Teaching of Safety Engineering during the COVID-19 Pandemic

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In this article, the authors describe the evaluation of safety-oriented teaching at a technical university during the COVID pandemic under the long-term closure of universities in the Czech Republic. Three practical case studies are presented to illustrate the current level of sophistication of virtual reality technology for industrial safety teaching.
The case studies are focused on the environment of small and medium-sized enterprises (SMEs) and cooperation with them. The proposed affordable and simple approaches describe virtual teaching at universities providing education in the field of safety engineering.

Keywords: Virtual reality, safety, teaching, digital twin, mechanical engineering.

1. Introduction

The COVID-19 pandemic has significantly disrupted the way of how technical universities in the Czech Republic provide their teaching. In contrast to the gradual transition to interactive teaching, there was a sudden paradigm shift; the transition from proximate to distance learning took place suddenly and without any preparation.

This study deals with the transition to emergency distance learning at the Faculty of Mechanical Engineering at Brno University of Technology in the courses related to the teaching of safety engineering and presents three case studies describing this type of teaching.

2. Situation of the COVID-19 pandemic in the Czech Republic

On December 31, 2019, the World Health Organization (WHO) was informed of a small group of pneumonia cases of unknown aetiology in Wuhan City, Hubei Province, China (Zhu et al., 2020). The new coronavirus was isolated on January 7, 2020 and genetically sequenced on January 12 (Wong et al., 2020).

The first three cases of the disease in the Czech Republic were confirmed on March 1, 2020; these were imported from northern Italy where the disease was spreading very quickly and, as usual, many Czech citizens went skiing to the Italian Alps. The rapid onset of the epidemic was marked by a critical lack of protective equipment in stock.

Since March, several measures have been introduced in the Czech Republic due to the disease. As of March 11, 2020, all schools, including universities, were closed.

On March 12 at 2 pm, a state of emergency was declared with a number of restrictions for citizens and businesses, and on March 14, restaurants and establishments other than

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the most important ones were closed. At midnight on March 15-16, with some exceptions, the state borders were closed. On March 22, 2020, the authorities announced the first death of a patient with covid infection in the Czech Republic.

The number of infected and sick people began to rise again during the summer 2020. In the last weeks of July and the first week of August, the incidence of the disease spread to almost all regions. The number of cases was successfully reduced in November, but after the Christmas loosening, the number of patients began to rise again.

The last, fourth wave of COVID-19 disease in the Czech Republic arrived at the end of February 2021.

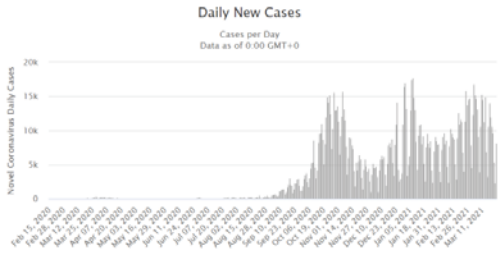

Fig. 1. Daily new cases of COVID-19 in the Czech Republic (*Worldometers.info, 2021)*

3. Situation at universities in the Czech Republic

As of March 11, 2020, all schools, including universities, were closed. Since then, teaching has only taken place at universities for the fields of medicine, healthcare and pharmacy, with many interruptions, when students of medical and healthcare disciplines were obliged to carry out work in hospitals to ensure their functioning

This situation persists to this day (March 2021) and the Czech Republic is now the third most affected country in the world in terms of deaths per 100,000 inhabitants after Gibraltar and San Marino.

After the closure of universities, for several weeks, teaching at Brno University of Technology, took place only in the form of e-mails, without direct interaction with students, then a central solution was put into operation via Microsoft Teams software. However, this did not solve the issue of providing practical training in tutorials.

4. Threats of restricted distance learning and dealing with the situation

Restrictions on practical teaching in tutorials limited the involvement of students. At Brno University of Technology, great emphasis is placed on the presence of students in practical training, which is mandatory.

Involvement of students may also be affected by technical problems, such as an unstable internet connection or a lack of suitable electronic devices on the part of the university or when working from home (Wimpenny, 2013). The unexpected shift towards distance learning means that even some students may not be technically prepared for distance learning and assessment. Therefore, appropriate accessibility must also be considered as a potential threat to the provision of distance learning and assessment. (Longhurst, G., 2020)

Another aspect related to practical teaching of engineering safety in technical subjects is providing clear guidelines for problem solving and linking the content to practice, which improves the engagement of students (Martin and Bolliger, 2018).

The last aspect of practical teaching in technical subjects is the visualization of the solution. At the same time, the results of studies (Sepasgozar, S. M. E., 2020) show that online virtual tools are valuable and useful for teachers in technical sciences to enhance students' learning and help them to use the knowledge acquired at lectures in a real context.

After the start of the COVID epidemic in the Czech Republic, we tried to teach safety-focused subjects using only the Teams app, but this proved inadequate because the hands-on exercises were too burdensome for teachers and provided little benefit to students. For this reason, an environment was prepared and tutorials were created for independent student experiments in online environment.

This article presents three case studies that can be used to teach engineering safety at a university.

5. Case study 1 – cardboard virtual reality of process equipment

Google Cardboard is a virtual reality (VR) platform developed by the Google company. Unlike advanced virtual reality tools, such as Oculus Rift or HTC Vive, where the image is drawn (projected) onto the built-in goggles screen, Google Cardboard uses only the smartphone screen. The reason why this platform was considered for ergonomic studies is its simplicity and the potential use by all university students. In addition, the platform is currently open-source.

We used the Unity 3D game engine environment with an editor to develop the application. Also, because Unity allows for easy import of 3D models and direct integration of the Goggle Cardborad plugin into its environment.

Subsequent work consists in the implementation of a stereoscopic camera of GVR Editor Emulator, which, in the Editor mode, allows for a simple view of the scene using keys simulating the movement of the smartphone, i.e., 360 ° view.

The next step is the import of the actual assessed model.

The following step in setting up the environment is to adjust the camera. It must be immersed under GVREditorEmulator due to the movement of the two components.

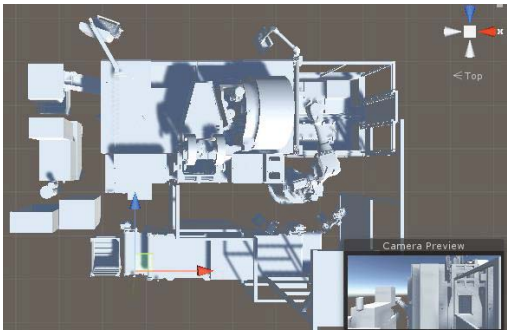

Fig. 2. Virtual reality model

In the course of testing, it was found out that the screen is torn due to the large size of the model. Therefore, it was necessary to reduce the model, at least by hiding the machine parts that do not need to be included in the user's reach. Provided that it would be necessary to use the whole machine, this approach is too complicated and it is rather recommended to use the restrictions in the rendering settings of the camera, the so-called Far Plane Clipping. Both approaches will increase the smoothness of the entire scene.

The virtual environment allows students to go through the process equipment and perform, for example, distance measurements. In risk analysis, this model can be used to get the students acquainted with a specific situation; in modelling the consequences, this environment can improve students' familiarity with the assignment.

6. Case study 2 –ergonomics of operator workplaces

A design of control panels and counters with regard to operator reliability has become a key aspect of technology design with a focus on safety. In addition to the methods of Human Reliability Analysis (HRA), which are only of limited use due to the high degree of indefiniteness and uncertainty, direct testing of control panels in virtual reality is increasingly being promoted. Virtual reality provides not only the environment for visualization in a three-dimensional environment, but also an interaction with objects to improve decision-making from both quantitative and qualitative points of view.

The advantage is to connect several participants to a study using a suitably selected VR device using the VR environment and to participate interactively from anywhere in creating a joint shared study either in the preproduction phase or creating innovations of existing production systems and robotic workplaces. (Holubek, R., 2021)

Experimental evaluation of the reliability of the operator (operation error rate) when operating the panel at the control room during testing the design of the control panel. Factors that need to be taken into account are, for example, the layout of the buttons on the panel and the type of stimulus (visual/audio).

The aim of the practical application for students is to design and test the layout of a simple control panel.

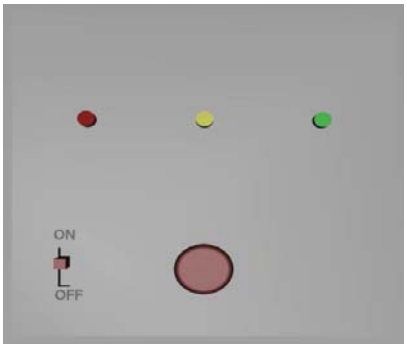

Fig. 3: Schematic layout of buttons on the control panel

After preparing the model of the selected workplace, the student should revive this workplace in the Labview environment and test it for the given task (e.g., shutting down the machine by pressing a button when the temperature is exceeded). The student should process several variants and compare them depending on the error rate and the time needed to solve the task.

7. Case study 3 – technology of digital twin

A digital twin of a fully automatic machining centre was created; it is placed in the laboratories of the university; students were given the task of analysing the risks on this machine.

The actual data collection from the machine is realized using several different technologies. Temperature sensors and accelerometers placed in and around the machine are used to sense temperatures and vibrations. Other acquired data represent the positions of key parts of the machine – these are read directly from the machine control system.

Particular emphasis is placed on the way of data visualization, including the environment of the CNC machine tool, and information from the safety parts. For efficient information handling, access to their display in virtual reality can be chosen. (Holub, M., 2019)

The application in virtual reality for monitoring the condition of the machine can be divided into backend and frontend part. The backend part contains all the functionality of the application together with the mechanism of data reading. The frontend part of the

application ensures the user's interaction with virtual reality and all visualizations of the measured data. The following values are visualized in the virtual reality environment:

Temperatures – temperatures are divided into five groups (Ruler X, Ruler Y, Bed, Stand, Surroundings) according to the location of temperature sensors. For individual temperature groups, it is possible to display an entire overview with actual temperatures. The colour of the tile depends on the actual temperature value and on the setting of warning and alert limits. If the warning limit is exceeded, the colour changes from green to yellow, and if the temperature rises further and the warning limit is exceeded, the colour changes to red.

Fig. 4. Temperature display on the digital twin

Vibrations - based on these values, an indicator is determined informing the user about the overall state of vibrations. As with temperatures, a warning and alert limit is set to inform the user of a machine failure condition.

Fig. 5. Vibrations display on the digital twin

Machine position - actual values of positions of individual axes are interpolated and used for positioning of 3D model of machine in virtual reality. This means that the user is able to monitor the movements of a real machine in real time using a 3D model in virtual reality. Furthermore, the exact values of the coordinates of the individual axes are available to the user.

Fig. 6. Position display on the digital twin

In addition to the operational documentation of the machine, the student can check the entire machine in operation in a web browser, can verify the parameters of the machine and at the same time decompose the machine into individual components when preparing a risk analysis, which will improve his/her understanding of the device. This has a positive effect especially in the identification of hazards by the FMEA or HAZOP method.

Discussion of the results

The chosen approach to conducting the seminars (online environment and tutorial, discussion and analysis of results with students via the Teams app) proved to be very beneficial for teachers either the students.

The main advantages for the teacher compared to just showing the solution via the Teams app by teacher are:

- simplification of teaching, less time consuming,

- no need to show the solution of one problem several times,

- the possibility to focus on the students who need it the most.

Benefits for students:

- possibility to choose the pace of learning in the practical seminar according to their needs,

- increased possibility of interaction in a virtual reality environment,

- reduced transmission outages due to internet connection failure or technical problems.

In the survey on the GVR (Virtual and Augmented Reality) course taught in a modified way, students appreciated the good level of teaching, according to the scores, they appreciated it more than the classical teaching in a computer room (90% satisfaction in 2019, 100% satisfaction of students in 2020).

The management of the institute will evaluate the new teaching resources and make adjustments for the next academic year.

Conclusion

The closure of universities in the Czech Republic arose similarly to other countries in the world. Educational institutions at all levels (pre-primary, primary, secondary and tertiary) have been closed in 188 countries worldwide, affecting more than 91 % of the world's student population. (Longhurst, G., 2020).

To improve the support of engineering safety teaching at the Faculty of Mechanical Engineering at Brno University of Technology, several tools have been proposed to increase the involvement of students in practical tutorials.

These tools aimed to increase the student involvement in teaching process using the following methods

- methods for identifying the hazards of machinery,

- methods of risk analysis of process equipment,

- methods of ergonomic analysis of the operator's workplace.

The proposed procedures build on previous research at the Faculty of Mechanical Engineering at Brno University of Technology.

Future research is necessary to evaluate the perception of the model by students and teachers using qualitative evaluations or questionnaires.

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