VIRTUAL REALITY AS A NEW PARADIGM OF TECHNICAL EDUCATION

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Abstract: In the last ten years, means of a digital technology have been intensively penetrating in an education. Education is gradually moving into online space as 3D technology, virtual and augmented reality, and other digital technologies and digital tools have been developing. This trend is also referred to as connectivism in education by contemporary information sources. In technical vocational education and training (TVET), the trend is not sufficiently researched and elaborated so far. Thus, our theoretical study is aimed to analyse the current state of knowledge related to virtual reality and to define the main areas of virtual reality that can be used in the condition of TVET. In the first part, we have focused on the evaluation of previous studies devoted to technology development, especially virtual reality useable in education. In other parts, we have then focused on the possibilities of using specific elements of virtual reality in condition of TVET, together with the development of necessary competencies of TVET teachers through further education.

Keywords: virtual reality in education; virtual reality and artificial intelligence relationship in education; virtual education program in technical education

1 Introduction

There has been an intensive penetration of electronic education into all educational areas in the last ten years. With the development of multimedia technology and virtual reality tools, these tools are becoming more accessible and penetrating the various fields of education. Thus, teaching and learning increasingly take place in the online space and become a subject of interest for further (professional) education and lifelong learning as well. This fact is pointed out by many Czech and foreign authors who focus on research in the field of using virtual reality in education, the Internet of Things (IoT) and interactive teaching aids and software (Adamec & Šimáně, 2021a; Bajtoš, 2022; Ha & Fang, 2013; Turek, 2014; Svoboda et al., 2020; Utami et al., 2018; and others).

Development of human society is accompanied by an effort to increase production possibilities, through which the needs of consumers are satisfied. Since the resources to produce scarce goods, which are mostly used to satisfy these needs, are limited, it forces producers to look for ways to increase productivity and efficiency. Thus, manufacturers are looking for ways to achieve this increase in production through technology. Constant pressure leads to technological innovation, introduced directly into production, which manifests itself through industrial revolutions (Marinič, 2022; Marinič & Pecina, 2021). The individual waves of the industrial revolution affect not only the production itself, but also create pressures on increasing the qualifications and retraining of workers in production, as well as pupils in vocational education (Pecina & Sládek, 2017). The conditions on the market, created due to the influence of technological innovations, in connection with the adequate quality of vocational education, can thus create a suitable environment for the application of young as entrepreneurs and contribute to the solution of the problem of the transition of young people to the labor market (Marinič & Zathurecký, 2016).

The last wave of the industrial revolutions is already a human-driven revolution, labeled Industry 4.0., which has brought the emergence of cyber-physical systems leading to communication between machines and men, machines to each other, the connection of the virtual world with the real world, and the emergence of so-called smart factories. In them, goods and products are created in virtual reality and then transferred to the real environment where they are manufactured. In smart factories, fully automated production takes place using robots and automata (National INDUSTRY 4.0 initiative). The Internet of Things (IoT) and the Internet of Everything (IoE) play an important role here. Virtual reality is gradually expanding into the field of education and is gaining an important role in this field (Lacina et al., 2015).

The aim of the presented theoretical study is to define virtual reality in the conditions of education and to evaluate the benefits and reserves of the use of virtual reality in the conditions of technical vocational education and training (TVET). Another goal of the study is to identify software in the field of virtual reality directly designed, or at least usable, for educational purposes and to demonstrate on chosen examples the use of such software.

2 Digital technology development and virtual reality

From the broader context, virtual reality belongs to the framework of electronic education and connectivism in education (Vaněček et al., 2016; Zounek et al., 2021). Connectivism represents the creation, sharing and editing of information that is created in the digital environment. As Zounek et al. (2021) points out, much information today is created in the digital environment and a large part of learning takes place in this space (see also Lorenzová & Svoboda, 2020). The same authors state that connectivism is a new paradigm of education. Connectivism is a contemporary educational theory that focuses on people's learning in the digital age. According to connectivism, learning is the process of creating and maintaining connections between different groups of people, sharing ideas and sources of information and technology. Connectivism emphasizes the great importance of networks and digital technologies in the whole learning process. Another dominant feature is the fact that learning today is not limited to formal educational institutions and areas. It is quite common for people to learn in informal and unplanned situations such as social networks, discussion forums and other online community platforms. As Gartner (2009) points out, the virtual space was created based on the connection of simulations, computer games and social networks. This created the so-called multi-usable virtual environment, which spread in science, entertainment, and education.

Virtual reality (VR) represents an interactive three-dimensional environment that is based on real foundations or created completely artificially. Lochmann (2020) specifies that we have two categories of virtual reality – projection virtual reality and desktop virtual reality:

- *Projection virtual reality* presents three-dimensional virtual models that are projected into the space of the room and can be viewed from different perspectives.
- *Desktop virtual reality* is shown on a computer screen using special glasses.

The main task of virtual reality as a created environment is to bring the environment to the reality as perceived by human senses. Currently, virtual reality is widely used in various areas, such as research and development workplaces, the entertainment industry or education. There are apps and software for virtual education in healthcare, architecture, military, construction, engineering, or gastronomy (Pecina & Adamec, 2022). In the mentioned broader concept, virtual reality in education includes the following tools and resources that form part of use of virtual reality in the educational environment:

- *Interactive aids* that use dynamic image, sound, and animation elements such as subtitles, labels, etc. (e.g., educational animations, simulations, etc.).
- The use of *3D technology and 4D technology* in education with the use of special glasses and other means with which people are transferred to virtual reality.
- *Means of augmented reality*, when existing elements and objects are combined with new – augmented – reality (e.g., virtually created object placed in the existing environment, virtual elements in map materials that are projected in means of transport, such as projection on the glass of a vehicle, etc.).
- *Virtual learning tools* (e.g., Virtual Bricklayer, Virtual Car Mechanic, Cooking Simulator, Surgery Simulator).

As can be seen, virtual reality represents a very diverse and relatively new dimension of educational reality, which uses all visualization elements that involve all the senses (sight, hearing, touch, movement, feel, smell, and taste). Virtual reality and other means of information technology have brought so-called media visualization (use of illustrative examples through media) into education, which is another and advanced level of visuality or use of illustrative examples (Vaněček, 2008; Vaněček, 2011). Today, these systems commonly use headsets that allow people to view and move around in a completely virtual world. There are also devices that allow tactile (haptic) response.

The possibilities of using virtual reality in education are appropriately summarized by Lorenzová (2020, pp. 140-142), who states that virtual reality can be used through virtual simulations, virtual games, experiential learning in virtual places, virtual schoolrooms and virtual classrooms, virtual and remote laboratories, virtual assistants for teaching, and wide spectrum of 3D models and 3D modeling in teaching. In this context, the connection between virtual reality, augmented reality, mixed reality, and artificial intelligence should be pointed out (Johnson et al., 2016). As Lorenzová (2020) points out, virtual reality, augmented reality, and personal assistants, in a form of Chatbots using artificial intelligence in teaching, are combined in virtual classes.

In the conditions of the Czech Republic, there are entire educational fields of study which are realized online and with the use of virtual reality. Appropriate example is the educational field of "Design of information services" at the Faculty of Arts at Masaryk University in Brno. In the following picture (Figure 1) we can see a recording of virtual reality enviroment testing of the mentioned educational field of study.

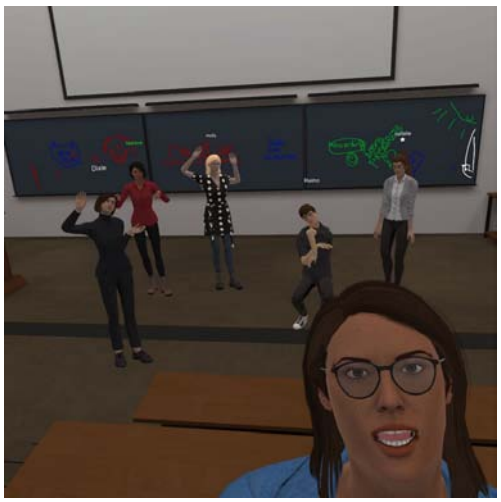

Figure 1: Educational program in virtual reality
(Source: https://kisk.phil.muni.cz/profilace/design-informacnich-sluzeb)

The study program in mentioned educational field of study uses virtual classes and didactic games in an online environment. Students can join classes from anywhere in the world. Synchronous online teaching is carried out during teaching hours every Friday. Personal meetings are optional. Thus, the virtual reality environment allows students to study in various ways in the environment such as frontal teaching, group activities with peer learning or collaborative teaching but also provides possibilities for individual meeting with students and between the students as a part of socialization.

3 The advantages and reserves of virtual reality in education

Virtual reality finds its application in educational reality and therefore advantages and reserves of virtual reality in education can also be identified. In the Czech Republic, the advantages of teaching and training using virtual reality have been pointed out by the Occupational Safety Research Institute [Výzkumný ústav bezpečnosti práce], which points to the activation of participants' training quite naturally in a safe environment and very realistically (VUP, 2021). Among other advantages inexpensive operation and maximum visualization of teaching through illustrative examples can be mentioned.

The main advantages of using virtual reality in education can therefore be summarized through the following arguments in the individual assessed areas:

- *Safety*. There is no danger of an occupational accident in virtual reality. Dangerous and risky actions and activities can be tried without endangering the health and life of participants and their colleagues. There are also no financial risks associated with damage to expensive equipment and tools in case of inappropriate handling during the teaching and learning process.
- *Maximum visualization of teaching and learning*. All senses can be engaged in virtual reality stimulating the learning process. Things and events can be shown literally from every possible point of view and in different situations and settings.
- *Measurable progress in education.* Virtual reality enables more effective acquisition of intellectual and psychomotor skills. It allows learning progress to be recorded in individual areas, providing invaluable feedback to the learners, and allowing them to adapt their pace and learning style to obtain new intellectual and psychomotor skills.
- *Use of gamification elements.* Due to their technical design, simulation and interactive software for virtual reality can be considered like computer games that use the advantages of didactic games in an electronic environment. Thus, virtual reality provides information and develops learning in a funny way, through funny activities in teaching, while stimulating the learning process.
- *Economical efficiency*. There is no need for expensive consumables or the purchase of expensive gadgets and accessories in virtual reality. It can be argued that interactive learning software for virtual reality are expensive in themselves. Although it is true, but once the educational institution acquires them, there is no need to purchase any additional accessories. Everything happens in virtual space. Virtual reality reduces the costs associated with potential damage of also expensive physical equipment, when virtual reality is not used, due to potential inappropriate handling during the educational process.

Like every technology and educational concept, virtual reality has also its reserves or disadvantages. The main disadvantage is the fact that it is the virtual reality, therefore, it is essentially separated from the actual reality, and even though almost all human senses can be engaged with it, it is still a simulation in a virtual environment. Some factors cannot be simulated without problems in virtual reality, e.g., the effect of tool wear on work, changing conditions at different temperatures, environmental influences, the effect of physical fatigue on the work performed, and many other factors encountered in the performance of work tasks in a real environment. In the event of an error, there are no injuries or material damage to the equipment. The simulation can be simply reset, and it is possible to continue working. This can lead to a loss of motivation and concentration, potentially leading to carelessness and recklessness, resulting from an exaggerated awareness of a safe environment, as opposed to the real conditions of performing the given actions in actual real environment.

The main reserves or disadvantages of using virtual reality in education can be summarized using the following arguments:

- *Virtual reality is in fact an illustrative preliminary stage of professional training* for the real performance of a given activity. It is still only a "faithful substitute for reality" for the purpose of more effective and economically efficient professional training for the performance of given expertise.
- *Virtual reality does not solve everything*; it is a simulation of activities and actions. The real world looks and can behave

differently. There are always situations and circumstances that cannot be simulated and pretended.
- *If virtual reality is not linked to artificial intelligence,* there will be no automatic evaluation of individual steps and actions of the learning subject nor any other form of active adaptation of the educational process to the learner based on the achieved educational progress. In that case, a trained expert (trainer or instructor; TVET teacher) must be available to do it.
- *The relatively high cost* of equipment and the necessity of training the teaching staff.

As can be seen from the above, teaching using virtual reality is associated with visualization through illustrative examples and safety of teaching, as well as with experience and connection with didactic games in an online environment. Didactic games in virtual reality are a suitable motivational element for involving pupils in teaching. Didactic games primarily interest pupils and they engage in pupils voluntarily. The secondary benefit of these activities is learning and fulfilling the set of learning objectives. In this context, we talk about the gamification of teaching. (Pecina, 2022).

4 The relationship between virtual reality and artificial intelligence in education

Human intelligence is defined as the general ability to solve problem and task situations. In addition, we currently have Gardner's theory of multiple intelligences, which states that each person has abilities and dispositions to excel in a specific area or more certain areas (Gardner, 2018). Artificial intelligence (AI) is defined as the entire field of informatics, which is focused on the development of systems that solve various tasks (calculations, classification, recognition, text processing, etc.). Another definition states that it is the ability of computer systems to mimic human cognitive functions, such as learning or problem solving. Artificial intelligence includes expert systems, chatbots, personal assistants and machine learning.

Virtual reality in the form of an educational software used for educational purposes in teaching and learning process may or may not be linked to artificial intelligence. If virtual reality is not linked to artificial intelligence, the learning subject does not receive feedback from the software. As we mentioned earlier, this activity must be done by the trainer. If the educational software in the form of virtual reality include connection with artificial intelligence, all actions are assessed and evaluated. In that case, there is no need the trainer is part of the activity. However, experts point out that in this case the artificial intelligence must learn everything during the education process, which is accompanied by greater costs for the development and implementation of such educational software for virtual reality.

So, in general, we recommend having interactive educational software in the form of virtual reality equipped with artificial intelligence for the educational purposes.

5 Research on the use of virtual reality in education

From the foreign authors who have dealt with virtual reality in education, a professor at Stanford University and the founder of the Virtual Human Interaction Lab, professor Bailenson can be mentioned. He specializes in research on human interaction with virtual environments (Bailenson, 2018). Other leading author is Eck (2018) who specializes in the development of educational games and simulators for teaching needs. The use of virtual reality in the teaching of chemistry is the area of interest of Young (2017) from the University of Connecticut. Dede (2005) from Harvard University focuses on the use of technology for education and learning in the digital age as well.

In terms of technical vocational education and training, foreign works by Vincenti et al., (2020), Dobre et al., (2020), Liderman et al., (2013) and Tiwari et al., (2019) focus on the area of the use of virtual reality in engineering education and training in production.

In the conditions of the Czech Republic, this area was mainly dealt by experts at technical universities. Informatics professor Jiří Štěpán focuses on research into human-computer interaction, virtual reality, and the use of these phenomena in education (Štěpán & Španěl, 2019). Another author is Jan Gajdoš, an expert in computer games and multimedia, who focuses on the development and use of game technologies and virtual reality in education and other areas (Gajdoš & Šimůnek, 2018). In the last place, we mention Radek Pelánek, who is a computer scientist and focuses on the use of artificial intelligence and virtual reality in education (Pelánek & Staš, 2017).

Further research into the use of virtual reality in technical vocational education and training is mainly focused on the use of interactive educational software. All areas of technical education have great potential for using virtual reality as the various authors point out (Vaněček, 2016, Dostál et al., 2017).

It is evident from the above that virtual reality in education is synthesized in a desirable way with didactic games in the conditions of electronic education. Didactic games are a popular motivational tool and a means of involving pupils in teaching. If the didactic game is provided in a three-dimensional environment, it is an ideal connection of virtual reality with motivational and activation processes in teaching and learning.

6 Virtual educational software in technical vocational education and training

Nowadays, education in virtual reality is most represented abroad, especially in the USA and Western Europe. However, we also have information about the use of virtual reality in teaching from Asia, e.g., in Singapore (Milko, 2017; Pozniak, 2021; Tan, 2017). Based on the available sources, it can be concluded that the area of virtual reality is the most developed area in education.

Currently, virtual teaching software are used in the practice of technical vocational education and training at secondary schools. Only the selected options of using the educational software for virtual reality will be presented due to the extensive scope of the topic. Among other things, the following virtual learning software is available on the market in the Czech Republic and abroad for the needs of teaching in technical vocational education and training:

- *Job Simulator* – a game focused on examples of work in various professions. It can be used at the beginning of vocational training in technical fields such as car mechanic, welder, CNC machine programmer. (Job simulator, 2016)
- *Simutech* – the system allows students to perform virtual simulations of electrical circuits, which enables them to understand electrical processes and concepts. (https://simutechgroup.com/ansys-software/electronics/)
- *Labster* – the system allows pupils to perform virtual laboratory experiments in biology, chemistry, and physics. Pupils can investigate and compare different processes and reactions in a safe and controlled environment. (https://www.labster.com/)
- *SolidProfessor* – the system allows students to learn to use various software for design and production in the field of CAD and CAM. (https://www.solidprofessor.com/schools/)
- *VR Welding* – the system is designed for teaching welding. Students can perform virtual welding operations and improve their skills in real time. (https://www.arclabs.edu/virtual-welding/)
- *Autodesk BIM 360, Bentley Systems* – systems provide tools for creating and managing virtual buildings and infrastructure. They enable students to learn practically in real projects. (https://www.autodesk.com/bim-360/)

The above-mentioned virtual reality systems can be used in teaching as part of the application of the teaching simulation method. We also present an example of a welding simulator from Fronius. The simulator may not be technically alike the tool or machine in actual reality, but the skills practiced must be the same. The welding simulator consists of a computer that is

integrated into the form of a welding source. Special software with drivers and controllers in the form of welding torches or electrode holders with sensors that detect the position and movements of these controllers are part of the computer as the welding simulator. Simulators usually focus on conventional arc welding technologies, which are the most used in welding practice today. There are also robotic welding simulators for the training needs of welding operators. The price of welding simulators is currently (2023) between €8000 and €12000.

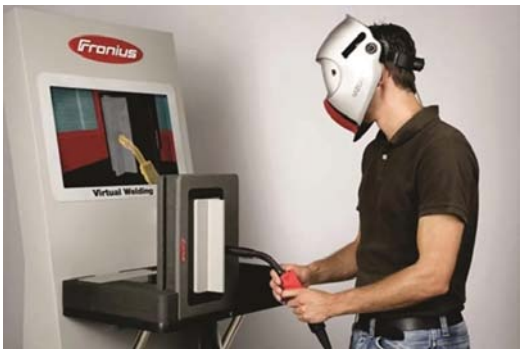

Figure 2: Welding simulator by Fronius
(Source: https://www.mmspektrum.com/clanek/virtualni-svarovani-simulatory-pro-vyuku)

7 Preparation of future TVET teachers and further education of TVET teachers in specific technical subjects

It will be necessary to implement the issue of virtual reality to the didactic training of future TVET teachers as well as in the further education of TVET teachers in pedagogical practice regarding the importance and contribution of this area to the technical vocational education and training. As Adamec (2021) points out, the importance of continuing professional education for pedagogues continues to grow. It is quite clear that the area of connectivism and virtual reality belongs there.

Although, there is material base, teaching topics and research findings, so far, however, there are not enough didactic sources in the field of branch didactics that would focus on the practical and application area of this issue in the field of technical vocational education and training in secondary schools. However, the sources are still rather fragmented and at the level of magazine studies or manuals. There are relatively few research papers with a practical application part. In the conditions of the Czech Republic, there is not yet a monographic study or a corresponding teaching text that would systematically treat this topic. The prerequisite for the development of the competencies of TVET teachers in the use of virtual reality for educational purposes is then the preparation of further education courses for TVET teachers of technical subjects in pedagogical practice.

For the implementation of this issue in TVET teacher training and further education, the following areas should be focused on:

- Justification, learning objectives and educational content in the field of using virtual reality in the preparation of TVET teachers.
- The concept and technology of teaching in this area.
- Specific inclusion of this issue in teacher training programs (time, scope, continuity with other areas of teacher training).
- Evaluation of the knowledge of the target group in this area.

The didactics of technical vocational education and training and the teacher of the vocational specific subject are on the border between two fields – the didactics of technical vocational education and training and the technical field, focused on the technical side of preparing and implementing virtual reality. However, a teaching project using virtual reality is a team effort in which both teachers and IT professionals must participate.

8 Conclusion

The potential of using virtual reality in education is expanding very quickly. As can be seen, these areas bring maximum visualization through illustrative examples, strong experience, vividness, dynamism, and an easier way to understanding relatively complex phenomena, processes, and systems into the teaching. However, it is necessary to keep in mind the reserves and disadvantages of this phenomenon, which is mainly the fact that it is an artificially created environment that is not real and cannot imitate or demonstrate certain things. In further development, a wider implementation of virtual reality in the education of all fields, including technical ones, can be expected. The next generation of devices and equipment will provide a more perfect experience and wider possibilities. In this context, experts talk about spending more time in virtual worlds.

It will be necessary to revise the system of didactics of technical vocational education and training in relation to this phenomenon, because apparently a new paradigm of technical vocational education and training is emerging. In further work, we have the ambition to map the currently available interactive programs and simulators for the needs of technical vocational education and training and their use in technical vocational secondary school. The output could be a monographic study on the issue of virtual reality in technical vocational education and training.

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