

## Experimental Implementation of New Technology into the Area of Teaching Occupational Safety for Industry 4.0



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### ABSTRACT

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The use of new technologies (additive technology, collaborative robotics, virtual or augmented reality) in teaching and preparing for it gives the teacher many different ways to activate students to learn. Therefore, this article focuses on the options for using virtual reality in the field of occupational safety. A work injury scenario was created in the XVR software environment. It was aimed at students studying Occupational and Process Safety at the Faculty of Safety Engineering (FSE), VSB-Technical University of Ostrava. In the future, they will be professionally qualified in risk prevention (Health, Safety, Environment Professional, HSE). The aim was to train students in: an employer's obligations during a work injury, the HSE Professional's job during a work injury, cooperating with the emergency services and the Czech Police.

## 1. INTRODUCTION

The concept and operation of Industry 4.0 will affect society as a whole. It will entail knowledge of:

- the systemic working of the Internet,
- the possibility of using the Internet whilst working in any profession,
- the benefits of applying new technologies,
- future development trends

for all graduates of educational processes. In the future, graduates should have a general ability to adapt, an active approach to the world, creativity and further education. Furthermore, the demands on workers' flexibility will increase [1].

Growing flexibility, variability and individualization bring demands and the need for lifelong education. People will need to constantly replenish their knowledge to do their job. Lifelong learning will play one of the main roles. This will also be crucial for individuals in the labour market. The time when one skill set and knowledge basis was enough for a life in employment is long gone. In the future, digital literacy will be as important as reading and writing. It is mainly related to the ability to work effectively with information, the ability to be familiar with these technologies and to know how to use them to effectively solve problems. In the future, all employees will experience greater demands on their digital knowledge. Knowledge about information and communication technologies (ICT) will gradually grow into all fields. Interdisciplinarity and technical skills will also be important. In many professions, it will be necessary to think beyond their disciplines in a more holistic manner. Employees will have to learn to work with robotic devices.

Work will also change very quickly. It will be important to be able to improvise, think logically, communicate and be familiar with the digital world. It will be necessary to be able to speak foreign languages well so that the worker can

understand information from other fields and sources. There is already a need for general and soft skills training in conjunction with a thorough understanding of the professional foundation, the field and its principles, which are immutable. The psychological impact of these new working conditions, as well as the new teams, which will include robots, will be individual, depending on each individual's disposition [2].

The use of new technologies (additive technology, collaborative robotics, virtual or augmented reality) in teaching and preparation for it gives the teacher many ways to activate students for learning.

The very definition of technology varies. In this article, technology is understood not only as a motor, computer, etc., but at the same time technology is seen as a set of knowledge and procedures that create a tool, processes or organizational practices. Advanced technologies, in the form of devices and technological units, have the most significant impacts.

Table 1 gives an overview of selected technologies according to their occurrence in the individual key studies. These are the most important technologies identified to have a significant impact on technological areas and the economy within a horizon of 10 years [1, 3, 4].

**Table 1.** Overview of selected technologies [1, 3, 4]

Technologies	
Artificial Intelligence	Cloud Computing
Blockchain	Smart electrical network
Internet of Things	Communication between machine
Augmented reality	Advanced production
Virtual reality	Interface human-machine
Robotics	Advanced storage energy
3D printing	Nanomaterials
Drons	Nanotechnologies
Big data	Autonomous automobiles
Cyber security	Advanced production

The main goal of integrating technology into education is to teach future students of education processes how to make meaningful use of digital tools with respect to their professional and everyday life.

For this reason, the article will focus on the experimental implementation of virtual reality in education, which could be used again in the field of Health, Safety and Environment.

The virtual reality provides a solution for such training tasks, and has been successfully applied in the field of safety training, emergency rescue, health service and education [5-8].

## 2. VIRTUAL REALITY AND ITS USE IN TEACHING

Nowadays it is necessary to ascertain the options for using modern virtual reality (VR) technologies. From the point of view of scientific research, the issue of applying these new virtual reality technologies is highly topical and is at the forefront of many researchers' interest.

In the field of health care, VR can be used to simulate medical procedures, thus reducing the risk whilst training new doctors [4].

VR can also be used in the field of modern control systems for production, testing and safety. VR can be used to simulate the introduction of new elements into a production process. Simulation using VR is economically less costly than testing new elements in operation. VR can be used in all fields to organize virtual meetings with colleagues from other locations or with potential clients [4].

As with augmented reality, virtual reality has great potential in marketing, by simulating the effect the product on offer has on a consumer's positive experience [4]. Outside of the entertainment industry, where virtual reality (VR) is most widely used today, virtual reality can also be used, for example, in learning processes and testing new approaches.

In the field of VR, the Czech Republic (CR) currently has similar starting conditions for development as anywhere else in the world. This is due to the fact that the last few years have seen the development of suitable hardware equipment, a growth in the performance of mobile devices and practical, usable VR glasses have appeared.

There are many kinds of 3D modeling and simulation software, for example 3DS MAX, Unity, MAYA, XVR, Apex Officer etc.

The XVR software tool was chosen for the experimental implementation of virtual reality in safety engineering education. This allows interconnection with VR glasses and is already used to train safety and emergency services personnel.

The XVR software has a wide range usability in training practice. It can be used as a utility to the standard teaching in classrooms, where the simulation is only presented and further discussed.

Next the possibility of use is individual training of one person, where the person solves and analyzes the presented scenario (problem).

One of the possibilities of using the XVR software is its use as a team training tool. More people who meet in can be involved in the training virtual environment XVR simulation and can train mutual communication, collaboration to solve problems, or in the case of leaders their leadership skills.

Within the training with the XVR software, there is always a person present who holds the position of training leader. The ensures the fulfillment of all training goals and also controls the scenario itself and, if necessary, adjusts it during the

training and determines its direction so as to ensure the most effective course of the training.

No real scenario has been found to address this topic in the area of occupational health and safety (work injury).

### 2.1 XVR software

XVR is a computer program used for education and professional training. In this program, virtual reality simulation can be used to control how Integrated Rescue System units intervene during various emergencies, such as: traffic accidents, fires, call outs for hazardous substances or mixtures, natural disasters, etc. In the XVR environment it is possible to carry out simulations on three management levels: the in situ tactical level at an emergency, the operational level and the strategic management level [9].

#### 2.1.1 The possibilities of use for teaching and professional training

There are multiple options for using this program.

The first option is to project the virtual scenario onto a screen for the students (Figure 1, a). This is done in accord with the manual, the "Classic Use of XVR", in which students cannot interfere in the course of the events, they simply follow the scenario. The instructor manages the course of the emergency and its solution from his/her computer. Thus, the students see the situation projected from the point of view that the instructor has set up [10].

The second option is the "One-to-One Use of XVR". This concerns two computers, connected to each other on a network, that are also running XVR software (Figure 1, b). One computer is used by the instructor to control the simulation, while the other computer is used by the student playing the scenario. The student can move freely in a virtual environment controlled by the instructor. The student moves in the environment from the perspective of the person whose role has been assigned to them (e.g. the commanding officer, crew commander, onlookers, etc.), but they do not see hidden objects and functional elements controlled by the instructor [10].

The third option is almost the same as the previous one, with the difference of using up to ten computers interconnected to the network (Figure 1, c). The set-up consists of one instructor computer and the others are for the scenario players. In their roles the students can move in a simulated environment and, depending on their behaviour or activities, the instructor changes the set parameters and how the scenario plays out. It is expected that the students will communicate with one another, thanks to which they can cooperate when dealing with the simulated emergency. However, this does not mean that the student can change the course of the simulation based on their interaction with objects alone. All changes must still be made by the instructor from the control PC [10].

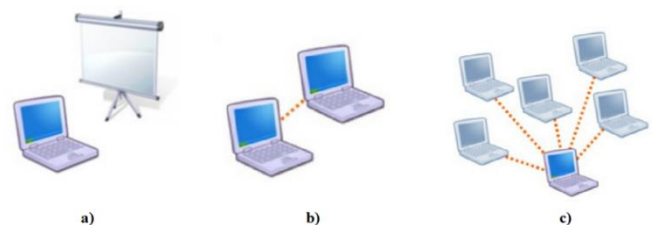


Figure 1. Options for using XVR [10]

### 3. CREATING A SCENARIO FOR AN OCCUPATIONAL INJURY IN XVR SOFTWARE

Scenario creation was aimed at students of the Department of Occupational and Process Safety, FSE, VSB-TU Ostrava. In the future, they will be professionally qualified in risk prevention (Health, Safety, Environment Professional, HSE). The HSE officer often encounters occupational accidents in their work and has to deal with this emergency.

Based on the knowledge obtained from Czech legislation and the principles of good practice, a scenario was created for a simulation in the environment of the XVR program. The aim was to give students practice in:

- the employer's obligations in the event of a work injury,
- the HSE Professional's cooperation during a work injury,
- cooperation with the emergency services and the Czech police.

The least favorable situation was chosen for the scenario, namely a work injury to an external employee resulting in death. Students (in the role of the HSE), who will follow the scenario's progress on the screen, will be able to move in the event environment using a single PC with a joystick and will be able to use glasses.

#### 3.1 Description of the work injury resulting in death

It concerns a fictitious fatal work accident in an industrial building. On 9 July 2019 around 8:20 there was a work accident in an industrial building. The work accident happened on the main mixed communication for forklifts. An external employee (EE) was checking the racks' technical state; during a visual inspection of the racks' upper bays the EE had to step onto the main mixed communication. During this activity, the EE moved from the racks onto communication, whilst walking backwards (the official way is to walk forwards onto a communication). At that moment, the EE had a head-on collision with a forklift. The material (glass sheets) being transported by the forklift slid onto the EE whilst the forklift subsequently reversed. As it did so, the material shattered and subsequently cut the EE. The EE began to bleed profusely from multiple sites on the body, including the neck.

##### 3.1.1 Characteristics of the site of the work injury

The work accident occurred in a part of the storage hall of an industrial building located in the industrial zone of Ostrava, Czech Republic. The hall is used to store semi-finished glass panels for windows and doors, carpet rolls. 10 LPG forklifts are used for the storage processes. A total of 30 employees work in the warehouse, including forklift drivers and one manager. During the work accident, which blocks the main forklift communication, the forklifts form a queue on the communication in front of and behind the work accident.

##### 3.1.2 Characteristics of the conditions at the site of the emergency

The accident occurred during the morning shift, on the main mixed communication the forklifts formed a column of two to three forklifts in front of and behind the work injury. Employees are moving freely around the site of the work injury.

##### 3.1.3 First aid and summoning a manager

This part of the intervention is not part of the fictional scenario. The student, in the role of a person qualified in risk prevention, comes to the site of the work injury 4 minutes later than the manager.

The EE sustained the work injury during a visual inspection of the racks on the main mixed communication for forklifts. The forklift driver crashed into the EE. After the crash, the forklift driver backed up sharply, at which point the transported material (glass panes) slid off and shattered on the prone EE. The EE was cut and immediately started to bleed profusely. The neck bled the most. This resulted in the EE becoming unconscious.

After getting out of the forklift and informing the manager of what had happened, the forklift driver, who crashed into the EE, collapsed and fainted. In doing so, his head smashed into the forklift. A passing employee immediately began to call for help. He began to treat the injured EE and told the co-workers to look at the forklift driver and call the manager.

The manager was called 2 minutes after the work injury. Those employees present were instructed to summon the person qualified in risk prevention. The manager immediately began calling an ambulance on 112 with a works mobile phone, giving instructions to the other employees present during the call:

- to bring the first aid kit,
- to inform the porter about the arrival of the emergency services. To tell the porter, to navigate the ambulance to the site of the work injury
- how to proceed in first aid (according to the operator's instructions).

##### 3.1.4 Arrival of the person qualified in prevention at the site of the work injury

At the time when the employees are completing the above activities, the HSE Professional (student) comes to the site of the work injury. The HSE Professional marks out a protected area in the vicinity of the work injury and gives instructions:

- for onlookers to go to the main entrance to the hall and wait for the ambulance,
- for the forklift drivers in the queue in front of and behind the site of the work injury to take the forklifts to a place where they will not get in the way of the rescue work,
- for other onlookers to summon the company director.

Takes photo documentation of the site of the work injury and the staff involved.

##### 3.1.5 Arrival of ambulances

The company director arrives after 4 minutes, as do two ambulances and one police car. The porter at the entrance to the grounds guides the vehicles to the hall, where the work injury occurred. The employee standing at the gate of the hall guides them to where the accident occurred. The emergency services immediately take over the work from those giving first aid. During treatment, the manager tells the doctor what happened. The emergency service workers try to revive the EE, but without success. The physician declares the EE as dead. They cover the EE's body with a tarpaulin.

The forklift driver is taken to the ambulance on a stretcher and transported to Vitkovice Hospital.

### 3.1.6 Interviews and explaining the causes of the work injury

After the ambulances leave with the injured forklift driver, two police officers give instructions to keep the site of the work injury in its current state. They cordon off the site of the work injury. They instruct all the employees involved (including the HSE, the company director) to stay where they are and give a statement. The police take photo documentation and secure the evidence (forklift...). They then interview the employee who was first at the site of the work injury. Other witnesses are questioned. One police officer asks the company director and the person qualified in the prevention of risks for copies of the current Occupational Health and Safety (OSH) documentation (training for forklift drivers and EE, traffic regulations, internal working procedures, ...).

During the interviews, the first police officer calls to the operations centre and asks for the crime scene response unit to come out.

### 3.1.7 Arrival of the crime scene response unit

The crime scene response unit (CSRU) arrives 30 minutes after being called. The CSRU is made up of a technician, an investigator and an operative.

The CSRU:

- takes the information from the Czech Police officers,
- starts interviewing witnesses,
- takes additional photo documentation, asks for copies of the current OSH documentation,
- cordons off the forklift as evidence and acquires additional evidence. Tells the first police officer to guard the forklift
- calls to the control centre and asks for the forklift to be towed off for a check (whether the brakes failed...).

The HSE calls the Regional Labour Inspectorate of the Moravian-Silesian Region and announces a fatal work injury. The work injury is entered into the work injury log.

The company director calls the EE's employer and informs them of the situation and the consequences of the work injury. Afterwards, the HSE goes through the OSH documents with the operative.

After individual interviews and securing the evidence to find out the cause of the work injury, the CSRU investigator calls the undertakers.

30 minutes after the call, the undertakers arrive and load the EE's body. The CSRU instructs the police officer to guard the forklift until the truck arrives and takes it away for examination.

The CSRU gives instructions to clean up the workplace.

## 3.2 Scenario modelling in XVR software

The XVR programming environment allows a number of different scenarios to be created. The original focus is on the safety and rescue services, but it is easily applicable to the field of occupational safety. There is a total of about 3,000 pre-built 3D objects available. Some can be animated, such as car doors opening or various lights blinking. It is possible to place cars, various vehicles, objects, people, etc. into 3D spaces. It is possible to change the environment, weather, individual people. It is possible to create fires or deform buildings to simulate an accident. One very good feature of the XVR system is the ability to perform various animations. In this case

it is possible to animate the movement of the forklift, the arrival of the worker who called the ambulance. To animate the ambulance's arrival and the work of the paramedics or police. The programming environment is excellent and, to a certain extent, it is easy and simple to use. However, it is necessary to get used to it. One of the few problems is the system's closeness. It is possible to insert new 3D objects in the object format, which are created using an external program.

Figures 2 and 3 show the modelled virtual environment of the XVW software according to the proposed scenario.

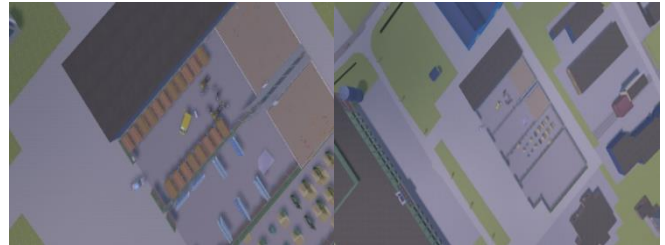


Figure 2. Map of the hall



Figure 3. Map of the hall

## 4. CONCLUSION

This article focuses on the options for using virtual reality in the field of occupational safety. This study supports the value of implementing structured interprofessional round simulations for students studying Occupational and Process Safety at the Faculty of Safety Engineering, VSB-TU Ostrava to promote understandings of the various roles of HSE Professional's job toward employee.

A work injury scenario was created in the XVR software environment.

The aim was to train students in:

- an employer's obligations during a work injury,
- the HSE Professional's job during a work injury,
- cooperating with the emergency services and the Czech Police.

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