COVID-19 Pandemic Challenges for Engineering Education

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***Abstract*—The COVID-19 pandemic has impacted all the spheres human activities. The problems related with the forced self-isolation of people, closed borders between the countries as well as within the states push towards digitalization opening opportunities for bringing new technologies into everyday life. The paper focuses on the resulting dramatic changes in engineering education due to the current classical learning process paradigm shift. The brief overview of the problems is presented. The main challenge is to teach the future engineers to work with and to operate real hardware not available at home. The implementation of a Digital Twin concept for industrial equipment can partially solve the emerged problem related with hardware unavailability by the remote learning process as well as to improve the professional training quality as the pandemic is over.**

Keywords— Engineering education, industry applications, distance learning

I. INTRODUCTION

The COVID-19 pandemic has impacted all the spheres human activities. The problems related with the forced self-isolation of people, closed borders between the countries as well as within the states push towards digitalization opening opportunities for bringing new technologies into everyday life. The significant changes were faced also by one of the most conservative communities of Russia – academia. Despite of various novelties across the country, such as the introduction of Bologna system, the Unified State Exam for university entrants and others, the current education system, for better or worse, is based on the approaches and technologies, which were available and successfully implemented in the Soviet Union times.

Before the education relative information has become available worldwide from the numerous sources in the internet, the university staff was practically the only trustful source of educational information. This required the students to note all the lectures in detail, as there will be a very low chance in obtaining the relevant information from any other source. It seems the mission of a lecturer of today and of the nearest future is to give the students the general concept and the state of the art approaches implemented in the field with the end goal to enable the future professionals to find the information which is likely to be trusted. The lecturer is analyzing the numerous information sources being a kind of a filter, teaching the students to filter the information themselves in their future works. The things are changing as rapidly as never before, especially in engineering. One cannot obtain the necessary knowledge at the university and be successful without further learning all the lifelong due to the global competition. If a professional does not change regarding to the demand or does it not fast enough, he will likely loose, as someone will might do it for him [1].

The problems and challenges faced by the academia in the pandemic times are the opportunity to better keep up with the rapid humanity development also in terms of physical workspaces replacing or complementing with the immersive ones [2].

The paper focuses on the resulting dramatic changes in engineering education due to the current classical learning process paradigm shift. The brief overview of the problems is presented. These include the legal perspective of distance learning, creating remote workplaces for both students and the university lecturers, increasing the efficiency of distant classes, choosing distant learning means as well as allocating the most problematic aspects, requiring special attention. The latter for the engineering education is teaching the future engineers to operate real hardware installations not available at distant classes. The partial solution might be introducing Digital Twins of the equipment this way also facilitating the introduction of modern industry 4.0 digital technologies into real life.

The paper is organized as follows. The 2nd section is related to the overview of the challenges faced by the engineering education system. The 3rd is devoted to the possibilities of the Digital Twin concept introduction to improve the education quality both in the pandemic and the ongoing times. Finally, section 4 concludes the paper.

II. DISTANCE LEARNING CHALLENGES

The section illustrates the distant learning challenges with the example of National Research University "MPEI". As all the other universities MPEI was forced to switch to completely remote education with a single snap. Although some disciplines were already have been introduced for distant learning in the recent years, it is more an exception. The university was not prepared for this sudden change. In general, the problems are similar to that experienced in many universities worldwide [3]. However, the details strongly depend on the geographical region, field of study.

A. Legal Perspective of Distance Learning

The first problem with any change coming is the legal basis. For distant learning there are two problems – the means for content transfer and the content creation.

Neither students, nor the university staff are obliged to have the necessary equipment (computer, internet connection, workplace, audio and video equipment) enabling the educational process outside of the university. This is a permanent problem with enabling the self-study process of those not having a computer at home, for example. For this the university is equipped with computer classes with the necessary software. These are impossible to be used for distant learning. The university cannot fund providing 15 thousand

students with the required equipment so is for several thousand staff members. So in practice the process is based on the informal win-win interest of all the parties: the university administration, the staff and the students. As the vast majority have the necessary means, they do not obstruct the distance learning process. However, there is always a risk for single special cases requiring individual solutions.

In [4] another problem is analyzed: the lack of legislative regulation in terms of protecting the results of intellectual activity for educational purposes. This means, firstly, the high quality educational material is not protected well enough to encourage the authors to develop high quality content and share it for distant learning purposes. And secondly, when using the distance learning means as well as electronic documents it is easier to tempt the students to compose their works from other sources available in the internet, including copying the results each other. For the remote educational process, it is way much harder to be easier controlled by the tutor, then by regular educational process.

B. Remote Workplaces

Another emerging problem for distance learning is the workplace itself. Even for professors it's not always easy to hold lectures, as there should be some quiet place with silence remaining for many hours each day. Any noise coming from the children, or from a neighbor – drilling or mowing forces to cease a class. As in quarantine times home is the only possible place for working and study, some tutors film their lectures in the night to ensure suitable atmosphere for that, providing the students with off-line material. However, the night lectures are not a suitable option for most of the lecturers, especially having multiple lectures each day, as this may negatively impact their health.

For the students it's also not always easy to find a suitable place. All in all, any compact housing shared by several people remotely working or studying tends to turn into some kind of a call-center with the possible psychological tensions penetrating.

C. Increasing the Efficiency of Distant Classes

On the other hand, switching to distance learning technologies brings new opportunities for interaction and communication. Despite the physical distance between the tutors and the students, the availability for online communication may bring the two parties closer reducing the communication cycle time.

The challenge here is to guide the students to learn individually and independently [5]. Of course the new means provide new abilities for interaction [6] also including cooperation, such as guest lectures, for example.

The current situation is more a challenge for the tutors. They should prepare and deliver the educational content in a way to involve each student into interactive work [7]. Compared to the person-to person communication it is much harder for the students to keep their attention on the studied subject [4].

Gradually the people are getting used to working remotely. There comes the understanding the quarantine is a long-lasting process and there is a chance of repeat. Another aspect is that the possibility to use distant learning techniques existed previously. However, from now on these are getting more common for the people and there seems to be a very high chance of the more effective use distant learning means not only to improve the remote education process itself, but to update the classical learning paradigms by integrating the newly tested technologies.

D. Choosing Distant Learning Means

Figure 1 depicts the situation with distance learning technologies used for educational process in the first month of quarantine, when the university was closed both for the students and the staff [8]. Only 17% of the classes were held as live webinars. For some classes the newly developed simulators were used along with interactive presentations, web and cloud services. Due to the above mentioned problems most of the classes (around 60%) were conducted with using email, messengers or social networks by the staff for distributing the tasks among the students and getting results back.

At the same time 11% of classes were impossible to be conducted, as normally some complicated equipment is involved into the process it being impossible to be promptly replaced by any existing distance learning technology. Working with equipment during at laboratories is the key point in engineering education. Only 2% of classes were moved to some interactive model in a simulation environment such as Matlab, Labview, Comsol, Elcut, Pspice and many other. The software package variety can be explained as the tutors are used to implementing in their engineering and research practice in the numerous fields of study being of interest at a technical university.

Licensing problem is also worth mentioning here. Some professors bought personals license for video conference software, simulation tools to conduct classes in a convenient environment rather than that recommended by the university administration.

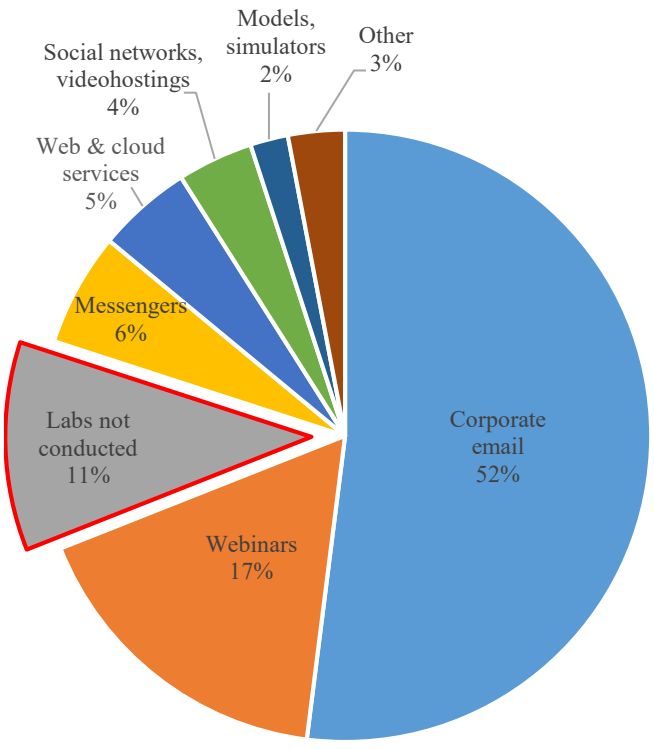

Figure 1. Share of classes at National Research University "MPEI" conducted with various distant learning technologies in the first month of exclusively remote study.

III. Digital Twin Concept

As mentioned above the very important practical part of the educational process in engineering cannot be rapidly switched to distant learning means. One of the possibilities to do so is using the sophisticated simulation models of real industrial equipment including assistant reality technologies.

At the same time simulation is one of the key points of the Industry 4.0 concept [9]. The digital twin concept considers the real object and a model – of the object itself, or complementary objects. Considering and analyzing the behavior of the two some autonomous decision can be carried out, including autonomous. For industrial purposes digital twins can be used for

- Analysis and optimization of industrial systems before setting it up or launching. For example, production line layout within a workshop and functioning simulation.
- Diagnostic purposes. Based on the difference in behavior of the equipment and the digital twin malfunctioning can be diagnosed.
- Commissioning or testing speeding up. For example, the fault handling features, can be tested faster with a digital twin, as the faults can be emulated at the required moment of time without involving hardware.
- Personnel training. Training of personnel to operate virtual or real hardware with interactive means, Including augmented reality.

Industry 4.0 is a paradigm for considering deep integration of the digital and physical worlds, also being referred to as the forth industrial revolution. Digitalization in industry is the emerging task for the nearest future. So is for education. Moreover, the new technologies brought to education not only improve the education quality itself, but expedite their application in industrial environment. From this point of view COVID-19 pandemic is an opportunity for academia to keep up with the changes. And the challenge is not in the fact that some changes are to be applied, as these should be introduced sooner or later. The COVID-19 challenge is that everyone was forced to start changing and the changes are rapid and versatile.

For holding many of the classes the lecturers and the student have to organize their workplaces, master distant learning software tools. And the changes are coming themselves with the people getting used to remote technologies and doing their best to organize the process more efficiently.

As for practical work with equipment – here there is some more to be done. Designing virtual simulators requires the corresponding competence and a significant amount of time and the corresponding funding. It is also worth mentioning, that the people capable of implementing such technologies are involved in many other information technology processes required to maintain vital functions of the educational institution. Even when buying the third-party solutions, the tutor does not always get exactly what is required and these still need competence and time to master and to prepare the education – related documentation and to modify the Curricula.

Using the digital twin concept however can not only enable remote learning, but can improve the educational process in non-pandemic times. For example, a digital twin of a laboratory installation can be used to firstly simulate the work of the properly working equipment. The tutor introduces some changes into the experimental setup and the students are to diagnose it. For this during the laboratory work the students compare the results obtained from the model and from the real object. With the people getting used to this format it will be easier to introduce classes with operating remote hardware not available on site, bringing unique equipment into the universities as an on-demand service.

IV. Conclusion

COVID-19 pandemic challenges force the engineering education to change as fast as never before. The system adopts legal norms, the people are getting familiar with the novel means, find the opportunities to improve their workplaces this way improving the education outcome. The main challenge still to be solved is to teach the future engineers to work with and to operate real hardware not available at home. The implementation of a Digital Twin concept for industrial equipment can partially solve the emerged problem related with hardware unavailability by the remote learning process as well as to improve the professional training quality as the pandemic is over.

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