Online Learning as a Necessary Measure During a Pandemic and as an Opportunity to Increase the Engineering Education Efficiency

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Abstract. This research aim was to analyze problems, which educational systems are facing in the global upheaval era, statement of tasks, which must be solved, as well as search for solutions. The engineering education system has been improved in recent years through the use of new features, which are provided by e-learning software. Future engineers will require such skills as creative thinking, ability to make informed, effective decisions, as well as social responsibility and eco-thinking. The research was carried out on the tools used to organize online learning during the COVID-19 pandemic in several universities. It gave a possibility to compare the effectiveness of using different virtual environments to organize the training of different profiles’ engineers, as well as to analyze the educational content and its difference from that used in traditional classroom teaching. To make a correct assessment, evaluation criteria were identified, which can be formalized, and also motivational characteristics were classified, which can be influenced on the quality improvement. For a case study, different student’s groups were selected to compare them involvement in the process with traditional and online training forms as well as their performance. Additionally, was done an analysis how a training form impacts on their projects quality.

Keywords: Engineering education · Online learning · Virtual educational environments · Educational content quality

1 Introduction

Modern society faces unprecedented challenges arising from urbanization and mobility needs, which associate with the globalization of all life spheres. One of these challenges is pandemics, similar to COVID-19, leading to a collapse in many activities areas and the economic systems’ imbalance. In such conditions, the educational system
gets increased requirements associated with the need to specialists training by various economy sectors, who could work in critical situations. The educational system should maintain ability to overcome inertia, in the same time it must be enough flexible both from the viewpoint of educational methods and technologies and from the process control viewpoint. In recent years, the engineering education system has been improved through the use of new opportunities e-learning software [1]. In the same time, the growing complexity of engineering and technology requires considerable efforts from students during both training and subsequent professional activities. Future engineers be able to make informed effective decisions, should be have creative thinking and eco-thinking and social responsibility. Currently, the emergence of new tools and techniques for engineering education is associated with processes in all spheres of public life and activities. These are such trends as Industry 4.0, Smart City, smart transport and logistics, industry digitalization, digital twins, etc. Smart education, virtual and augmented reality technologies allow improving the educational environment, increasing the students’ motivation and their competitiveness, as they prepare them for life in the digital age.

University professors are often committed to traditional lecturing and laboratory teaching methods, which is why many of them experience stress under unusual external circumstances. To avoid stress, it is necessary to pre-test various resources, combining traditional and online learning. A similar stress is experienced by students who have in ordinary conditions a motivating factor by the conscious choice of the form and method of receiving education, but in critical situations there is no such choice and the student is faced with a dilemma: either to submit to the conditions accepted due to external circumstances, or to refuse training. Based on the above-mentioned facts, the following challenges were formulated: (1) What changes in the management system of universities, departments as well as educational processes should be implemented in order to increase efficiency during critical situations? (2) What changes in educational contents are necessary to ensure the necessary quality of education as well as involvement and motivation of students? (3) How will it be possible to use the gained experience after the crisis? In the authors’ opinion, the most effective tool for the reactive management of learning process, as a complex system, is feedback. Due to the duration of learning process, the educational system is very inert. That is why the effective feedback is a tool to overcome this inertia. The way to implement feedback between teachers and students is a key factor determined the quality of the educational process and student involvement. To give a teaching staff the real possibility to monitor and evaluate the quality of education, it is necessary to identify objective criteria for such evaluation in the context how motivational features are differentiated. In addition, in such way an academic teacher will be able to assess the effectiveness how a particular method influences on the motivational criterion. Such a system, which were developed using formalized criteria, will be more objective and reveal problems for an individual student or group of students, as well as within the framework of a training course or a separate section of a course unit.
2 Problem Status: E-learning and Distance Study Tools

2.1 Concepts and Methods to Realize Distance Study

Distance study is an important tool of a modern education. The article [2] presents how the students’ experience was tested as well as the methodology of teaching in remote format was assessed by students in real time. The results show that the flexibility and usefulness of the course format are important elements for students’ experience. The article identifies a number of questions and starting points for the next study, focused on the perception of gender or the real impact of course content.

The author of the article [3] proposes a new approach for learning and examination of students in the discipline “Theory of Electrical Engineering”. It is recommended to duplicate theoretical materials from lectures, uploading them to Moodle, where the student can study the theory while solving examples, then to check the acquired knowledge with the help of tests uploaded to the system. Thus, students could prepare for the final exam. The final grade is made up of two parts: the first one is the sum of the points obtained when studying the course and passing the control tests, the second part is the grade for the exam. The article [4] presents a learning model, which uses the YouTube video repository for engineering courses. Some results show students’ preference for this model over the more traditional learning models, which use a live video. The results can be applied to develop hybrid models for engineering courses, which can have a positive impact on student satisfaction and, in general, on the course where the model is used. The article [5] describes an experimental study of the Online Flipped Classroom Learning Model (OFCLM) in relation to open and distance learning for adults in a training center. The main results showed that students liked the flexibility and convenience of the proposed model. Smart Classroom is defined as a concept, which needs to adapt to synchronous and asynchronous learning using artificial intelligence technology, that teachers and students can approach different learning styles, engage interactively, and share content. The study [6] provides a system of “intelligent classes”, which covers the process of distance learning within the framework of the Smart Learning System (SLS) as well as learning in a classroom using the Smart Learning Environment (STE). The proposed Smart Classroom allows to facilitate both classroom learning and distance learning processes.

2.2 Interaction and Its Realization During Distance Education

Distance learning is one way to achieve equal quality education. The study [7] proposes a new technological solution for video conferencing using webRTC technology as an alternative for applications, which are still based on the flash memory technology. The technology allows users to conduct video conferences, use additional functions, such as a function, which allows to share a recording screen.

Distance learning courses are becoming more and more attractive for students and educational institutions, and it is necessary to assess the extent, to which online education can provide opportunities to promote the personality of researchers. The researcher’s identity can be defined as a combination of such features as confidence, logical thinking and the ability to plan experiments, interpret the results and the desire
to seek and succeed in genuine research. But as the authors of the article [8] point out, real research should only be partially replaced by online activities, although the activities of outbreak case study—group project are an economical and attractive tool. Students at a distance often experience social exclusion and lack of communication with their peers. A survey was conducted to better understand the nature of the relationships established between distance students and peers. The analysis performed by the authors [9] shows how connections are formed and tested in the online learning environment in various social contexts and technologies, which strategies and practices promote or impede connections that can satisfy students’ social needs.

The article [10] discusses the level of the joint learning strategy that students of distance learning programs have. The reason is so that team work allows people to realize the common goal and objectives, as well as to understand what everyone in the team must accomplish to achieve a common goal. The authors believe that one of the ways to achieve this positive interdependence is to motivate students and that the development of teamwork requires the intervention of both the student and the teacher.

2.3 Remote Laboratories

E-learning should include not only web courses and virtual classes, but also remote laboratories with an effective recognition system, which will allow students to interact with real-life experiments conducted at a distance. The work [11] analyzes the influence of students’ emotions on the improvement of the educational process in two aspects: (i) filling in existing gaps among students and (ii) improving the usability and readability of the platform. The authors create a new intelligent learning system called “LabTutor”, which is adapted to the profile of each student, providing students with access to experimentation on real laboratory equipment in the field of engineering education. Social requirements promote an educational approach based on the premise of “anywhere, anytime”. Remote laboratories start to be a response to the requirements of technical fields of education to adapt to this scenario. The result [12] not only benefited students of distance learning, but also provided new learning scenarios for both teachers and students, and also allowed a flexible approach to experimental topics.

Web courses have achieved a high level of recognition in all areas of education. In this sense, many web-based platforms for online courses offer resources as a complement to theoretical studies [13]. In the fields of STEM (science, technology, engineering and mathematics), online resources can include online labs, which are typically needed in an automated learning process. Remote laboratories [14] can serve as the basis for the development of physical experiments for training in the field of STEM. Thus, one of the VISIR + project goals is to disseminate best practices in the field of teaching electrical and electronic circuits. The article [15] authors propose a model for the informational interaction integration in projects to create training courses, which are based on virtual and complementary reality technologies. A sequence of technological stages to create virtual learning systems and algorithm for its creation is proposed.
2.4 Issues Connecting with the Organization Process of Distance Study

In the field of engineering education, the possibility of using a real management system and virtual laboratories in the educational process motivates teachers to improve students’ knowledge and skills. That also can reduce costs and increase the variety of experiments. The authors of the study [16] suggest that distance experimentation is an alternative didactic methodology. The WebLabs use will improve the engineering education quality, as it will allow direct information analysis in real time and bring industrial scopes problems closer to the academic space. Student feedback indicates that this is the engineering education’s future.

The article [17] shows how tests were conducted such as training, which is becoming more common in the educational environment. This hybrid teaching method combines a massive open online course (MOOC) with students’ personal work. As a new form of distance learning, the Blended Synchronous Learning Environment (BSLE) is a new learning environment that allows students to participate in the learning process synchronously. In China, BSLE has a more unique practical meaning - the Blended Synchronous Classroom (BSC) - to solve the problem of educational equilibrium. The purpose of the study [18] is to compare and analyze the preliminary results of the BSC project, then investigate the key problems of the BSC and give appropriate countermeasures in combination with specific situations to lay the foundation for the future development of BSC and increase its reliability. In recent years, the successful integration of virtual reality in the context of distance learning has led to the development of various structures related to virtual learning approaches, which are used to improve interaction with students and improve their overall learning experience. The purpose of the study [19] is a thorough study and a deep understanding of the impact that embodied pedagogical agents have on the students’ learning experience, as well as on their academic performance. In a future work, the authors of the article plan to create agents that resemble well-known scientists (for example, Albert Einstein), and evaluate how the appearance of agents affects the learning experience of students.

Feedback is an integral part of the distance learning system. This helps students to recognize strengths and areas for improvement, as well as identify actions to increase their effectiveness. In addition, it helps teachers focus on educational policies to improve their content. The authors of [20] propose a model for analyzing student traces in the cloud. Teaching styles in the field of natural and technical sciences were compared by analyzing the totality of lecture transcripts in English and Japanese at leading universities in the USA and Japan, respectively [21]. Science and engineering education in the Japanese educational context tends to reflect and reinforce a teacher-centered personalized knowledge-style transfer that characterizes the field style of the Japanese cultural context and can reinforce this style among students, while teaching in the American context seeks to match and strengthen learning styles characterized by impersonal, inductive thinking, typical of the mainstream American culture.
3 Case Study: Experience of Distance Study Realization During COVID-19 Pandemic

3.1 Features of the Educational System and Its Readiness for Global Challenges

It makes sense to consider the educational system from the point of view of both the processes and the participants. The impact on the process is carried out through organizational and managerial structures, which include different departments, all of which is responsible for its own process and, accordingly, controls it. For these purposes, there are various regulatory documents and instructions, as well as feedback. As a rule, management is carried out in accordance with the activities types. Traditionally, the learning process was carried out by transferring educational content in the classroom: in the lectures, laboratory and practical exercises. With the advent of computers and the information technology’s development, new types of educational content have appeared, as well as new teaching methods. To expand the possibilities in implementing the concept of “life-long learning”, technologies for the distance education implementation have appeared. As can be seen from the above review, these technologies currently provide the opportunity to receive a quality education, although they have problems.

The modern university implements both traditional and distance learning. However, it should be borne in mind that, firstly, these are two completely autonomous processes with their own management systems, and secondly, the participants in the process (administrators, teachers and students) consciously chose one form or another and, therefore, are mentally prepared to the features of the learning implementation.

3.2 Problems Encountered in the Countries of the World: The View of Teachers, Students and Administrators

Enough time has now passed since the pandemic began, for which some experience has been accumulated, a number of problems have emerged, including those that were resolved to some extent and those that could not be resolved promptly. Interviews appeared in the public domain, in which teachers, students and administrators share experiences, problems and ways to solve them. As shown in [22], Covid-19 forced Indian universities, as in the world rest, to switch to online classes, suspending physical classes. Online training is conducted both using recorded classes, including MOOC, and through online classes conducted in the sessions form with zoom or webinars. To do this, professors need high-speed Internet and platforms to provide education or a learning management system, as well as a stable IT infrastructure and professors who are ready to teach online. High-speed Internet and computers or mobile phones are also needed by students to attend or review previously recorded classes.

In India, diverse online education platforms are supported by the Ministry of Human Resources Development (MHRD), the National Council for Educational Research and Training (NCERT), and the Department of Technical Education. There are also initiatives such as SWAYAM (online courses for teachers), e-PG Pathshala (electronic content) and NEAT (enhancing employability). Other online platforms are
aimed at improving communication with institutions and access to content. They are used for training materials and classes, as well as for working with online modules. These include the National Knowledge Network (NKN), the National Project on Technology Enhanced Learning (NPTEL), the National Academic Depository (NAD), and others.

For provide online education, to have web and video courses in engineering, science and management, NPTEL and project of MHRD, initiated by seven Indian Institute of Technology (IIT), along with the Indian Institute of Science Bangalore was created in 2003. During Covid-19, more than ever before, the need for online learning increased for both institutions and teachers and students. However, despite the availability of technology, there is a problem of access, since not every student has a fast Internet and a computer. A survey conducted by an IIT teacher showed that 9.3% of its 2789 students were unable to download materials sent by the institute or study online. Only 34.1% of them had a reasonably good internet connection for streaming lectures in real time. Another study conducted by LocalCircles among 25,000 respondents found that only 57% of students at home had the necessary equipment — a computer, router, and printer — to attend online classes. Students note difficulties in obtaining materials due to lack of internet-traffic and connection problems, as well as the stress caused by the need to be in touch all the time and watch the whole day to a computer or phone screen. In addition, both students and teachers note the insufficiency of direct contact, discussions, debates, etc. According to the director of Takshashila University, the model of online education cannot replace the physical class, but can only be an addition.

Similar problems were encountered in other countries. For example, on the World Economic Forum platform has accent the gap in digital learning; both between countries and within many countries [23]. Thus, according to the OECD, while 95% of students in Switzerland, Norway and Austria have a computer for study, in Indonesia this index is only 34%. In the US, many are also concerned that the pandemic will gap to a digital technology use, as there is a significant divide: while almost all 15-year-olds from privileged families have their own computer, and almost 25% of children from disadvantaged families do not have such opportunities.

There is evidence that online learning can be more effective for those who have access to the right technology, since according to research, on average, students retain 25–60% more material when online learning compared to only 8–10% in class. E-learning requires 40–60% less time for learning, as students can learn at their own pace, skipping part of the lecture or speeding up the pace at their discretion. But it should be understood that the effectiveness of online learning varies among age groups. But transition to online learning can be a catalyst for creating a more effective method of teaching students. The problems identified during the pandemic confirm the book [24] author opinion that schools continue to focus on traditional academic skills and rhythm-based learning, rather than on skills such as critical thinking and adaptability, which will be more important for future success. However, there is a positive point in the fact that the though haste of the transition to online learning may have reduced its quality, but, using the advantages of such training, can be done its part of the traditional.
3.3 Features of the Educational Process Implementation in KFU During COVID 19

In the forced “switch” case, problems arise due to both the participants’ internal unreadiness for changes and the need for a quick transition to another process implementation way, which may be not prepared both from a technical-organizational and normative-legal points of view. In order to increase the educational system sustainability and its readiness to work under stress, it is necessary to identify the risks causes, ways to its minimize and measures to manage the system in a risk situation. Since the transition to distance learning was carried out in accordance with the order of the Ministry of Russia Education and Science, the Ministry, together with the Institute for Social Analysis and Forecasting of the Russian Academy of National Economy and Public Administration at the end of the academic year, conducted a mass survey of the universities’ teaching staff on the development of the online environment in the context of coronavirus infection. It summarizes the attitude of teachers to distance education in the context of a sharp change in their professional activities and the organization of their personal lives. 33987 teachers, or about 15% of the total of the teaching staff, were taken part in the survey. The results of the study showed that teachers are organizationally ready for the transition to distance learning formats, but psychologically they do not accept such a sharp break with traditional full-time education. A skeptical attitude to what is happening is due to both the peculiarities of the disciplines taught (for example, technical and experimental), and conservative views on the nature of teaching. Although teachers formally accept the transition to distance education, they have an internal, latent rejection of it in all areas of training, regardless of gender, age, social and professional status. The survey recorded two positive social characteristics of the professional community of university teachers: the adoption of a state policy on countering coronavirus infection and the availability of skills and abilities to work in an online environment.

At the same time, the breakdown of the usual life way, the destruction of the existing day race-order, in which work and rest are distributed not only in time, but also in space, led to stress and, as a result, rejection of distance education: 66% of teachers indicate that they don’t like working at home; 34% of teachers have no place at home for comfortable teaching; 85.7% of teachers have less free time, they have an idea of an increase in the workload; 87.8% believe that it is better to conduct their classes in full-time format. The main request of teachers comes down to three components: material (providing with computer equipment and software); communicative (an environment for communication, necessary and sufficient to support distance learning, inclusion in the team and maintaining a high level of learning); organizational (reducing bureaucratic pressure and providing more freedom in the choice of teaching means and methods).

46.1% of the respondents disagree with the change in education towards individualization and adjustment for each student. The main threats associated with the impossibility of liberalizing education, the transition to a distance format, are called: the decline in students’ motivation to learn; lack of students’ skills and abilities to maintain discipline and diligence in distance learning; emotional breakdowns of both students and teachers; increased workload on teachers; lack of an individual approach
in the education system, impersonality; inability to control the level of knowledge; restriction in some spheres (for example, in engineering) on the remote transfer of knowledge; formalization of educational processes, a tendency to stereotyped, unified solutions. In general, the results of the survey in Russia coincide with the opinion of the teachers in our university (Fig. 1). In our research, we studied the following issues: (1) What virtual environments have shown the greatest efficiency in terms of process control, education quality, student involvement, increasing their motivation; (2) How the transition to online learning has affected the quality of educational content, its structure, the employment of teachers and students, class attendance; (3) What resources should be developed to control learning quality and the process organization.

The university implements both the traditional form of education and the distance learning. For these purposes, a special “virtual audience” has been created. Each teacher can access to it and use this resource as an addition to traditional teaching. At the beginning of the transition to online mode, courses were held for teachers on the use of this resource. But when the mass connection began, it turned out that the technical capabilities of mass simultaneous use of this resource are clearly not enough since access is through the university’s website. It was decided to use Microsoft Teams for these purposes.

This solution turned out to be effective for most teachers, since almost all of them have high-speed Internet and a computer at home. For most students, this option of training also did not cause problems, most of them quickly adapted to the new form of training, as evidenced by the increase in attendance at classes by 10–15% at different courses. From an organizational point of view, there were no problems with the control of classes, since the classes were conducted according to the schedule approved at the beginning of the semester, however, the load on the controlling staff, who had to analyze and summarize the data, increased. Assessment of students’ knowledge was carried out in different ways - by testing, checking the work sent to the teacher, protecting online projects during their presentation. An online conference of students was also held, where they shared the results of their research.

Fig. 1. Results of the teacher survey
To study the quality of teaching academic disciplines and the entire educational process, two questionnaires “Teacher through the eyes of a student” and “The educational process through the eyes of a student” were developed. The research was carried out with the help of the information-analytical system “Electronic University”, where access to the questionnaires was opened to students in their Personal Accounts. The research results were accumulated in a single final base, and then processed.

In the course of the questionnaire “Teacher through the eyes of a student” for each student, according to the disciplines of the curriculum, a list of teachers was generated and 10 criteria were formulated. Each criteria could be evaluated on a 10-point scale (minimum - 1 point, maximum - 10 points): I always understand the lesson purpose; The teacher presents the material in a clear and creative way; The teacher emphasizes the importance of the subject for the future profession; I actively use teaching aids developed by the teacher; The teacher uses visual aids and technical teaching aids during classes; The teacher demonstrates general erudition; The teacher is objective in assessing the work of students; The teacher is friendly and tactful, treats students with respect; I am impressed by the appearance and demeanor, organization and discipline of the teacher, his culture of speech; The teacher is available for consultation.

During the questionnaire “The educational process through the eyes of students” the following questions were asked: (1) Evaluate the quality of the knowledge obtained in the disciplines of the basic part (compulsory disciplines); (2) Evaluate the quality of the knowledge obtained in the disciplines of the variable part (discipline of choice); (3) Are you satisfied with the list of variable disciplines for your specialty/direction? (4) Are you satisfied with the quality of the organization of laboratory and practical classes? (5) Are you satisfied with the quality of teaching foreign languages? (6) Are you satisfied with the quality of the industrial practice organization? (7) Do teachers help you to effectively organize your independent work? (8) Do teachers help you find the information you need for independent work? (9) Are you satisfied with the control over the performance of independent work by teachers? (10) What difficulties do you experience when working independently? (11) Are you satisfied with the procedure for providing topics for coursework? (12) Appreciate the help of supervisors in writing term papers; (13) Are you satisfied with the current knowledge assessment system.

On the whole, students were satisfied with the organization of the educational process. At the same time, technical difficulties arose, as in other countries. So, during the online broadcasts there were interruptions in communication, students complained about the difficulty of listening to online lectures. In order to minimize this shortcoming, many teachers gave students self-study materials. The greatest difficulties arose with laboratory experiments in which students were unable to participate. Only some of them became possible to implement as online broadcasts (Fig. 2).
We have summarized organizational problems that must be resolved before crisis situations arise. According to the results obtained during the educational process during the COVID-19 pandemic, it is possible to obtain the probabilities of their occurrence and develop measures to overcome it.

4 Conclusion

Major global events are often a watershed for rapid innovation, as SARS has seen an increase in e-commerce. Although it is too early to make conclusions whether COVID-19 will affect the development of e-learning, it is already clear that it is important to spread knowledge across borders, include all companies and sectors of society in this process, fully revealing the potential of online learning technology.

The researches revealed the advantages of online education for teachers: the possibility of innovative teaching methods using online tools; wider coverage of students from different regions; development of distance learning technologies. At the same time, there are drawbacks: such a transition takes time and practice; there are doubts about the fairness of student assessment; the impossibility of personal communication with students; the inability to reach all students due to technological limitations. The advantages of online learning for students: the ability to use various online tools and methods; observance of the education terms; the ability to re-listen to classes and study at your own speed. Disadvantages: lack of personal communication; technological difficulties associated with weak devices or Internet access; the need for online communication and evaluation skills; learning in conditions not adapted to study - off campus.
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