

Operations Research in Online Environment Using ICT in Higher Technical Education

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Abstract: Operations research is now in the renaissance because organizations are optimizing their processes using analytical methods and different research approaches to improve the managing of processes/tasks/problems. Operations research, requiring analytical, systems thinking, the ability of abstract thinking, so it is considered by its complexity and the scope of required knowledge to be a subject that is a challenge to master for students of higher technical education. The objective of the paper is to analyze and compare the situation in the teaching of operations research, identify the prerequisites for the development of analytical thinking of future graduates, and predict the possibilities for improving the education of operations research during distance learning. Part of the paper deals with the description and comparison of areas and methods of operations research taught at technical higher education institutions (HEIs) and universities in Slovakia and the Czech Republic, including the use of software support for calculating and learning the curriculum. The analysis considers results about teaching subjects related to the operations research, comparison of the form, methods, research areas, and software used for teaching at Slovak and Czech HEIs and universities, and semi-structured interviews/surveys among students about the quality of education process identified areas where there is potential for improvement. At the same time, the results of distance education were analyzed the degree of student satisfaction, awareness, comprehensiveness to conduct the new possibilities and threats of distance education. The statistical evaluation of data indicates strong relationship between the two variables: satisfaction of students and awareness of students about online education.

Keywords: operations research; quantitative methods; higher technical education; education process; awareness; online learning

1 Introduction

The precision of operations research methods brings to the decision-making certainty and substantiation of the decisions by measuring, analyzing, and interpreting the data. Graduates of technical disciplines need to master analytical systems thinking, and mastering methods of operations research (further OR) can help them. The acquired knowledge and competencies are used by engineers and managers in decision-making tasks [1].

Nevertheless, according to research findings, there are several issues in the form of teaching method, using software and content of teaching OR and related subjects, and therefore the role of the paper is to examine the situation in the field of technical higher education. Identification of possibilities in the mentioned area enables prediction of the future challenges in improving education in OR.

Several authors, including [2, 3, 4, 5, 6] claim that the use of ICT in teaching subjects including OR, significantly helps students to understand concepts, basic principles, and procedures for solving assigned tasks/defined problems.

Information and communication technology (ICT) means an important source of innovations and improvements for many sectors around the world. We can say that in the field of technical education, ICT applications are a strategic component of the success and enhancement of the education process of higher education institutions and universities [7, 8]. Therefore, government and stakeholders have invested over the last two decades in the ICT adoption in the education system, as stated by the authors [4, 5]. Most universities that have fully adopted ICT have made significant progress in the application of ICT to improve learning methods, education, research and development [4].

Education has been one of the major areas disrupted by the COVID-19 pandemic. [9] The rapid transition of courses to an emergency remote teaching and learning format at the onset of the COVID-19 pandemic in early 2020 created challenges across the university landscape for faculty and students and, inevitably, affects the future of higher education. [10, 11] Studies from the pre-Covid period and also studies conducted during the pandemic [12, 13, 14, 15, 16] approve the wide application of ICT as support tools for teaching in higher education. Another study [17] provides evidence that students prefer ICT-based learning and (they?) believe that knowledge and general learning skills acquired through use of ICT would not be achieved by traditional teaching.

Today's learners expect educators to effectively use information technologies in the classroom. [18, 19] Educators and students had to adapt in short time to the new reality and learn to work with new digital tools and technologies including *Blackboard*, *Moodle*, *Canvas*, *Adobe Connect*, *Zoom*, *MS Teams* and *Panopto*. Teaching and learning activities used in new virtual environment included online lectures and teamwork, the use of a virtual whiteboard, providing feedback to

students in real-time, also recording the lecture, adding comments to the presentation for many academics. [20, 21, 22]

2 Theoretical Background - Operation Research

As early as 1968, OR was defined by Jakff and Sasienio as follows: "Operations research can be considered the application of a scientific method by interdisciplinary teams to problems involving the control of organized (man-machine) systems to provide solutions that best serve the purpose of the organization as a whole." [23]

At present, OR is a discipline focused on solving management problems using mathematical models and methods, while ICT is used to solve "problems". In the United States, it is often referred to directly as "management science." In the article, the term OR will be understood as a scientific discipline, the subject of which is the study and analysis of operations and processes that take place or are planned in a particular organizational unit (enterprise, plant, workshop), the study and analysis of these operations are most often carried out using mathematical modelling." [24]

According to [25], Operations Research (OR) is a branch of applied mathematics and, thanks to its interdisciplinary nature, OR finds application in several areas, such as logistics, production and equipment planning, marketing and finance. We also agree with the authors that: "OR can show the possible connections between mathematics and the real world, which can support the students' learning process, helping them to reason and develop problem-solving and analytical skills. Moreover, a positive attitude towards mathematics could foster students *to pursue a career in scientific disciplines or to continue the study at the university level*".

OR has a broader scope, using methods and techniques from other mathematical sciences, such as statistical analysis, mathematical modelling, predictive analysis, and mathematical optimization, makes it possible to indicate optimal solutions to complex decision problems. Due to its comprehensive and practical focus on practical application, OR has overlapped with other disciplines, such as industrial engineering, logistics, and operations management.

3 Methodology

The research aimed to find out the specifics of teaching OR at an institution of higher technical education, to describe the issues and situation in this field with a focus on OR as a key subject of the master study, to evaluate the relationship between satisfaction, awareness, and fullness during online teaching.

The contribution of this paper is to identify opportunities for improvement and the challenges/potential risks of online education in the field of OR. The article aims to analyze the specifics of online teaching with a focus on OR at higher technical education institutions, including technical universities.

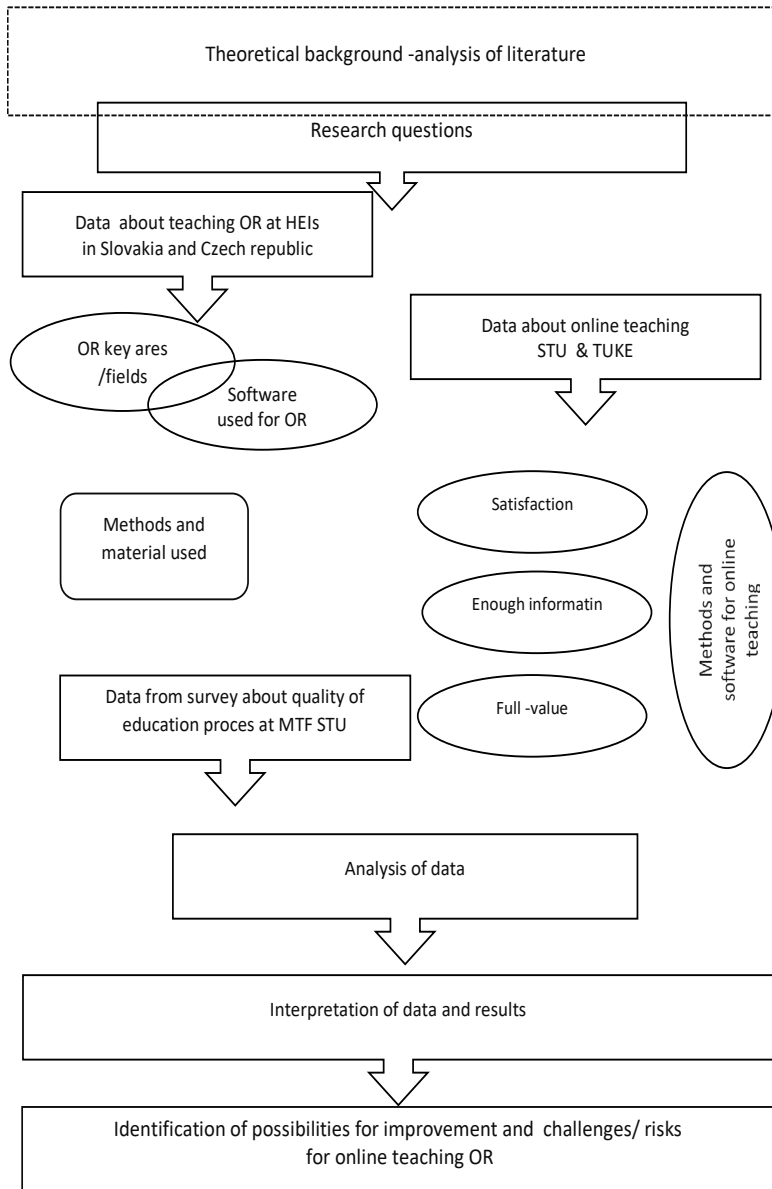


Figure 1
Analytical framework – methodology (drawn by authors)

The theoretical background has been introduced by a review of the available literature regarding OR, online teaching, and competencies. Subsequently, after identifying the gap, the research questions were claimed as follows (Fig. 1):

- Which are the key methods and key areas in OR?
- What kind of software is used to teach OR?
- What is the quality of education and the satisfaction of the students who are enrolled in subject OR?
- Can be expected the same value in online teaching as face-to-face teaching?
- What affects students' learning satisfaction in online teaching most?

First, we focused specifically on OR as a key subject of study at the Faculty of Materials Science and Technology in Trnava, the Slovak University of Technology in Bratislava, Slovakia (further MTF STU). The findings from online surveys (years 2015-2019) about the quality of the educational process at MTF STU with a focus on OR were revised.

Another important source of research was secondary data for comparing OR areas of OR and the use of software in teaching OR at other universities in the Czech and Slovak Republic. Therefore, several online questionnaire surveys and also a semi-structured interview were used in the data collection.

The third source was focused on the education of students during the crisis in 2020-2022 (COVID), with a sample of bachelor's and master students studying at the two biggest and most important institutions of higher technical education in Slovakia – the Slovak University of Technology in Bratislava (STU) and the Technical University in Košice (TUKE).

4 Teaching Operation Research at Universities in Slovakia and the Czech Republic

The results of surveys considering the subject OR at universities in Slovakia and in Czech were analyzed, and the interconnections using both primary and secondary data. Not only the Slovak but also the Czech Republic has been chosen due to the common history of education in the years 1918-1991, linguistic proximity, and continuing current scientific and pedagogical co-operation.

4.1 Operation Research at Universities in Slovakia

Analysis of current state in teaching of the subject Operational Research in tertiary education at Slovak universities was carried out using the questionnaire method in

year 2015. As a supporting tool of the analysis university websites was carried out to determine the level of teaching of the subject OR (or related subjects) at universities in Slovakia (mentioned method was implemented also in year 2019). The survey focused on economic and technical higher education institutions, therefore higher education institutions with an artistic, medical, social focus were excluded from the sample, and foreign higher education institutions were not approached either. Using introduced pattern 12 public universities, 2 state HEIs and 4 private universities were addressed by the questionnaire. 14 completed questionnaires were returned, which represents a 77% return of questionnaires. To compare teaching issues, 50 OR areas were selected for the questionnaire, covering the areas of linear, nonlinear, and dynamic programming, decision theory, game theory, stochastic and simulation models, graph theory and project management methods, inventory models, collective service, recovery, and some other associated areas. Based on the questionnaire and information on university websites, we find out the number of subjects related to the monitored area, if subjects are compulsory for bachelor or master studies, and especially the educational content of subjects. The scope of teaching OR at some universities may be larger than indicated in the survey, as some areas of OR extend into other disciplines (mathematics, statistics, logistics, project management, etc.). Next, results from the questionnaire survey relevant to the focus of the article are presented.

The results stated that OR is taught at a doctoral, master and bachelor degree as follows: 64% of the respondents answered that it is taught at a master's degree, 36% at a bachelor's degree and 21% at third (doctoral) degree.

The key areas taught from OR are linear programming (LP) (79%); then the formulation of models and the graphical solution of LP problems (64%); problem-solving using software is mentioned by 57% of respondents and 50% of respondents mentioned numerical solution of LP problems, the duality of LP tasks, traffic problem and assignment problem. The least taught are the following areas: parametric and quadratic programming, Markov chains, neural networks, multicriteria and target programming, group decision making, and production planning (Fig. 2). We assume that areas that are less represented in the subject of OR are taught at universities in other subjects, such as logistics, production management, project management, statistical methods, and others.

In another question, 14% of respondents confirmed the interconnection of the OR issues with other subjects such as game theory, logistics, project management, systems to support mathematical modeling, quantitative methods in economics, methods, and models of efficiency evaluation, optimization. The key areas of OR taught in other subjects at universities are network analysis methods and LP tasks.

As software used in OR, 64% of respondents reported Microsoft Excel.

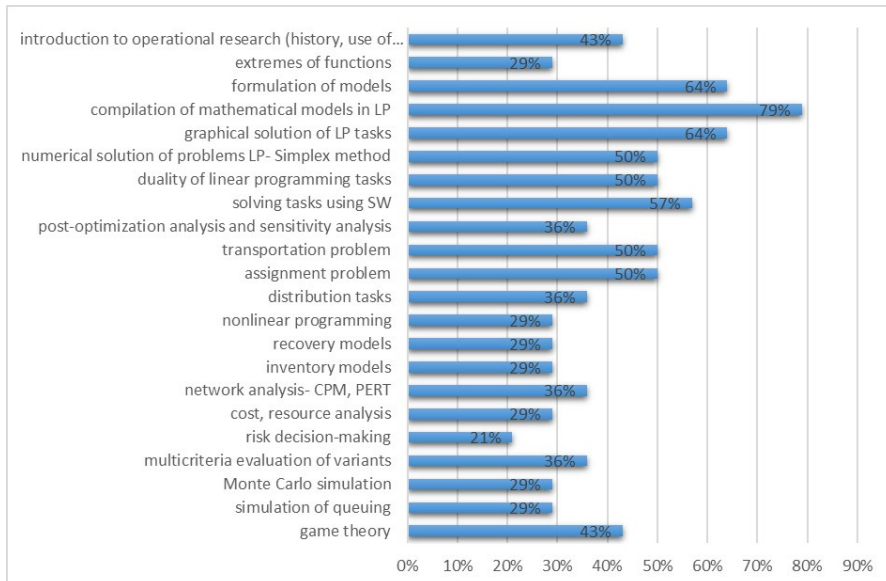


Figure 2

Areas taught within Operation research subject (drawn by the authors)

Online resources have been identified as the main study material for OR. It is positive for students, mainly because the study material is available 24 hours a day 7 days a week, and in every place where there is the Internet.

4.2 Operation Research at Universities in Czechia

In the Czech Republic, a survey was conducted in the previous period (2008, 2010) to compare the teaching of the OR subject and subsequently a comparison of the teaching at universities in the Czech Republic using methods of multicriteria evaluation of variants [26, 27] (The conducted results of the survey were revised and confirmed in years 2015, 2018 and 2019 using surveys in the final theses under the supervision of Kuncová [28, 29, 30], who was also involved in the realization of previous survey in 2008 and 2010). The survey was conducted on a selected sample of 18 public universities and was carried out based on data presented on the websites of individual universities. According to research 81 topics were gradually selected for comparison of teaching (covering the areas of linear, nonlinear, integer, quadratic and dynamic programming, decision theory, game theory, etc.) At the end of the comparison, it was found that 11 areas (out of 81 monitored) are taught at all compared universities:

introduction - practical use of models, formulation of models, LP problems - mathematical models, solution options, graphic design, duality, numerical solution

- simplex, software solution, post-optimization analysis, traffic problems (tasks), models of collective service, simulation - Monte Carlo method.

Based on the results of the questionnaire survey at universities in Slovakia and the results of the survey in the Czech Republic, we concluded that 11 areas (out of 81 monitored in the Czech Republic and out of 50 monitored in the Slovak Republic) are taught at all compared universities.

Also, software support for teaching the subject OR is comparatively provided at universities in the Slovak Republic and in the Czech Republic, the most frequently used are Microsoft Excel, Microsoft Project, LINDO, LINGO, WITNESS. Surveys also show that OR methods are taught in both economics and technical fields and most often are used for online learning e-scripts, e-learning platforms, PowerPoint presentations, e-consultations, etc.

5 Comparison of Teaching OR Before and During Covid Crisis

The authors compared the teaching of the OR subject before and during the Covid-19 crisis. The subject OR is taught at 2nd year of Master study at MTF STU in the winter term for following study programs: industrial engineering and management; personal policy, production technologies and production management; process automation and informatization in industry. In the standard (contact) way of teaching, students had lectures and exercises in the range of four hours per week, while they could have an appointment for face-to-face or via email consultations. In the standard situation, students can borrow literature for free (textbooks, lecture books, and books) in the academic library and/or study it in study room of the MTF STU during its opening hours or use the online textbook "Operation research" by authors H. H. Chovanová, P. Sakál, A. Štrpka and others. Students have three textbooks with lectures (scripts), two of them are available as well as e-scripts, and three scripts with instructions for practicing calculations, which are also available as e-scripts.

The survey about the quality of the educational process used for identification of the needs of students was analyzed from time period 2015-2019. The average number of students studying OR is about 319 students. Participation in the survey varies between 2% and 16% of the enrolled students.

Recommendations for improvement were as follows:

- Need to calculate more examples within key areas of OR;
- The time intensity of the curriculum (cannot be adapted to the individuality of the student);

- Dislike of the manual calculation in OR;
- “Lack” or not enough possibilities of calculation using software (SW: POM QM for Windows is used within the subject, and it is also possible to use MS Excel adds Solver).

During the Covid-19 pandemic, teaching conditions changed significantly, changing toward distance learning through GSuite and/or Microsoft Teams. Lectures and calculations are conducted only online using an interactive whiteboard - eBeams Edge, while lecture is recorded, and recordings are freely provided to students as mp4 files.

Students using GSuite and/or Microsoft Teams can be active and respond to the teacher's questions or ask questions to the teacher. Among the identified shortcomings of online teaching, students included technical problems in using online application (audio, video dropouts and connection difficulties). According to semi structured interviews with students the following positives were found during the online teaching as follows: the possibility to view the lesson more than once from the recording (the student can adapt the speed of the downloaded curriculum to his / her individual needs), the teacher has the opportunity to record more comprehensive videos and thus explain more in detail. Some students have stated as an advantage that they can now to follow the lesson for longer and without interruption; thus understanding is better.

If we summarize what contact and distance education also have similarities, because all lectures are provided as ppt files via the Academic Information System at MTF STU (AIS), students have access to the "e-library", where they have e-scripts available 7 days a week and 24 hours a day, subject-relevant online files that help to master the curriculum are uploaded to AIS as well as in clouds (MSTEAMS). It is possible to consult with teacher online using TEAMS or Gsuite platform or via e-mail.

6 Teaching During Crisis -Survey at STU and TUKE

The Student Council of Higher Education and the Slovak Accreditation Agency for Higher Education conducted a comprehensive analysis of education during the pandemic situation in 2020 through a joint questionnaire survey [31].

The joint questionnaire survey of the Student Council of Universities and the Slovak Accreditation Agency for Higher Education took place from 10th to 22nd June, 2020. The online questionnaire was placed on the websites of both analyzed institutions and was disseminated using social networks and official communication with individual universities. In total, 3490 respondents from 23 universities, representing 105 different faculties, answered the questions.

The analyzed data about education of students during the crisis in 2020 (COVID), include a sample of bachelor's and master students studying at the two largest and most important institutions of higher technical education in Slovakia – the Slovak University of Technology in Bratislava (STU) and the Technical University in Košice (TUKE). The article will only focus on the results of the two already mentioned universities with a technical focus - Slovak University of Technology in Bratislava (STU) and Technical University in Košice (TUKE). From the respondents participating in the survey studied 892 at STU and 612 at TUKE. The sample obtained, which represents both genders, each faculty and several study programs, correspond to the population.

When comparing the satisfaction, awareness and comprehension of online education at technical universities STU and TUKE, we can state that there exist many similarities in examined areas. Within used five - point Likert scale (strongly agree, mostly agree, not sure, mostly disagree and strongly disagree) students confirm that they are satisfied with online education in the study program with 61.92% at STU (strongly agree 26.91% and mostly agree 28.8%) and with 57.58% at TUKE (from them 32.68% strongly agree). Only 8.9% of students strongly disagree with online education satisfaction at STU, and 13.06% strongly disagree at TUKE. Mostly disagree with this online form 14.69% at STU, 12.42% mostly disagree at TUKE. Regarding awareness, most of students agreed strongly or mostly to be informed enough to handle distance (online) learning namely almost 62% of STU students and 63.57% of TUKE students. The results of comprehensiveness of online lessons compared to face-to-face teaching show that 16.48% fully agree and 31.17% partially agree with STU, while 14.22% strongly agree with TUKE and 19.12% partially agree. Dissatisfaction with the comprehensiveness of online teaching compared to face-to-face teaching was indicated by 15.47% completely and mostly 24.44% at STU, this is also confirmed by the results at TUKE where 25.65% mostly disagree and 30.23% of survey respondents strongly disagree.

Important finding in area of technical higher education is that online education is regarding respondents not comprehensive 15.47%, mostly not comprehensive with 24.44% from STU and confirmed by respondents from TUKE strongly not comprehensive 32.97% and mostly not comprehensive 24.33% (Fig. 3, Fig. 4).

In second part of the survey was analyzed which methods of online teaching were used the most at STU and TUKE, (online lectures, video conferences, e-learning, shared presentations, work on seminar papers and self-study of scripts and study literature). The most preferred were the presentation shared by the teacher (STU 23.65%, TUKE 27.94%), the study of literature (STU 23.21%, TUKE 37.75%) and least used were claimed from archive (not in real time) 8.30% at STU and the lectures online 8.72% at TUKE.

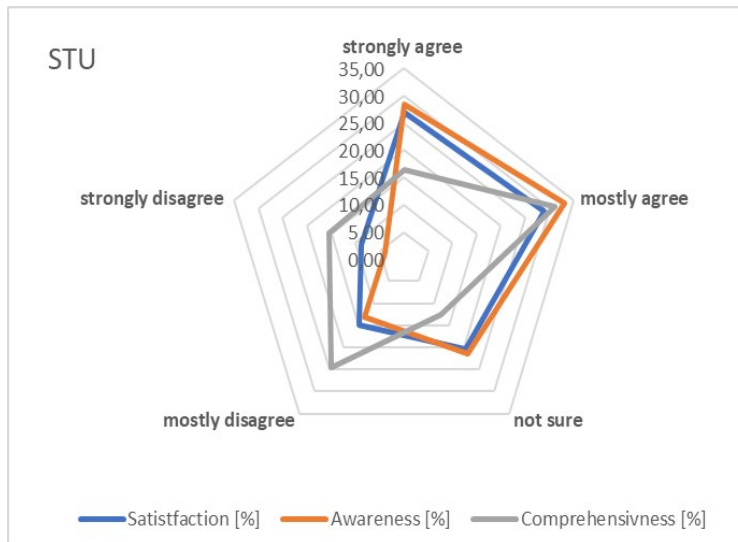


Figure 3

The data visualization - comparing satisfaction, awareness and comprehensiveness of online education at STU (drawn by authors)

Third, after visualization and comparing satisfaction, awareness and comprehensiveness in radar chart for both analyzed institutions (Fig. 3, Fig. 4), it indicates the relationship between awareness and their satisfaction with online teaching. Therefore, it is very important to inform and make familiar students with new possibilities in education process and their specifics, and so to increase their awareness and interest to be satisfied.

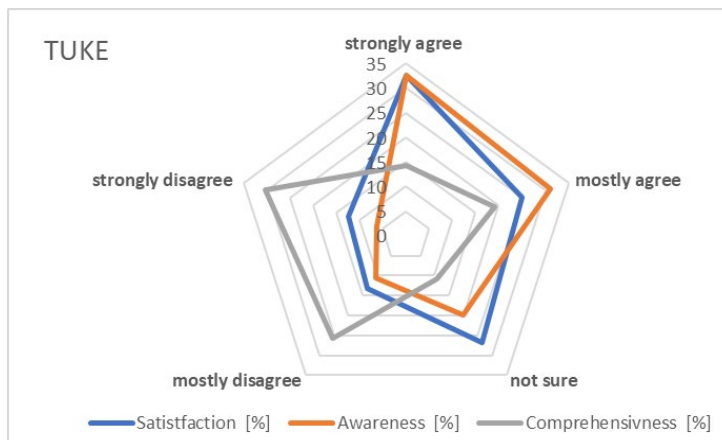


Figure 4

The data visualization - comparing satisfaction, awareness and comprehensiveness of online education at TUKE (drawn by authors)

Conclusions

Following the results and materials that the readiness of universities for the distance form of teaching we can conclude that teaching at the beginning of the pandemic was chaotic and new challenge for both students and teachers, but in a short time most of them were able to adapt to the situation so that the quality of the teaching process for students was secured. Education is a process during which new knowledge, skills and attitudes are acquired and developed. [32] The need for better technical support for teachers and education also emerged. E-learning proved to be a powerful tool for education, it made it possible to continue the educational process. Digital transformation of education is required in tertiary education to make the learning more attractive and easier for students. [33]

This also confirmed that information communication technology is among the latest innovations that have revolutionized various operations in the world [6, 34], including education and enables the enhancement of learning in the online environment [35].

On the other hand, based on survey results, it is confirmed from the students' point of view that E-learning methods cannot fully replace proper face to face education process, and to bring advantages of both it is best to use combination of both methods to achieve optimal results and improvement. In our opinion, the new crisis experience will help in the modernization of teaching and learning at universities especially in technical education. We agree with [4] that it is particularly important ICT in the field of education since it has recently created such platforms and opportunities that have facilitated to some extent the acquisition of knowledge.

An interesting trend is emerging as the possibility of switching to a combined teaching method with the use of online methods and modern information technologies.

During the first wave of the pandemic (March 2020), the new research project KEGA “*The implementation of innovative educational methods and MM guide for decision making area and application of analytical methods in the teaching process of selected subjects in the field of Industrial engineering*” under the Slovak ministry of education was submitted by Institute of Industrial Engineering and Management at MTF STU. The project was approved in January 2021. The main goal of the project is the creation of a portal for e-learning, a pilot for the three core subjects OR, Statistical methods and Business logistics, while the portal will contain, among other things, presentations of the core subjects of the subjects, solved examples (also with video support), electronic scripts, etc. As part of research project results, a survey is planned for students to specify, how the content and e-learning portal structure helped to acquire new knowledge and skills in mentioned areas. The new study will comprise and analyze the results of students before, during, and after the end of the pandemic including the academic years 2022/2023 and 2023/2024. In the future, the portal will represent support for

students' self-study and also an opportunity for professional and lay faithful to learn about the methods, procedures and models that the given subjects offer. In the future, it is planned that other subjects taught will be gradually added to the portal. The recent past and current situation confirms the trend that universities will have to be prepared for similar circumstances, as was and still is the Covid-19 pandemic. Therefore, further research will analyze the possibility of creating virtual laboratories and supporting education using the tools of virtual /augmented/mixed reality. The main aim of further research will be to analyze the effectiveness of implementing innovative methods o in higher education, including: Using virtual reality technology, Blended learning, Project-based learning, Cloud computing teaching, Flipped Classroom.

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