SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 187

REVIEW OF VIRTUAL REALITY APPLICATIONS APPLIED IN INDUSTRIAL PRACTICE

Kinga STECUŁA

Silesian University of Technology, Faculty of Organization and Management; kinga.stecula@polsl.pl, ORCID: 0000-0002-6271-2746

Purpose: The paper aims to explore the utilization of virtual reality applications in industrial practice, particularly focusing on Polish industrial enterprises. It identifies the various areas of VR application in the industry, provides new insights into VR's practical usage, and shows successful real-world examples, thus contributing to scientific knowledge by highlighting the extensive practical potential of virtual reality in Poland's industrial sector.
Design/methodology/approach: The objectives of the paper are achieved through a review and analysis of virtual reality applications used in Polish industrial enterprises. It focuses on specific VR solutions adopted by these companies, characterizing their practical applications and positive outcomes.
Findings: In the course of the study, the author conducted an in-depth review and analysis of virtual reality applications used in Polish industrial enterprises. The research identified various areas of practical VR implementation within the industry, and through the examination of specific applications, highlighted the positive outcomes and benefits of these solutions.
Research limitations/implications: The study's findings contribute new insights into the practical use of virtual reality in industry and can be a basis for developing directions for future research in exploring and expanding the scope of VR applications within industrial enterprises.
Practical implications: The practical implications of the study are significant for both the industrial sector in Poland and the broader application of virtual reality technology. By reviewing and characterizing specific VR applications used by Polish industrial enterprises, the paper offers practical insights into the diverse areas where VR can be effectively utilized in industry. These findings provide valuable information for companies seeking to improve their operations, efficiency, and safety through the implementation of virtual reality solutions.
Originality/value: The research addresses a knowledge gap by providing detailed descriptions and characterizations of VR applications that have been developed for specific companies and are actively used in practice. This emphasis on real-world examples and positive outcomes adds practical relevance to the study's findings, making it a valuable resource for businesses, researchers, and professionals interested in using the potential of virtual reality to enhance various aspects of industrial operations.

Keywords: virtual reality, VR, VR training, VR simulation, industrial practice.

Category of the paper: Research paper.

1. Introduction

With the development of technology, companies are faced with new opportunities to adapt modern Information and Communications Technology (ICT). Companies improve human-machine communication because it provides good results in terms of improving work effectiveness, providing work monitoring, and minimizing errors. The use of artificial intelligence (Bahroun et al., 2023), which is one of the very important pillars of Industry 4.0, by manufacturing companies can be observed on an increasingly large scale. Industry 4.0 is an important contributor to industrial innovation (Calabrese et al., 2023). Elements such as the Internet of Things (Iot) (Nauman et al., 2020), cloud computing (Sadeeq et al., 2021), additive manufacturing (Orzeł and Stecuła, 2022), autonomous robots (Aubin et al., 2022), and use and generating data (Stecuła et al., 2022) are the marker of the New Era. One of the elements of Industry 4.0 is also virtual reality (VR), augmented reality (AR), and mixed reality (MR), creating great opportunities for both manufacturing and service companies. Virtual reality can be used for various purposes. One of the application areas of virtual reality is, naturally, entertainment. On many digital distribution platforms (Stecuła, 2022), next to video games, virtual reality applications, designed to be played by users from all over the world, can be found. Virtual reality can also be applied to industrial practice in various areas of the company's operation and for various purposes. And it was the industrial practice that inspired the author to carry out the research described in the article.

Therefore, the author reviews the virtual reality applications used in industrial practice. The author of the study focuses on VR solutions used by Polish industrial enterprises. Therefore, the main objective of the research is to identify the areas of use of VR in practice in industry in Poland. Furthermore, the other objective of the study was to provide new knowledge on VR applications applied in industry practice in Poland. The paper reviews, describes, and characterizes VR applications that have been ordered by specific companies and are used in practice; additionally, these solutions bring positive results. Therefore, the article contributes to science and is of novelty because, by presenting practical examples, it reveals the wide practical possibilities of virtual reality used in industrial enterprises operating in Poland.

The paper is divided into 5 chapters. Chapter 2 includes the literature review, and chapter 3 includes the methods. Chapter 4 contains the results of the research that are the characteristics of the reviewed applications. Chapter 5 presents a summary and conclusions.

2. Literature review

Virtual reality technology is defined as the use of computer technology to create the effect of a three-dimensional interactive world in which objects give the impression of being physically present (Biocca, Lanier, 1992; Lanier, 1992). This environment allows every user to interact directly with an alternative reality. The user can immerse themselves in the virtual world. The VR environment allows one to activate the senses of sight, hearing, and touch. De-spite audiovisual effects, users most often use controllers that are their virtual hands, so they can touch objects, pick them up, drop them, etc. The creator of the term "virtual reality" is Jaron Lanier (Lanier, 1992), an American computer scientist, futurologist, and founder of VPL Research. VR applications are developed in special programs operating in 3D modeling. Virtual reality design consists of multimedia that creates an image of the real or fictional world, objects, space, or events (Sherman, Craig, 2003). The process of creating a virtual reality application is very time consuming. Modern IT technologies enable the creation of any scenario for virtual reality applications using various engines, e.g., Unreal Engine 4 (Kobak, 2016), Unity (Jungherr, Schlarb, 2022; Wilk, 2017), In-house (Skop, 2018). More and more companies specialize in developing dedicated applications are founded.

Virtual reality can be applied in different industries and for different purposes. Naturally, it is the entertainment industry that has been affected by VR. Many virtual reality applications are available on free-available digital video game distribution platforms. Next to video games, their VR counterparts are available; however, original applications designed to be used with VR headsets are also obtainable. An example of such a platform is Steam, which offers over 125,000 games and applications, of which almost 6700 are VR applications (data on July 2022) (Stecuła, 2022). According to the results of my previous research (Stecuła, 2022), the most numerous group of VR applications on Steam is action applications – they represent more than half of all VR applications (51.22%). Subsequently, there are casual applications (40.78%), and then the third most numerous group of applications consists of simulation VR applications (37.35%). Then, there are adventure, atmospheric, strategy, exploration, arcade, puzzle applications, and so on.

Naturally, virtual reality can be used not only for entertainment. In the literature, papers showing the use of virtual reality in education. There are examples of applying VR in education for studying engineering (di Lanzo et al., 2020; Soliman et al., 2021), human anatomy (Izard et al., 2017), medicine (Baniasadi et al., 2020; Pottle, 2019), architecture and construction (Alizadehsalehi et al., 2019; Bashabsheh et al., 2019; Safikhani et al., 2022), foreign languages (Peixoto et al., 2019; Pinto et al., 2019; Symonenko et al., 2020), aviation (Brown et al., 2021; Fussell, 2020; Fussell, Truong, 2020), kinematics (Dergham, Gilányi, 2019; Nersesian et al., 2021; Xu et al., 2020) and many more. Other papers present proposals of educational VR laborato-ries (Zhang et al., 2018) and of application VR at technical universities (Stecuła, 2019).

Virtual reality is also used in counteracting and overcoming mental problems, such as post-traumatic stress disorders (Kovar, 2019; Lyu, 2021; Park et al., 2019), anxiety (Aniki-na et al., 2021; Baghaei et al., 2021; Boeldt et al., 2019; Caponnetto et al., 2021), depression (Baghaei et al., 2021; Migoya-Borja et al., 2020) and so on. It can be also helpful with rehabilitation (Blasco et al., 2021; Maggio et al., 2019; Smits et al., 2020).

Finally, VR applications are applied in different industries. In the literature, there are papers referring to VR in, among others, the following industries: construction (Ghobadi, Sepasgozar, 2020), chemical (Fracaro et al., 2021), concrete industry (Joshi et al., 2021), hotel (Leung et al., 2020), tourism (Ozdemir, 2021), maritime (Makransky, Klingenberg, 2022), architecture (Dinis et al., 2020) and many more. Some authors show advantages of VR trainings applied in industry, such as better effectiveness (Norris et al., 2019), performance (Roldán et al., 2019), and efficiency (Naranjo et al., 2020) compared to traditional trainings. It should be noted that, especially in the case of production companies, effective preparation of employees to work at given workstations is also very important in the context of the efficiency and effectiveness of the entire production process (Loska, 2015; Loska, Paszkowski, 2022). It is also related to the effective production (Loska et al., 2016) and management of machines (Aripin et al., 2023; Balahurovska, 2023), so VR training can be an opportunity for companies.

The market of virtual reality applications is constantly evolving, and new improved goggles are being created. New controllers and other accompanying devices are introduced, and new features, such as finger recognition, are being worked on. Resolution, graphics, scenarios, and many more are improved (Xie et al., 2021).

3. Methodology

Due to the fact that one of the pillars of Industry 4.0 (Martin, Leurent, 2017) is the use of virtual reality in industrial practice, the author decided to review the virtual reality applications actually used in enterprises in Poland. The author reviews the application, guided by the following research questions:

- Q1: in which industries are VR applications used in practice in industry in Poland?
- Q2: in what areas of business activity are VR applications used in practice in industry in Poland?
- Q3: What are the different applications (referred to in Q1 and Q2) for?

The main objective of the research is to identify the areas of use of VR in practice in industry in Poland. The other objective of the study was to provide new knowledge about VR applications applied in industry practice in Poland. The research part of the article is presented as follows: subsequent subsections of Chapter 4 show various industries and areas of application of virtual reality applications. Each sub-chapter contains information about the

followings: which company ordered the application and which one developed it, what type of application it is, what it is for, what is its content, i.e. what application scenario is presented, and what was the goal of the project. It should be emphasized that the applications are actually used in practice by companies.

In the first stage of the investigation, the author reviewed the practical application. She then chose to research only those related to industry. Subsequently, she divided them into groups related to industries or areas of activity. The following methods are used in the study:

- Reviewing the websites of companies offering VR ser-vices in Poland.
- Reviewing websites to find practical VR applications.
- Conducting consultations with selected companies and institutes developing VR applications, companies that use VR applications in practice, and with graphic de-signers and computer graphics.

It is worth emphasizing that some of the VR trainings, simulations, and films presented in this article, the author of this article also had a chance to experience personally using VR headset – as part of studying the subject.

4. Results

This chapter reviews virtual reality applications. The studied VR applications were provided by companies specializing in designing and developing virtual reality applications. The applications presented below have been prepared at the request of a given production or service company – this means that the VR applications are unique. They were dedicated to the given company and its special order. Each application was dedicated to a given company, which means that the application has its own original scenario, according to which it had to be prepared. The scenario of a given ap-plication had to take into account the specificity of the company that ordered the application. The applications have been applied and put into practice by companies. The applications have been used in various industries, which con-firms the great potential and wide range of possibilities for using virtual reality in industrial practice.

4.1. Production line changeover process simulation

The first example of a virtual reality application in the industry is a solution that provides simulations of the production line changeover process by Velvet Care – the application was developed by Epic VR. The application is intended for employees of the mentioned company who need to be prepared to operate the production line. The application allows to master the activities necessary to perform the changeover. The training participant is instructed step by step what they must do. Training with the use of virtual reality enables the participant to have audio-visual instruction. For example, the participant receives voice commands, sees subtitles,

sees arrows, and certain elements are marked or highlighted in a different color (Figure 1). Training greatly affects the sense of sight and hearing. In addition, virtual reality also activates the sense of touch, because virtual hands can touch, lift, and translate individual elements. Using the application, a person trained is under constant control, therefore he or she receives feedback on the activities and operations performed all the time. Very often, they receive feedback on what has been done well and what needs to be improved. In case of this application Epic VR transferred the entire production line consisting of 10 machines from the real world to the virtual reality. The simulation allows to teach how to change over in an effective way, unscrewing exactly the same screws with the same wrenches as in reality (EpicVR, 2021).

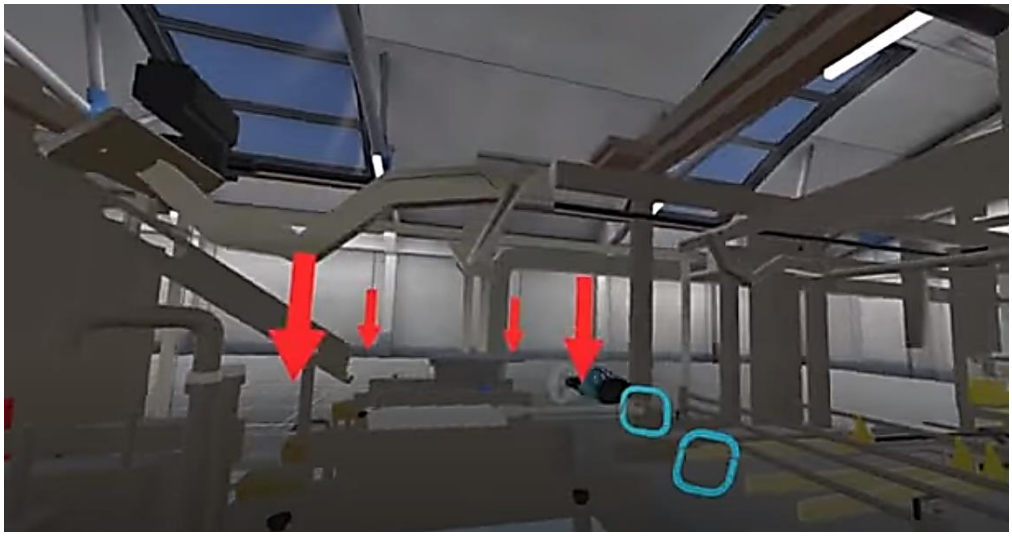

Figure 1. A screenshot of VR simulation of the production line changeover process for the Velvet Care company by EpicVR.

Source: (EpicVR, 2022a).

This type of training increases the safety of trainees be-cause the conditions of virtual training are safe, unlike training on real machines, where a mistake may result in the loss of health of the trainee or other people. Furthermore, training a person in virtual conditions does not stop the production line, as would happen in the case of training on a real machine. Production can be in progress, and at the same time, employees can train themselves without contributing to any loss of production line time. Also, several people can be trained at the same time. The developed training is flexible, which means that it is possible to change the order of the tasks performed. This means that the trainee will not memorize the training but will have to think while performing subsequent tasks. Training allows training muscle memory due to repetition of movements. All the movements made in virtual reality are exactly the same as in the real world. It should be noted that the training application also verifies the correctness of the given tasks and their order of solving. The use of virtual training brings many benefits to the company that implements this training. The first benefit is shortening the changeover time and reducing the number of errors made by the employee in this regard. This, in turn, results in increased work efficiency at individual workstations and the entire production line. Training also improves employee safety (EpicVR, 2021, 2020a).

4.2. Gantry Crane Simulator

Another solution is a gantry crane operator simulator, developed by EpicVR. The developed VR application fully reproduces the physics and mechanics of crane operation. The simulator allows to check the skills of future and cur-rent employees. In addition, it can also be used for initial employee training. Before the employees have the opportunity to work in reality as a crane operator, they can pre-pare themselves for work in a non-invasive way and without the risk of damaging the transported goods. Thanks to the use of such a simulator, employees will be better prepared to work in real conditions. This application is not a typical training application, but it allows to simulate work in a very realistic way. An employee who has dealt with a machine in the virtual world will not start from scratch, when they start working in real conditions then. The simulator is so realistic that the worker can master the required actions and learn the range of movements of the manipulators. In the case of the crane, precision in moving the manipulators is extremely important. Making mistakes in virtual reality will not have any negative consequences for the employee and the crew and will make the employee aware of how difficult the job is, how it should be performed, and how sensitive the manipulators and control system are. Thanks to the application, the employer can not only reduce the probability of making a mistake by the operator, but also reduce possible losses related to it (EpicVR, 2019a). Figure 2 shows the screenshot from the simulator.

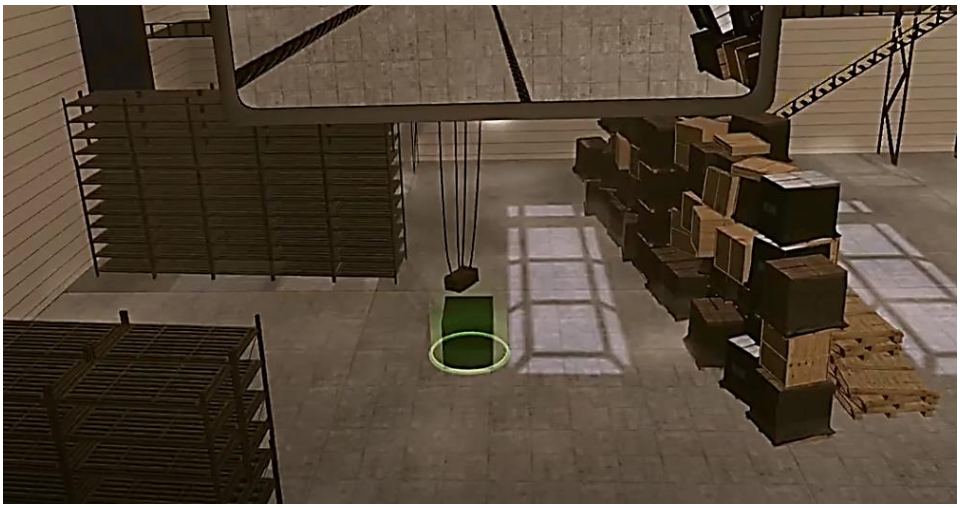

Figure 2. A screenshot of the VR simulation of gantry crane work.
Source: (EpicVR, 2019b).

4.3. Forklift simulator

Another example of a practical application of VR in the industry is the forklift simulator, also developed by Epic VR. The simulator is dedicated to future forklift operators. It allows to prepare them for work. Trainees will learn the procedures to unload various goods. Virtual reality allows to verify the user's behaviour and provide him with feedback on the correctness of the tasks performed. The application allows to select training and examination

modes. Mode 2 allows to check the acquired skills during the training mode and obtain information on the degree of mastery of individual operations, activities, and tasks. For a given application, in addition to the VR headset, additional advanced physical controllers are necessary: steering wheel, joysticks, pedals. This has also been included in the Epic VR project. The simulator is therefore an advanced configurator that allows to map different spaces. The application also allows you to add your own objects or choose from the available ones, e.g., different types of pallets, packages, as well as employees of the hall with different behaviours. The application includes several training scenarios. The applications will verify the employee's readiness to start work. The application also allows to save the results obtained by the trainee. Due to training, the employee can prepare to react appropriately to unusual and crisis situations. VR simulates certain crisis situations that an employee will find themselves in, but always in controlled and safe virtual conditions (EpicVR, 2023). Figure 3 shows a screenshot from the simulator.

Figure 3. A screenshot of the VR forklift simulator.
Source: (EpicVR, 2022b).

4.4. Chainsaw and harvester operation training

The CinematicVR company has created a VR training ap-plication for employees of the Oborniki Forest Inspectorate (CinematicVR, 2020a). The application consists of modules, thanks to which the user learns how to work safely with a chainsaw and a harvester. In the first module (harvester), the trainee is acquainted with the scope of activities related to the operation of the harvester. It is a machine used in the mechanized technological processes of wood harvesting, which allows, among others, the cutting of trees, moving trees, falling trees, pruning trees, and logging them. The user learns how to drive (move) this machine, how to move the organ, how to control the cabin, how to cut tree trunks, how to move tree trunks and logs, and many other activities. As part of the second module (chainsaw), the trainee learns how to operate a chainsaw. The user directly acquires skills on how to cut trees and precisely how to hold the saw (at what angle), how to turn it on and off. In addition, the user learns how to behave during this work with a device from the safety point of view.

Operators of these machines have a difficult job, because they are exposed to a lot of harmful factors such as noise and mechanical vibrations (Paszkowski, 2020, 2019) and health risks related to tree cutting. For this reason, an application that trains in such a real way is a very promising solution. The application shows written instructions to the trainee that they must follow step by step. The instructions gradually guide the trainee through the training process. Thanks to virtual reality training, the user can effectively remember sequences of movements, operations, and activities that they will then perform at work in reality. In case of failure, the trainee can repeat the activities in VR until success. The application provides feedback on the accuracy of the task. It uses two controllers that are virtual hands. Figure 4 shows a screenshot of the harvester operation training (CinematicVR, 2020a).

Figure 4. A screenshot of VR harvester operation training by CinematicVR.
Source: (CinematicVR, 2020b).

4.5. Aviation trainings

VR can be used for aviation training. EpicVR offers training to prepare aviation personnel for procedures. The company also prepares virtual reality training and flight simulations. This type of training allows pilots to prepare for various scenarios. The application allows the user to familiarize themselves with various scenarios in which future pilots will learn how to stay calm, not panic, and save themselves and others. The application can be used by professional soldiers of the military academies and civilian aviation personnel. The use of this training should contribute to increased safety in airspace. The company also offers flight training in the field of emergency landing procedures on water and on land, as well as proper behaviors in case of a fire on board. As part of training, the participant learns how to safely land the plane considering the passengers. Additionally, the participant learns to make appropriate decisions when threats occur during flight. The application also enables the creation and analysis of training reports. The system monitors the learner's progress and shows their result at the end. The training can also be monitored remotely by the lecturer (EpicVR, 2020b, 2020c). Figure 5 shows a screenshot of aviation training – emergency landing on water scenario.

Figure 5. A screenshot of VR aviation training by EpicVR.
Source: (EPIC VR (EpicVR, 2020d).

Another company, named CinematicVR, also developed training for the aviation industry. The company developed a training course for Rzeszow's University of Technology Aviation Training Center. Using this application, future pilots can learn and train themselves how to operate a plane. This is an example of a simulation application which allows pilots to train themselves in landing a plane. The application in a very realistic way reproduces the pilot's deck and work conditions, and allows for virtual control of the aircraft (CinematicVR, 2020a).

4.6. Mining trainings

One of the most dangerous professions with a very high risk of loss of health and life is the profession of a miner. The work conditions underground are changeable, unpredictable, and very difficult (Stecuła, Brodny, 2018). Therefore, training is a very important element in the work of a miner (Palka, Hąbek, 2017). Effective assimilation of the content provided during training reduces the risk of making a mistake while working underground, i.e., when operating mining machines, performing subsequent activities and operations, and communicating with other miners and dispatchers. In addition, training should prepare employees to react appropriately to unusual events, e.g., faults, breakdowns, or accidents.

In every enterprise, training, especially health and safety training, is very important, and in the mining industry, training an employee must result in the most effective preparation for work because working underground is associated with a high risk of loss of health and life and exposure to many harmful factors. In connection with this, mining companies can also introduce training for miners. The purpose of such training is primarily to improve overall safety at work.

The first example of using VR training in the mining industry is Jastrzębska Spółka Węglowa S.A. (JSW) (JSW Szkolenie i Górnictwo, 2020; NetTG, 2020). JSW is the largest producer of high quality hard coking coal in the European Union and one of the leading producers of coke used for smelting steel. Many research studies with great potential are conducted for JSW on coal production and coal quality (Dyczko, 2023a, 2023b, 2022; Dyczko et al., 2022; Kulpa et al., 2021; Strojny et al., 2023; Tobór-Osadnik et al., 2020), digital way of changing quality (Kopacz et al., 2020), and alternative way of using mines (Kulpa et al., 2021; Olczak et al., 2019). In the case of a new project on VR trainings, the Central Mining Institute (pl. Główny Instytut Górniczy, GIG) develops training scenarios based on real mining accidents. GIG analyzes reports of mining accidents and then extracts key situations for which training scenarios are being developed. Then, JSW Innovations (pl. JSW Innowacje – from 2022, it changed its name to JSW New Projects, pl. JSW Nowe Projekty) prepares VR applications based on prepared scenarios – it is the main contractor of the programming part. It develops a virtual environment from which up to five people can train at the same time. JSW Training and Mining (pl. JSW Szkolenie i Górnictwo), in turn, is responsible for the didactic aspects of the training environment. The application presents underground work in a very realistic way, and allows the trainees not only to obtain and supplement their theoretical knowledge, but also to develop proper procedures for dealing with dangerous situations, which are impossible to imitate in traditional training. Training scenarios cover actual accidents that took place in hard coal mines. The training plot provides users with the choice of an individual course of action and gives them the opportunity to have a real impact on how they end them (JSW Szkolenie i Górnictwo, 2020; NetTG, 2020).

Another example of VR in mining is the project also ordered by Jastrzębska Spółka Węglowa. Epic VR has pre-pared a training movie/video that can be watched in virtual reality. In order to make the film in the correct order, the company had to use a 360° camera, which allowed recording of natural conditions and the underground environment. In the virtual reality environment, it allows one to watch the movie in 360°, i.e., giving the impression that the person watching the movie is in a place shown in the movie. Thanks to the recording, the company was able to fully present the conditions of underground mining and show the longwall and corridors using virtual reality. The video has an educational character. The movie maps selected partial processes that are included in the mining production process and shows the work of miners underground. The application is used to train employees (EpicVR, 2019c). Figure 6 shows a screenshot of the 360° VR training video.

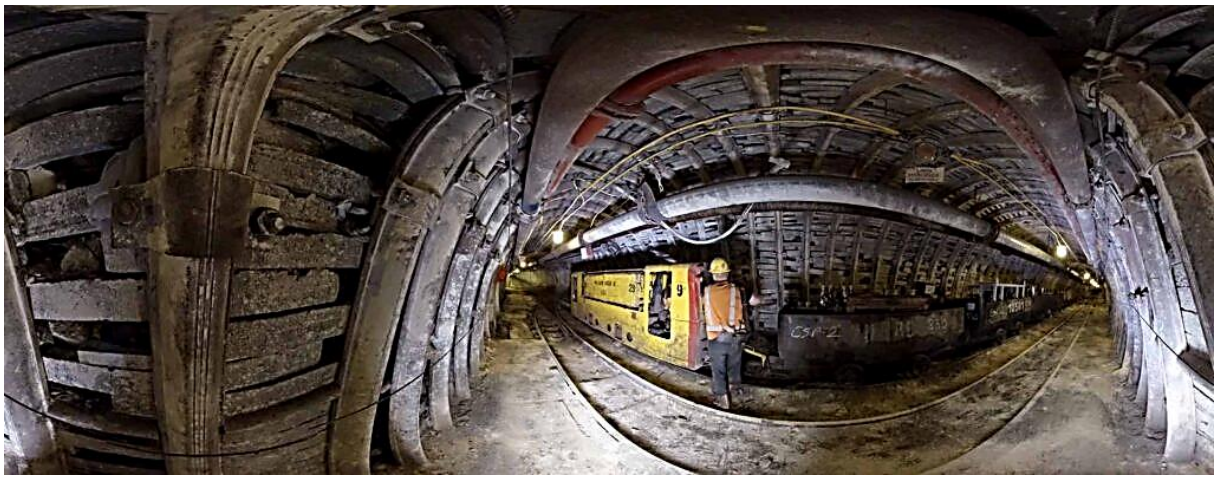

Figure 6. A screenshot of the 360° VR training video entitled „Wirtualno gruba" by EpicVR.
Source: (EpicVR, 2019c).

4.7. Machine tool installation training

The MojoApps.co company has prepared a virtual reality training on the machine tool installation process that must be done at the customer's place. The training is intended for new employees of Abplanalp Sp. z o.o. The VR application consists of two parts. In the first part, the user learns how to use the VR equipment and how to move in the virtual world. The other part, on the other hand, contains training, including specific tasks to be done in accordance with the rules and requirements applicable in the company. The result of training is the preparation of the employees for the correct installation and configuration of the machine tool in a given place. The undoubted advantage of using this training is that employees can learn the procedures at any time and repeat the activities until they are mastered. The trainee acquires knowledge of how to properly and in what order the machine should be installed at the company's customer. The training uses screwdrivers, screws, wrenches, ladders, and spirit levels – all in virtual form. During training, the user always sees written instructions on what they must do in a given phase of the training. The application also provides feedback to the user on whether they have followed the correct order of operations and whether they have installed the machine in accordance with all rules (MojoApps, 2020).

4.8. Occupational safety training

Another example of a practical VR solution in the industry is applications used for occupational health and safety training. Epic VR has developed an application for health and safety training consisting of four modules to educate employees. The subsequent modules contain the following areas (EpicVR, 2022c):

- Occupational health and safety engineering.
- Hazards within production plants.
- Personal protective equipment (PPE).
- Fire hazard.

The training prepares employees in a practical way on topic in particular areas. In addition, each module ends with a theory test that the employee must complete with a positive result (EpicVR, 2022c). Figure 7 shows a screenshot form the training.

Figure 7. A screenshot of the occupational safety training by EpicVR.
Source: (EpicVR, 2022d).

The application is an example of the modernization of the OHS training process, which in reality is not carried out at the highest level in many enterprises and is usually purely theoretical. Unfortunately, theoretical training does not provide the expected results. Virtual reality training helps prevent accidents at work, as it is interactive, immersive, and highly practical. The training participant prepares effectively to respond in crisis situations according to all health and safety procedures. During theoretical training, it is not possible to train an employee to be able to react to situations where there are various threats, for example, how to put out a fire. On the other hand, virtual reality training meets the real effective preparation of an employee who is able to face various health and safety problems directly in the virtual world, that is, under very safe and controlled conditions. For example, the trainee can try to put out a fire in VR, which first increases their imagination about fire hazards, secondly allows them to practice using a fire extinguisher in practice, thirdly allows them to mentally prepare to react during a fire (they learn how to keep cool), and additionally to all of this, the employee gains experience. In the event of failure, the employee does not suffer any dam-age to the health and, in addition, can repeat the given task in VR. It should also be added that no occupational health and safety equipment (e.g., protective clothing, fire extinguisher, etc.) is used during the training, so the company effectively trains the employee without bearing additional costs related to the consumption of materials and equipment.

Issues related to occupational safety are also dealt with by 4Help VR. The company provides VR software to improve the quality and attractiveness of OHS training. The company currently offers three types of trainings (training scenarios) (4HelpVR, 2020a):

- Legal basis in the field of occupational health and safe-ty (containing, among others, legal basis for OHS, obligations of the employer and employee, as well as types of hazards at the workplace and methods of their elimination).
- Occupational risk assessment (including assessment of the sources of threats at selected workplaces, indication of possible effects of a given threat, determination and taking preventive measures, use of personal protective equipment).
- 5S method (containing, among others, what is the 5S method, what are its stages, organizing and systematizing the workplace, increasing employee awareness).

Figure 8. presents a screenshot from the VR training – it shows a fragment from module on 5S method.

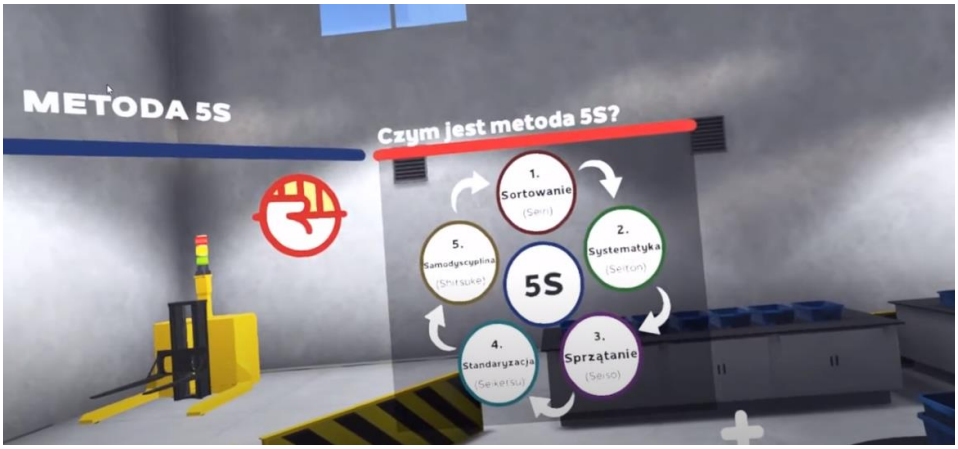

Figure 8. A screenshot of the occupational safety training – 5S training – by 4HelpVR.
Source: (4HelpVR, 2020b).

4.9. Warehouse simulator

The WSS VR Warehouse Simulator is an application developed by Epic VR for a logistics company. The WSS VR application is a simulator of warehouse activities in logistics. Training in VR combines theory with practice. Training allows one to improve the ability to collect orders and fulfil them according to the standards of the distribution center. Thanks to the application, the user can learn and how the whole way of the package shipment looks like. As part of the training, the trainee can learn how to pack and send parcels, pick orders, label parcels, scan codes, prepare warehouse documents, and many others (EpicVR, 2022e). Training is dedicated to current and future employees. On the other hand, the application is a good option for students studying logistics. Figure 9 shows a screenshot of the mentioned warehouse simulator.

Figure 9. A screenshot of the warehouse simulator by EpicVR.
Source: (EpicVR, 2022e).

5. Summary and conclusion

As a result of the research, it can be claimed that in practice virtual reality is not yet used on a large scale in Poland. The examples from practice that were cited in the article were few due to the fact that virtual reality technology is not yet very popular when it comes to application in industrial practice. VR is an innovative technology related to Industry 4.0, so it is natural that companies are yet to show resistance and fear of introducing it into practice. Nevertheless, there are companies in Poland that have decided to use this technology.

The research objectives, which included identification of the areas of use of VR in practice in industry in Poland and providing new knowledge about VR applications applied in industry practice in Poland, have been achieved. Based on the research results of the review of the practical VR applications used in practice in Poland, it can be concluded that VR training, as well as VR simulations, are most often ap-plied in industrial practice. Referring to the first research question Q1, it has been concluded that virtual reality is used, among others, in the mining industry, aviation, logistics, transportation, machining, forestry, and many more. It is mostly used for the following (an answer to the third research question Q3):

- General training.
- On-the-job training.
- Occupational and health training.
- Machine operation training.
- Soft skills training.

- Work (of machines, of production line, at the given workstation, etc.) simulation.
- Simulation of crisis situations (for example, fire or machine failure).
- 360° videos.

When it comes to the second research question Q2, it can be claimed that the use of VR in the context of business activities of enterprises is still very limited. VR is applied on a small scale only in basic operation. It only supports basic activities through virtual trainings. On this basis, it can be concluded that the use of virtual reality in enterprises is in a very early stage.

Virtual reality has great potential to be used in industrial practice also for purposes other than those listed above. VR can be a very good working environment, for example, for architects and designers who can prepare their projects and see them in 3D. Designers often use various programs, for example (AutoCAD or Inventor), using a computer. If these programs were possible to run in VR, it would be easier for designers to imagine the designed element and work on it. In addition, the client could also get acquainted with future projects in an accessible 3D form. Thanks to this, they can get a more realistic visualization of future projects.

Machine diagnostics using virtual reality is also a very interesting direction. Thanks to the use of goggles, service technicians do not have to come to the place where the machine is located. They could work remotely, seeing a given machine in a virtual remote way and diagnosing it. Another direction is also the monitoring of a selected production line or even the entire production process using virtual reality equipment. For example, a supervisor or manager would be able to quickly control the progress of work without approaching specific positions or the production line.

Thus, in summary, virtual reality has great potential and possibilities of application in industrial practice. The possibilities and directions are huge, and VR can be used in various companies of various industries and in various areas of their activity. It should also be emphasized that, apart from VR, AR is also a very promising direction. Both technologies, as the pillar of Industry 4.0, are developing at a rapid pace and the companies that use them gain benefits.

Acknowledgements

This research was funded by Silesian University of Technology from grant number BKM-648/ROZ3/2022 (13/030/BKM22/0072) entitled “Categorization of virtual reality applications available on selected digital platforms”.

References

1. 4HelpVR (2020a). *BHP VR*, https://4helpvr.com/oferta/bhp-vr/, 5.30.23.
2. 4HelpVR (2020b). *5S method H&S VR training*, https://www.youtube.com/watch?v=zcyzh-ZII88&ab_channel=4HELPVR, 5.30.23.
3. Alizadehsalehi, S., Hadavi, A., Huang, J.C. (2019). *Virtual reality for design and construction education environment*. AEI 2019 Integr. Build. Solut. Natl. Agenda, 193-203.
4. Anikina, V.G., Pobokin, P.A., Ivchenkova, J.Y. (2021). The use of virtual reality in overcoming the state of anxiety. *Experimental Psychology, 14*, 41.
5. Aripin, N.M., Nawanir, G., Mahmud, F., Fauzi, M.A., Hussain, S., Lee, K.L. (2023). Systematic Literature Review: Theory Perspective in Lean Manufacturing Performance. *Manag. Syst. Prod. Eng., 31*, 230-241.
6. Aubin, C.A., Gorissen, B., Milana, E., Buskohl, P.R., Lazarus, N., Slipher, G.A., Keplinger, C., Bongard, J., Iida, F., Lewis, J.A. (2022). Towards enduring autonomous robots via embodied energy. *Nature, 602*, 393-402.
7. Baghaei, N., Chitale, V., Hlasnik, A., Stemmet, L., Liang, H.-N., Porter, R. (2021). Virtual reality for supporting the treatment of depression and anxiety: Scoping review. *JMIR Ment. Heal., 8, e29681*.
8. Bahroun, Z., Tanash, M., As'ad, R., Alnajar, M. (2023). Artificial Intelligence Applications in Project Scheduling: A Systematic Review, Bibliometric Analysis, and Prospects for Future Research. *Manag. Syst. Prod. Eng., 31*, 144-161.
9. Balahurovska, I. (2023). The Development of Technological Support Organizations as an Indicator of Management Efficiency. *Manag. Syst. Prod. Eng., 31*, 242-247.
10. Baniasadi, T., Ayyoubzadeh, S.M., Mohammadzadeh, N. (2020). Challenges and practical considerations in applying virtual reality in medical education and treatment. *Oman Med. J., 35, e125*.
11. Bashabsheh, A.K., Alzoubi, H.H., Ali, M.Z. (2019). The application of virtual reality technology in architectural pedagogy for building constructions. *Alexandria Eng. J., 58*, 713-723.
12. Biocca, F., Lanier, J. (1992). An insider's view of the future of virtual reality. *J. Commun. 42*, 156-157.
13. Blasco, J., Igual-Camacho, C., Blasco, M., Anton-Anton, V., Ortiz-Llueca, lvaro, Roig-Casasus, S. (2021). The efficacy of virtual reality tools for total knee replacement rehabilitation: A systematic review. *Physiother. Theory Pract., 37*, 682-692.
14. Boeldt, D., McMahon, E., McFaul, M., Greenleaf, W. (2019). Using virtual reality exposure therapy to enhance treatment of anxiety disorders: Identifying areas of clinical adoption and potential obstacles. *Front. Psychiatry, 10*, 773.

15. Brown, C., Hicks, J., Rinaudo, C.H., Burch, R. (2021). The use of augmented reality and virtual reality in ergonomic applications for education, aviation, and maintenance. *Ergon. Des., 10648046211003468*.
16. Calabrese, A., Costa, R., Tiburzi, L., Brem, A. (2023). Merging two revolutions: A human-artificial intelligence method to study how sustainability and Industry 4.0 are intertwined. *Technol. Forecast. Soc. Change, 188, 122265*.
17. Caponnetto, P., Triscari, S., Maglia, M., Quattropani, M.C. (2021). The simulation game—virtual reality therapy for the treatment of social anxiety disorder: A systematic review. *Int. J. Environ. Res. Public Health, 18, 13209*.
18. CinematicVR (2020a). Szkolenia VR – do czego służą? https://cinematicvr.pl/aplikacja-szkoleniowa-vr-dla-nadlesnictwa-oborniki/, 5.29.23.
19. CinematicVR (2020b). *VR Training App. Chainsaw + Harvester training. Szkolenie VR dla Nadleśnictwa Oborniki*. https://www.youtube.com/watch?v=SFV7KxeAC1Y&ab_channel=CinematicVR, 5.29.23.
20. Dergham, M., Gilányi, A. (2019). *Application of virtual reality in kinematics education.* 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom). IEEE, pp. 107-112.
21. di Lanzo, J.A., Valentine, A., Sohel, F., Yapp, A.Y.T., Muparadzi, K.C., Abdelmalek, M. (2020). A review of the uses of virtual reality in engineering education. Comput. *Appl. Eng. Educ., 28,* 748-763.
22. Dinis, F.M., Sanhudo, L., Martins, J.P., Ramos, N.M.M. (2020). Improving project communication in the architecture, engineering and construction industry: Coupling virtual reality and laser scanning. *J. Build. Eng., 30, 101287*.
23. Dyczko, A. (2022). Modeling of quality parameters of the coking coal as a process of adapting the output to the contracted parameters. *Acta Mon-tan. Slovaca, 27,* 11-26.
24. Dyczko, A. (2023a). Production management system in a modern coal and coke company based on the demand and quality of the exploited raw material in the aspect of building a service-oriented architecture. *J. Sus-tain. Min., 22*.
25. Dyczko, A. (2023b). The geological modelling of deposits, production de-signing and scheduling in the JSW SA Mining Group. Gospod. S*urowcami Miner. (Miner. Resour. Manag.), 39,* 35-62.
26. Dyczko, A., Kamiński, P., Jarosz, J., Rak, Z., Jasiulek, D., Sinka, T. (2022). Monitoring of roof bolting as an element of the project of the introduction of roof bolting in polish coal mines—case study. *Energies, 15*.
27. EpicVR (2019a). *Suwnica VR*. https://epicvr.pl/pl/portfolio/suwnica-vr/, 5.8.23.
28. EpicVR (2019b). Wirtualna Rzeczywistość Symulator Pracy Operatora Suwnicy Gantry Crane Simulator, https://www.youtube.com/watch?v=H54t0SxK7f4&list=PLE9EFfAvrkYbx-iwaxXKjUFvDA3sh96v8&t=1s&ab_channel=EpicVR-VRARExpert, 5.8.23.

29. EpicVR (2019c). Szkolenie VR dla górnictwa – JSW S.A., https://epicvr.pl/pl/portfolio/szkolenie-vr-dla-gornictwa-jsw-s-a/, 5.23.23.
30. EpicVR (2020a). VR w przemyśle 4.0. – Jak usprawniamy pracę zakładu Velvet Care za pomocą wirtualnej rzeczywistości? https://epicvr.pl/pl/vr-w-przemysle-4-0-jak-usprawniamy-prace-zakladu-velvet-care-za-pomoca-wirtualnej-rzeczywistosci/, 4.20.23.
31. EpicVR (2020b). Lotnicza Akademia wojskowa w Dęblinie, https://epicvr.pl/pl/portfolio/lotnicza-akademia-wojskowa-w-deblinie/, 5.20.23.
32. EpicVR (2020c). Szkolenie Lotnicze VR, https://epicvr.pl/pl/szkolenie-lotnicze-vr/, 5.20.23.
33. EpicVR (2020d). VR i pożar w samolocie? Jak VR pomaga w szkoleniach dla lotnictwa? https://www.youtube.com/watch?v=lAGuI8L71Og&t=1s&ab_channel=EpicVR-VRARExpert,5.20.23).
34. EpicVR (2021). Jak VR wspiera transformację cyfrową firm? Case Study – Symulator Przezbrojenia Linii Produkcyjnej w Wirtualnej Rzeczywistości w Velvet Care, https://epicvr.pl/pl/jak-vr-wspiera-transformacje-cyfrowa-firm-case-study-symulator-przezbrojenia-linii-produkcyjnej-w-wirtualnej-rzeczywistosci-w-velvet-care/, 4.20.23.
35. EpicVR (2022a). Velvet Care - symulacja VR procesu przezbrojenia linii produkcyjnej, https://www.youtube.com/watch?v=Cqf8L68l3VI&t=17s, 4.20.23.
36. EpicVR (2022b). VR Forklif Simulator z zaawansowaną fizyką i konfiguratorem scenariuszy! https://www.youtube.com/watch?v=bmqF14bsK74&ab_channel=EpicVR-VRARExpert, 5.9.23.
37. EpicVR (2022c). Szkolenia BHP, https://epicvr.pl/pl/portfolio/szkolenia-bhp/, 5.25.23.
38. EpicVR (2022d). Szkolenia BHP w VR, https://www.youtube.com/watch?v=HSJkgomRoVo&ab_channel=EpicVR-VRARExpert, 5.25.23.
39. EpicVR (2022e). WSS VR Warehouse simulator - Symulator czynności magazynowych dla branży logistycznej, https://www.youtube.com/watch?v=0Ha5OxO7o_M&ab_channel=EpicVR-VRARExpert, 5.28.23.
40. EpicVR (2023). VR Forklift Simulator - Symulator wózka widłowego w wirtualnej rzeczywistości EPIC VR, https://www.youtube.com/watch?v=18kbRG-DlAg&ab_channel=EpicVR-VRARExpert, 5.9.23.
41. Fracaro, S.G., Chan, P., Gallagher, T., Tehreem, Y., Toyoda, R., Bernaerts, K., Glassey, J., Pfeiffer, T., Slof, B., Wachsmuth, S. (2021). Towards de-sign guidelines for virtual reality training for the chemical industry. *Educ. Chem. Eng., 36*, 12-23.
42. Fussell, S.G. (2020). *Determinants of Aviation Students' Intentions to Use Virtual Reality for Flight Training.* Embry-Riddle Aeronautical University.
43. Fussell, S.G., Truong, D. (2020). Preliminary results of a study investigating aviation student's intentions to use virtual reality for flight training. *Int. J. Aviat. Aeronaut. Aerosp., 7, 2*.

44. Ghobadi, M., Sepasgozar, S.M.E. (2020). An investigation of virtual reality technology adoption in the construction industry. *Smart cities Constr. Technol*., 1-35.
45. Izard, S.G., Juanes Méndez, J.A., Palomera, P.R. (2017). Virtual reality educational tool for human anatomy. *J. Med. Syst., 41*, 1-6.
46. Joshi, S., Hamilton, M., Warren, R., Faucett, D., Tian, W., Wang, Y., Ma, J. (2021). Implementing Virtual Reality technology for safety training in the precast/prestressed concrete industry. *Appl. Ergon., 90, 103286*.
47. JSW Szkolenie i Górnictwo (2020). *O projekcie*. https://www.jswsig.pl/projekty/o-projekcie, 5.30.23.
48. Jungherr, A., Schlarb, D.B. (2022). The Extended Reach of Game Engine Companies: How Companies Like Epic Games and Unity Technologies Provide Platforms for Extended Reality Applications and the Metaverse. *Soc. Media+ Soc., 8, 20563051221107640*.
49. Kobak, A. (2016). *Tworzenie wirtualnej rzeczywistości za pomocą silnika Unreal Engine 4.* Uniw. Jagielloński.
50. Kopacz, M., Kulpa, J., Galica, D., Olczak, P. (2020). The influence of variability models for selected geological parameters on the resource base and economic efficiency measures - Example of coking coal deposit. *Resour. Policy, 68*, 101711.
51. Kovar, I. (2019). Use of virtual reality as a tool to overcome the post-traumatic stress disorder of pensioners. *Int. J. Adv. Sci. Eng. Inf. Technol*.
52. Kulpa, J., Kamiński, P., Stecuła, K., Prostański, D., Matusiak, P., Kowol, D., Kopacz, M., Olczak, P. (2021). Technical and Economic Aspects of Electric Energy Storage in a Mine Shaft—Budryk Case Study. *Energies, 14*.
53. Lanier, J. (1992). Virtual reality: The promise of the future. *Interact. Learn. Int., 8*, 275-279.
54. Leung, X.Y., Lyu, J., Bai, B. (2020). A fad or the future? Examining the effectiveness of virtual reality advertising in the hotel industry. *Int. J. Hosp. Manag., 88, 102391*.
55. Loska, A. (2015). Methodology of variant assessment of exploitation policy using numerical taxonomy tools. *Manag. Syst. Prod. Eng.*, 98-104.
56. Loska, A., Moczulski, W., Wyczółkowski, R., Dąbrowski, M. (2016). Inte-grated system of control and management of exploitation of water sup-ply system. *Diagnostyka, 17*, 65-74.
57. Loska, A., Paszkowski, W. (2022). Geometric approach to machine exploitation efficiency: modelling and assessment. *Eksploat. i Niezawodn., 24*.
58. Lyu, A. (2021). *Applications and Future Perspectives of Virtual Reality in the Treatments of Post Traumatic Stress Disorder*. 3rd International Conference on Intelligent Medicine and Image Processing, pp. 151-155.
59. Maggio, M.G., Latella, D., Maresca, G., Sciarrone, F., Manuli, A., Naro, A., De Luca, R., Calabrò, R.S. (2019). Virtual reality and cognitive rehabilitation in people with stroke: an overview. *J. Neurosci. Nurs., 51,* 101-105.

60. Makransky, G., Klingenberg, S. (2022). Virtual reality enhances safety training in the maritime industry: An organizational training experiment with a non- WEIRD sample. *J. Comput. Assist. Learn., 38,* 1127-1140.
61. Martin, C., Leurent, H. (2017). *Technology and innovation for the future of production: Accelerating value creation.* Geneva Switzerland: World Economic Forum.
62. Migoya-Borja, M., Delgado-Gómez, D., Carmona-Camacho, R., Porras-Segovia, A., López-Moriñigo, J.-D., Sánchez-Alonso, M., Albarracin Garcia, L., Guerra, N., Barrigón, M.L., Alegría, M. (2020). Feasibility of a virtual reality-based psychoeducational tool (VRight) for depressive patients. *Cyberpsychology, Behav. Soc. Netw., 23,* 246-252.
63. MojoApps (2020). ABPLANALP, https://mojoapps.co/pl/portfolio/abplanalp/, 5.30.23.
64. Naranjo, J.E., Sanchez, D.G., Robalino-Lopez, A., Robalino-Lopez, P., Alarcon-Ortiz, A., Garcia, M.V. (2020). A scoping review on virtual realitybased industrial training. *Appl. Sci., 10, 8224*.
65. Nauman, A., Qadri, Y.A., Amjad, M., Zikria, Y. Bin, Afzal, M.K., Kim, S.W. (2020). Multimedia Internet of Things: A comprehensive survey. *IEEE Access, 8,* 8202-8250.
66. Nersesian, E., Vinnikov, M., Lee, M.J. (2021). *Travel kinematics in virtual reality increases learning efficiency.* IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC). IEEE, pp. 1-5.
67. NetTG (2020). Górnictwo: Innowacyjne rozwiązania mają służyć poprawie stanu bezpieczeństwa w kopalniach, https://nettg.pl/gornictwo/173396/gornictwo-innowacyjne-rozwiazania-maja-sluzyc-poprawie-stanu-bezpieczenstwa-w-kopalniach, 5.30.23.
68. Norris, M.W., Spicer, K., Byrd, T. (2019). Virtual reality: the new pathway for effective safety training. *Prof. Saf., 64,* 36-39.
69. Olczak, P., Kryzia, D., Matuszewska, D., Halbina, A. (2019). *Analysis of financial risk of a hard coal mine participation in DSR mechanisms in Poland–a case study*. E3S Web of Conferences. EDP Sciences, p. 1005.
70. Orzeł, B., Stecuła, K. (2022). Comparison of 3D Printout Quality from FDM and MSLA Technology in Unit Production. *Symmetry (Basel), 14,* 910.
71. Ozdemir, M.A. (2021). Virtual reality (VR) and augmented reality (AR) technologies for accessibility and marketing in the tourism industry. In: *ICT Tools and Applications for Accessible Tourism.* IGI Global, pp. 277-301.
72. Palka, D., Hąbek, P. (2017). *Analysis of impact of ohs training quality on knowledge of workers in mining companies in the field of occupational safety*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, pp. 61-68.
73. Park, M.J., Kim, D.J., Lee, U., Na, E.J., Jeon, H.J. (2019). A literature over-view of virtual reality (VR) in treatment of psychiatric disorders: recent advances and limitations. *Front. Psychiatry, 10,* 505.

74. Paszkowski, W. (2019). The assessment of acoustic effects of exploited road vehicles with the use of subjective features of sound. *Eksploat. i Niezawodn., 21*, 522-529.
75. Paszkowski, W. (2020). Modeling of vibroacoustic phenomena using the method of parameterizing the audio signal. *Eksploat. i Niezawodn., 22*.
76. Peixoto, B., Pinto, D., Krassmann, A., Melo, M., Cabral, L., Bessa, M. (2019). Using virtual reality tools for teaching foreign languages. *New Knowledge in Information Systems and Technologies, Vol. 3.* Springer, pp. 581-588.
77. Pinto, D., Peixoto, B., Krassmann, A., Melo, M., Cabral, L., Bessa, M. (2019). Virtual reality in education: Learning a foreign language. *New Knowledge in Information Systems and Technologies, Vol. 3.* Springer, pp. 589-597.
78. Pottle, J. (2019). Virtual reality and the transformation of medical education. *Futur. Healthc. J., 6,* 181.
79. Roldán, J.J., Crespo, E., Martín-Barrio, A., Peña-Tapia, E., Barrientos, A. (2019). A training system for Industry 4.0 operators in complex assemblies based on virtual reality and process mining. *Robot. Comput. Integr. Manuf., 59,* 305-316.
80. Sadeeq, M.M., Abdulkareem, N.M., Zeebaree, S.R.M., Ahmed, D.M., Sami, A.S., Zebari, R.R. (2021). IoT and Cloud computing issues, challenges and opportunities: A review. *Qubahan Acad. J., 1,* 1-7.
81. Safikhani, S., Keller, S., Schweiger, G., Pirker, J. (2022). Immersive virtual reality for extending the potential of building information modeling in architecture, engineering, and construction sector: systematic review. *Int. J. Digit. Earth, 15,* 503-526.
82. Sherman, W.R., Craig, A.B. (2003). *Understanding virtual reality*. San Fr., CA: Morgan Kauffman.
83. Skop, P. (2018). Porównanie wydajności silników gier na wybranych platformach. *J. Comput. Sci. Inst., 7*.
84. Smits, M., Staal, J.B., Van Goor, H. (2020). Could Virtual Reality play a role in the rehabilitation after COVID-19 infection? *BMJ open Sport Exerc. Med., 6, e000943*.
85. Soliman, M., Pesyridis, A., Dalaymani-Zad, D., Gronfula, M., Kourmpetis, M. (2021). The application of virtual reality in engineering education. *Appl. Sci., 11, 2879*.
86. Steculа, B., Steculа, K., Kapczyński, A. (2022). Compression of Text in Selected Languages—Efficiency, Volume, and Time Comparison. *Sensors, 22, 6393*.
87. Steculа, K. (2019). *Application of Virtual Reality for Education at Technical University*. Proc. ICERI2019 Conf. 11th-13th Novemb. 2019, 7437-7444.
88. Steculа, K. (2022). Virtual Reality Applications Market Analysis—On the Example of Steam Digital Platform. In: *Informatics. Multidisciplinary Digital Publishing Institute*, p. 100.
89. Steculа, K., Brodny, J. (2018). *Role and meaning of coal mining in Poland*. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM. pp. 801-808.

90. Strojny, J., Witkowski, K., Wąs, S. (2023). Influence of Sustainable Strategic Management on Methane Projects as Exemplified by the Jastrzębska Spółka Węglowa S.A. Mining Company. *Energies, 16*.
91. Symonenko, S., Zaitseva, N., Osadchyi, V., Osadcha, K., Shmeltser, E. (2020). *Virtual reality in foreign language training at higher educational institutions*.
92. Tobór-Osadnik, K., Wyganowska, M., Brejdak, A., Kowal, B. (2020). Prosocial activities within the CSR by the Jastrzębska Spółka Węglowa SA – A case study [Działania prospołeczne w ramach CSR Jastrzębskiej Spółki Węglowej – Case study]. *Inz. Miner., 2,* 47-52.
93. Wilk, P. (2017). *Wykorzystanie silnika Unity do stworzenia gry 3D z użyciem technologii VR na urządzenie mobilne.* Uniw. Jagielloński.
94. Xie, B., Liu, H., Alghofaili, R., Zhang, Y., Jiang, Y., Lobo, F.D., Li, C., Li, W., Huang, H., Akdere, M. (2021). A review on virtual reality skill training applications. *Front. Virtual Real., 2, 645153*.
95. Xu, X., Guo, P., Zhai, J., Zeng, X. (2020). Robotic kinematics teaching system with virtual reality, remote control and an on–site laboratory. *Int. J. Mech. Eng. Educ., 48*, 197-220.
96. Zhang, M., Zhang, Z., Chang, Y., Aziz, E.-S., Esche, S., Chassapis, C. (2018). Recent developments in game-based virtual reality educational laboratories using the Microsoft Kinect. *Int. J. Emerg. Technol. Learn., 13*, 138-159.