practice.

6. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

In conclusion, there are two main strategies that educational systems may take towards the challenges of Industry 4.0: education followers or change-makers. Followers have the right skillset for reacting to the changes in their working environment, learning to cope with the technological development system via thinking, and high-level transferrable skills. Education 4.0 should identify and develop the most required skills that are essential for creating the change and find an opportunity in a time of crisis.

The analysis of the acquisition of Education 4.0 digital tools in a real-life environment offers the possibilities for quantitative as well as qualitative analysis in this area. The advantages, as well as the barriers and limits of newly adopted digital tools, should be analysed in practice, e.g. by taking into account the type of student´s personality and the health issues during the use of augmented reality and mixed reality tools.

Education 4.0 digital tools that have been introduced in this article, represent new and innovative ways not only in formal, but also in post-formal education. Experimental research methods offer a possibility to verify adaptation to AR participation by testing the impact of the age, gender, socio-economic background, psychological factors (level of stress, trust, perceived threat, and type of personality), previous experience on the ability to perceive and extract information from a virtual surrounding, or the area of the well-being of people working in AR (as a level of stress measured by smartwatches). This experimental research should involve students as well as workers of different ages (young, middle-aged, older adults) to test the prerequisites of successful adaptation to the AR environment.

Subjective measurement of the levels of well-being of the students studying or working e.g. in AR or hybrid human-robot work teams could contribute to the sustainable development of Work 4.0 competencies based on Education 4.0 tools.

In the case of Slovakia, there is still a lack of statistical evidence on using innovative

Education 4.0 tools in education systems. In this paper, we presented some of the applications of new digital learning tools in technological education in Slovakia in the case of Slovak Technical University.

Future research will focus on monitoring the practical applications of learning tools 4.0, supporting international cooperation on research projects, creating integration platforms and identifying new challenges as specifics of cooperation between humans and robots. In the case of BIM, the application should be conducted both in learning experiences and in practice. Also, the identification of the term Education 4.0 itself in international strategy concepts could support the statistical and empirical evidence in this field for the future.

Finally, we agree with [34] that by involving scientists, scientific facilities, services, and educational networks in the process of scientific research and education, it is possible to achieve positive changes in the implementation of research activities, improve their qualitative and quantitative indicators, and introduce new forms and models of organization that positively affect students' educational outcomes.

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ВИКОРИСТАННЯ ІНСТРУМЕНТІВ «EDUCATION 4.0» У СИСТЕМІ ВИЩОЇ ОСВІТИ СЛОВАЧЧИНИ

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Анотація. У статті розглядається використання цифрових інструментів навчання в закладах вищої освіти Словаччини в контексті розвитку Індустрії 4.0. Ґрунтуючись на огляді літератури та емпіричних висновках за результатами інтерв'ю з професіоналами в галузі освіти в закладах вищої освіти, обговорюються питання і проблеми, пов'язані із застосуванням деяких цифрових інструментів для навчання Education 4.0, а саме Побудовою технології інформаційного моделювання (Building Information Modeling - BIM), доповненою реальністю і цифровим ігровим середовищем. Використання цифрових інструментів навчання, а також співпрацю викладачів і дослідників представлено як успішну практику Словацького технологічного університету в Братиславі. Словацький технологічний університет відповідає сучасним інноваційним тенденціям в концепції Education 4.0: Побудова технології інформаційного моделювання та методи доповненої реальності використовуються як частина модульної навчальної системи з використанням датчиків у виробництві, профілактичному обслуговуванні, моделюванні, проєктуванні і 3D-друку. Збір даних здійснювався шляхом аналізу вебсторінок, зокрема веб-сторінок факультетів, а також шляхом інтерв'ю з вибіркою фахівців у галузі освіти.

Ключовим завданням словацької системи освіти є поліпшення взаємозв'язку між системою освіти і промисловістю. Сьогодні зусилля вчених і вчителів спрямовані на визначення майбутніх тенденцій, методів, досвіду і навичок, необхідних для досягнення успіху в освіті відповідно до вимог середовища Індустрія 4.0. У статті обговорюється доповнена реальність з її перевагами з точки зору економії часу, ергономіки та екології. Конкретні проблеми, пов'язані з інструментами навчання Education 4.0, аналізуються з урахуванням віку учнів, ставлення до цифрових технологій, попереднього досвіду і обізнаності з ситуацією. У статті підкреслюється важливість стратегічної підтримки застосування цифрових інструментів навчання Education 4.0 в освітньому процесі в Словаччині.

Ключові слова: цифрові інструменти навчання; Education 4.0; заклад вищої освіти; технологічна освіта; цифрові компетентності; доповнена реальність.

ИСПОЛЬЗОВАНИЕ ИНСТРУМЕНТОВ «EDUCATION 4.0» В СИСТЕМЕ ВЫСШЕГО ОБРАЗОВАНИЯ СЛОВАКИИ

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Аннотация. В статье рассматривается использование цифровых инструментов обучения в высших учебных заведениях Словакии в контексте развития Индустрии 4.0. Основываясь на обзоре литературы и эмпирических выводах по результатам интервью с профессионалами в области образования в высших учебных заведениях, обсуждаются вопросы и проблемы связанные с применением некоторых цифровых инструментов для обучения Education 4.0, а именно Построением технологии информационного моделирования (Building Information Modeling - BIM), дополненной реальностью и цифровой игровой средой. Использование цифровых инструментов обучения, а также сотрудничество преподавателей и исследователей представлено как успешная практика Словацкого технологического университета в Братиславе. Словацкий технологический университет следует современным инновационным тенденциям в концепции Education 4.0: Построение технологии информационного моделирования и методы дополненной реальности используются как часть модульной обучающей системы с использованием датчиков в производстве, профилактическом обслуживании, моделировании, проектировании и 3D-печати. Сбор данных осуществлялся путем анализа веб-страниц, в том числе веб-страниц факультетов, а также путем интервью с выборкой специалистов в области образования.
Ключевой задачей словацкой системы образования является улучшение взаимосвязи между системой образования и промышленностью. Сегодня усилия ученых и учителей направлены на определение будущих тенденций, методов, опыта и навыков, необходимых для достижения успеха в образовании, связанном с требованиями среды Индустрия 4.0. В статье обсуждается дополненная реальность с ее преимуществами с точки зрения экономии времени, эргономики и экологии. Конкретные проблемы, связанные с инструментами обучения Education 4.0, анализируются с учетом возраста учащихся, отношения к цифровым технологиям, предыдущего опыта и осведомленности о ситуации. В статье подчеркивается важность стратегической поддержки применения цифровых инструментов обучения Education 4.0 в образовательном процессе в Словакии.

Ключевые слова: цифровые инструменты обучения; Education 4.0; высшее учебное заведение; технологическое образование; цифровые компетентности; дополненная реальность.