ICT Support for Successful Face-to-Face and Online Teaching Process

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***Abstract* - ICT as a technical support is an important factor for improving the success of the teaching process. Requirements for ICT support are elaborated in detail for Face-to-Face, asynchronous and synchronous Online teaching process as well as for Blended teaching environment used in the post-pandemic period as a selection of the best practices aforementioned teaching methods. The success of the analyzed methods of teaching processes was quantified via key performance indicators for the effectiveness and efficiency of the teaching / learning process in the case of the undergraduate and graduate study of Electrical engineering at the Zagreb University of Applied Sciences.**

Keywords* - *Effectiveness of teaching, Efficiency of teaching, Key performance indicators, ICT support for teaching activities, Biclustering, Jaccard index

I. INTRODUCTION

With the aim of determining the factors that influence the effectiveness of teaching and especially the motivation of both students for learning and teachers for teaching, an internal scientific project was launched at the Zagreb University of Applied Sciences (*Tehničko veleučilište u Zagrebu* - TVZ): *Research on the influence of synchronous and asynchronous forms of teaching on the success of electrical engineering students*. Based on the results of the project research for undergraduate and graduate studies in electrical engineering, factors and guidelines were determined for improving the success of Online teaching as well as for improving the quality of teaching that take place again face-to-face (F2F) [1], [2], [3].

Contemporary teaching activities require intensive use of ICT support, which was particularly evident in the (sudden) transition from F2F teaching to Online teaching due to the Covid-19 pandemic which required the establishment of new and adaptation of existing ICT systems to support teaching [1], [4]:

- Video conference platform (*MS Teams*);
- New version of LMS (learning management system);
- Integration of work authentication software (*Turnitin*) with the LMS system;
- Upgrading the options of the intranet portal intended for teaching (*mojTVZ*) etc.;
- Software for emulating laboratory exercises.

The pre-pandemic teaching process mainly consists of F2F manner with asynchronous Online teaching enhancement in the form of available online materials for students. Some classes were conducted synchronously online via the LMS, but only for laboratory exercises, exams and attendance records.

During pandemic period teaching was organized synchronously online and hybrid (F2F with synchronous online video streaming). In addition, lectures were video recorded thus creating new teaching materials for asynchronous online learning as well as more intensively use of LMS. Post-pandemic teaching process is again mainly F2F with the supplements resulting from the best experiences from Online teaching, presented in Fig. 1.

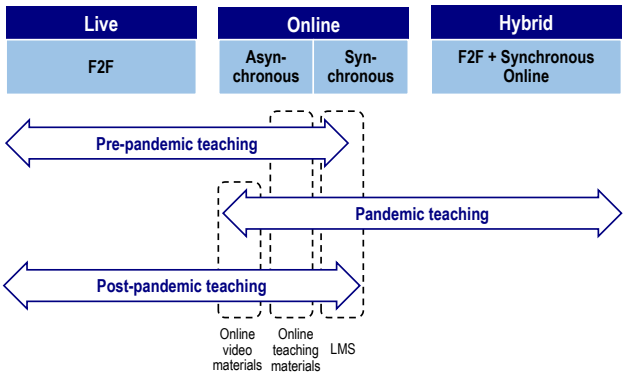

Fig. 1. Teaching process at the study of Electrical engineering at the Zagreb University of Applied Sciences (TVZ)

The requirements for ICT support have been elaborated in detail, depending on the form of teaching (lectures, classroom, laboratory and seminar exercises) and teaching activities (preparation and conducting of lessons, testing of students' acquired knowledge, etc.) in Section II. In Section III. particular examples of ICT systems used for F2F and Online teaching are given. In Section IV. data collection and similarity analysis of the values of key performance indicators (KPI) are presented.

II. ICT SUPPORT FOR TEACHING ACTIVITIES

Based on the analysis of the teaching methods and forms, for the courses held by the authors, Tab. I. was compiled with a list of ICT support items related to each teaching activity depending on the teaching process before, during and after the pandemic period. The importance and / or intensity of use is indicated with the appropriate symbols.

The new ICT support used intensively for Online teaching during the pandemic period was: Video streaming and conferencing, Video material repository, Delivery of documents during exams, Software for emulating laboratory exercises, and on a smaller scale: Intelligent board / graphics

tablet and Instant messaging among students for collaborative tasks.

TABLE I. ICT SUPPORT FOR PRE-PANDEMIC, PANDEMIC AND POST-PANDEMIC PERIOD

ICT support	Teaching / Learning activities: Teacher preparation	Lectures and exercises	Lab. and seminar exercises perform.	Student self-preparation for exams	Performing of exams
Course administering and conducting	○○ ●● ●●		○○○ ●●● ●●●		○○○ ●●● ●●●
Announcement writing	○ ● ●	○ ● ●	○ ● ●		○ ● ●
Classroom reserving		○○ ●●	○○ ●● ●●		○○ ●●
Document creating	○○○ ●●● ●●●				○○○ ●●● ●●●
Projector using		○○○ ●●●	○ ●		
Video streaming and conferencing		●●●	●●		●●●
Intelligent board / graphics tablet using		●● ●●			
Teaching material repository	○○○ ●●● ●●●	○○○ ●●● ●●●	○○○ ●●● ●●●	○○○ ●●● ●●●	⊘ ⊘ ⊘
Video material repository	●●●	●●● ●●●	●● ●●	●●● ●●●	⊘ ⊘
Document delivering			●● ●●● ●●●		●●● ●
Online exams, student work originality checking			○ ● ●		○ ●●● ●●
SW for lab exercises			○○ ● ●●●		
SW for emulating lab exercises			●●● ●	●● ●●	
Instant messaging			●●		⊘ ⊘ ⊘
Legend	○ Pre-pandemic period ● Pandemic period ● Post-pandemic period ⊘⊘ Not allowed *Intensity of use* Three symbols High Two symbols Moderate One symbol Low				

In post-pandemic period ICT support, includes best practices from Online teaching, such as: Video material repository for previously recorded lectures as new teaching material and Software for emulating laboratory exercises, both for self-preparation of students at home. Online exams are more frequent, resulting in more intensive use of the LMS, as well as verification of the originality of student's reports submitted in the text form.

III. ICT SUPPORTING SYSTEMS

Particular examples of ICT systems used to provide ICT support for F2F and Online teaching activities of electrical engineering courses at TVZ are listed in Tab. II.

TABLE II. ICT TEACHING / LEARNING SUPPORTING SYSTEMS

ICT support	ICT systems: MS 365	Intranet portal	LMS	Turnitin	MS Teams	Specific Apps*
Course administering and conducting	●●●	●●	●●●		●●	
Announcement writing		●●●	●			
Classroom reserving		●●●				
Document creating	●●●		●●			●●●
Video streaming and conferencing					●●●	
Intelligent board / graphics tablet using						●●●
Teaching material repository		●●●	●●		●	
Video material repository					●●●	
Document delivering		●●●				
Online exam, student work originality checking		●●	●●●	●●		
SW for lab exercises						●●●
SW for emulating lab exercises						●●●
Instant messaging					●●●	●●●
Legend	*Intensity of use* ●●● High ●● Moderate ● Low ** Note: for PC and/or mobile devices*					

The success of ICT supporting systems is evaluated through the following courses which are in the scope of this research:

The undergraduate study

1. *Personal computers in electrical engineering* (**PCEE**) in winter semester of academic year 2019/2020 held F2F and in winter semester of academic years 2020/2021 and 2021/2022 held Online;

2. *Signals theory and processing* (**STP**) in winter semester of academic year 2019/2020 held F2F and in winter semester of academic years 2020/2021 and 2021/2022 held Online;
3. *Information theory and coding* (**ITC**) in summer semester of academic year 2018/2019 held F2F and in summer semester of academic years 2019/2020 and 2020/2021 held Online, but in summer semester of academic year 2021/2022 held F2F again;
4. *Digital circuits* (**DC**) in summer semester of academic year 2018/2019 held F2F and in summer semester of academic years 2019/2020 and 2020/2021 held Online, but in summer semester of academic year 2021/2022 held F2F again.

The graduate study

5. *Protection of the environment and the quality of life* (**PEQL**) in winter semester of academic year 2019/2020 held F2F and in winter semester of academic years 2020/2021 and 2021/2022 held Online.

The examples of ICT support systems best practices that were primarily used during the transition to Online teaching, also proven useful in the post-pandemic F2F teaching period, are given below:

Intranet portal

The portal is available to all teachers and students. The teaching materials are visible to students and teachers of the entire TVZ, which allows better information exchange. The portal is the result of in-house development as well as its maintenance and enhancements. It enables: news, notifications, course curriculum info, timetable management, student service information, reservations of classrooms, dates and groups. The easy-to-use repository management enables the submission and placement of teaching materials (Teacher => Student) as well as delivery of student works (Student => Teacher).

Learning management system (LMS)

The Moodle system is open-source software for learning management which provides numerous useful options for teaching and learning process. In our case, it is mostly used for: record of attendance, knowledge and skill assessment, record of exam results, notifications, repository of teaching materials, delivery of student works, student work originality check with Turnitin software. During Online teaching, it was used intensively, and teachers adapted LMS to their courses and needs.

Turnitin

It is mandatory for checking the originality of final and diploma theses, and it is proven useful for checking all written works of students, for example: seminar papers, program codes, laboratory reports. In TVZ, it is integrated with LMS [5].

MS Teams

MS Teams is Microsoft's video conferencing platform. It enables the storage of documents in the MS Sharepoint cloud, so it does not consume the TVZ's storage systems. In this way, video recordings of lectures are stored, which requires about 15 GB per course (about 4 MB per minute of video recording). It also supports attendance records, a repository of teaching materials and collaboration in subteams within course teams. Therefore, it is suitable for group solving of seminar and laboratory exercises, when the cooperation of students is required.

Specific software for emulating laboratory exercises

The software suite used to emulate the lab environment at home consists of:

Audacity - free software under General Public License for recording, reproduction, processing, generation and analysis of audio recordings and programming in the Nyquist programming language. It is also possible to develop modules (*plug-ins*) for Signal analysis (multimeter emulation), Signal quantization, Generation of digital transmission signals with additive noise, Signal decimation, Amplitude histogram and aperture, etc.

Logisim - free software under General Public License for simulating digital circuits. Simple implementation of virtual laboratory exercises in form of XML files enables additional interventions such as protection of templates.

Multisim - electronic schematic capture and simulation software tool (Electronic design automation), also available on mobile devices.

GeoGebra - free dynamic math software under General Public License that includes geometry, algebra, tables, graphing, statistics and calculus. It can easily be adapted for tasks and demonstration exercises in electrical engineering.

IV. DATA COLLECTION AND KPI ANALYSIS

The analytical part of the research is based on extensive, multi-year data related to lectures and exams at undergraduate and graduate studies in Electrical engineering. In total, data were collected for 1 554 full-time study students for courses in the scope listed in Chapter III.: in pre-pandemic period 544 students, during pandemic period 888 students and in post-pandemic period 122 students.

One of the goals of paper is to determine variations of key performance indicators for evaluating the effectiveness and efficiency for different forms of teaching (F2F, Online, Blended) [6]. Additionally, the question arises whether these variations can be reduced by using appropriate ICT support.

According to previous research [7], the following Key Performance Indicators (KPIs) for the teaching/learning process were taken into account:

- Average exam grade,
- Exam pass rate,
- Share of top grades,
- Early exam pass rate and
- Success in taking exams.

KPIs definitions are presented in Tab. III. For the courses in research scope, the values for all the listed KPIs were calculated for the pre-pandemic, pandemic and post-pandemic period, and they are presented in Tab. IV.

TABLE III. KEY PERFORMANCE INDICATORS FOR TEACHING / LEARNING PROCESS IN SCOPE

KPI_i	Name	Description)
KPI_1	Average exam grade	Average grades for all students who successfully passed the exam of the course during the academic year. Grades range from 2 (lowest passing grade) to 5 (highest possible grade). This KPI is measure of ***effectiveness***.
KPI_2	Exam pass rate	The number of students who successfully passed the exam of course divided by the number of enrolled students in the course during the academic year. This KPI is measure of ***efficiency***.
KPI_3	Share of top grades	The number of students with top grades: 4 and 5 divided by the number of students who passed the exam of course during the academic year. This KPI is measure of ***effectiveness***
KPI_4	Early exam pass rate	The number of students who successfully passed the early exams of course divided by the number of all students who successfully passed the exam of course during the academic year. Early exam terms include continuous course assessment via midterm exams and exams within 4 weeks after the end of lectures. This KPI is measure of ***efficiency***.
KPI_5	Success in taking exams	The number of students who successfully passed the exam of course divided by the total number of exam attempts of course in academic year (AY). This KPI is measure of ***efficiency***.

TABLE IV. VALUES OF KEY PERFORMANCE INDICATORS FOR COURSES IN THE SCOPE

Course	AY	Period	KPI_1	KPI_2	KPI_3	KPI_4	KPI_5
PCEE	2019/20	Pre-pandemic	2.605	0.783	0.062	0.955	1.000
STP	2019/20		2.609	0.687	0.043	0.761	0.676
ITC	2018/19		2.761	0.826	0.085	0.958	0.910
DC	2018/19		2.653	0.890	0.116	0.917	0.818
PEQL	2019/20		4.552	1.000	0.828	0.828	1.000
PCEE	2020/21	Pandemic	2.594	0.618	0.109	0.930	1.000
PCEE	2021/22		2.699	0.649	0.124	0.903	0.724
STP	2020/21		2.533	0.692	0.089	0.911	0.600
STP	2021/22		2.500	0.556	0.067	0.667	0.588
ITC	2019/20		2.511	0.734	0.106	0.638	0.701
ITC	2020/21		2.615	0.736	0.103	0.974	0.765
DC	2019/20		2.964	0.775	0.273	0.927	0.846
DC	2020/21		2.773	0.838	0.136	0.909	0.815
PEQL	2020/21		4.425	0.909	0.825	1.000	1.000
PEQL	2021/22		4.490	0.961	0.918	0.918	1.000
ITC	2021/22	Post-pandemic	2.714	0.667	0.143	0.929	0.718
DC	2021/22		3.015	0.850	0.279	0.882	0.840

In order to find out if there are deviations in KPI values depending on the teaching period (such as a significant decrease or increase), the data were analyzed using the biclustering technique. Biclustering technique simultaneously clusters both rows and columns of a data (in our case, data on the *y* and x axes), allowing for the identification of subsets of objects and features that exhibit coherent patterns of behavior [8]. Average exam grade (KPI_1) was chosen as the *x*-axis, and each remaining KPI_2 – KPI_5 was analyzed separately, through their value on the *y*-axis. For each KPI separately, an *x*-*y* plot with points showing the KPI values for all five courses in the scope in three teaching environments (pre-pandemic, pandemic and post-pandemic) are shown in Fig. 2 – Fig. 5.

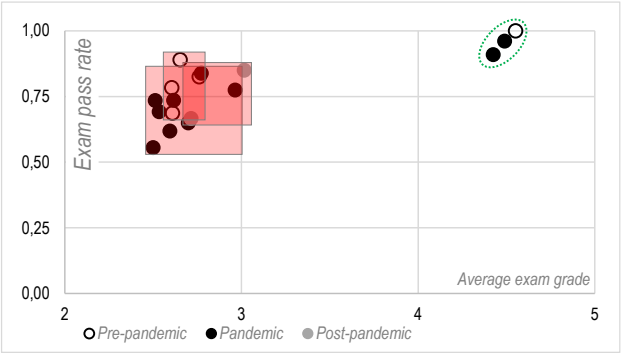

Fig. 2. KPI_2 Exam pass rate (*y* axis) – depending on KPI_1 Average exam grade (*x* axis) for all courses and teaching periods

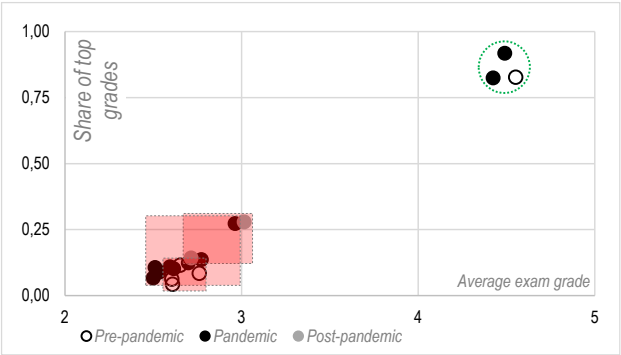

Fig. 3. KPI_3 Share of top grades (*y* axis) – depending on KPI_1 Average exam grade (*x* axis) for all courses and teaching periods

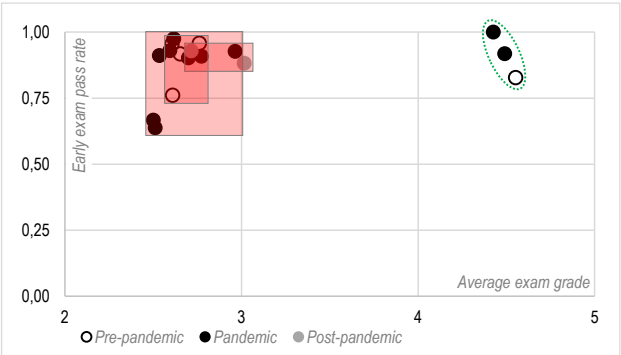

Fig. 4. KPI_4 Early exam pass rate (*y* axis) – depending on KPI_1 Average exam grade (*x* axis) for all courses and teaching periods

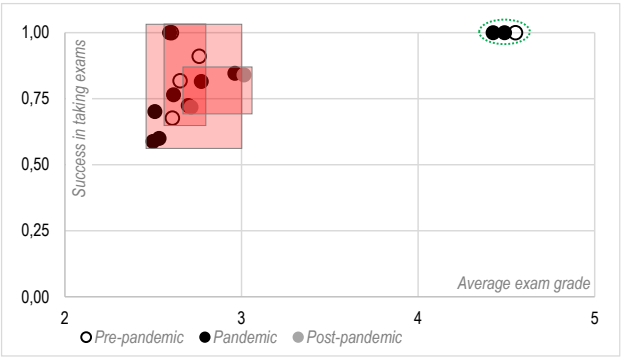

Fig. 5. KPI_5 Success in taking exams (*y* axis) – depending on KPI_1 Average exam grade (*x* axis) for all courses and teaching periods

In addition to points, rectangles are drawn on the *x-y* plots, that cover all the KPI values for a particular teaching period with their surface, which will be described in continuation.

The first feature that can be seen on the *x-y* representation is that the values of the KPIs are grouped into two clusters: the values for the undergraduate courses (covered by red rectangles) and the values for the graduate course (circled by a green line). This is to be expected, since graduate study are attended by the most successful students and therefore the average grades are generally higher. Another feature that can be noticed is that for each KPI the values for all undergraduate courses are mixed, without a disjunctive distribution according to the form of teaching.

In order to determine the closeness of the KPI values according to the form of teaching, a measure of similarity was calculated using the Jaccard index [8]. The Jaccard index measures similarity between finite sets, and it is defined as the size of the intersection divided by the size of the union of the sample sets (1). In our case:

$$J_i(R_A, R_B) = \frac{|R_A \cap R_B|}{|R_A \cup R_B|} \quad (1)$$

Where:

- i is index of observed KPI_i, i = 2, 3, 4 and 5;
- *A* and *B* are different forms of teaching;
- Denominator: the union of the area of the rectangle R_A that covers all the points of the observed KPI_i for the *A* form of teaching and the rectangle R_B that covers all the points for the *B* form of teaching.
- Numerator: the intersection of the sets i.e., the common (overlapping) surface of rectangles R_A and R_B.

TABLE V. SIMILARITY MEASURE BY JACCARD INDEX

i	KPI_i	Pre-pandemic vs. Pandemic	Pre-pandemic vs. Post-pandemic	Pandemic vs. Post-pandemic
1	Exam pass rate	17 %	10 %	30 %
2	Share of top grades	8 %	0 %	31 %
3	Early exam pass rate	20 %	5 %	7 %
4	Success in taking exams	26 %	7 %	15 %
	Average	**18 %**	**5 %**	**21 %**

The results in Tab. 5 show that the KPI values are more similar between the pre-pandemic period and the pandemic period (i.e., when there was a transition from F2F to Online, similarity is 18 % in average), than between the pre-pandemic period and the post-pandemic period (both periods are F2F, similarity is only 5 % in average). The obtained high similarity of KPI values during the transition from F2F to Online teaching proves that the transition was successful and that, in addition to the efforts made by students and teachers, the selected ICT support was effective during the pandemic period.

Additionally, the high similarity of KPI values between the pandemic and post-pandemic periods show that the use of new ICT support, which proved to be effective, continued to be effective in the post-pandemic period.

V. CONCLUSION

Based on experience in Face-to-Face (F2F) and Online teaching, as well as in Blended teaching that resulted from the best practices of the mentioned ones, the paper presents the required ICT support for each teaching activity.

The success of teaching is verified through KPI for efficiency and effectiveness. Efficiency and effectiveness of teaching for each teaching method is analyzed via the following key performance indicators (KPIs):

- Effectiveness: *Average exam grade* and *Share of top grades*;
- Efficiency: *Exam pass rate*, *Early exam pass rate* and *Success in taking exams*.

KPIs were collected for five courses encompassing 1 554 students of undergraduate and graduate studies in Electrical engineering at Zagreb University of Applied Sciences.

By using Jaccard index, it was shown that the efficiency and effectiveness KPIs from pandemic period are more similar to KPIs in pre-pandemic period than KPIs from post-pandemic period to KPIs in pre-pandemic period despite both being F2F. In other words, teaching in the post-pandemic period, even though it is F2F, has adopted the best practices from Online teaching process. The above confirms that, in addition to human efforts in teaching and learning, ICT support for Online and Blended teaching is optimally selected.

The overall conclusion could be that contemporary ICT support is very important in today's education since it increases the availability of learning for everyone, anytime and on any device and improves personalization, collaboration, administration, knowledge assessment and innovation.

Future steps could be activities that will encourage and support teachers for more advanced use of the LMS platform and other ICT related tools: social networks as an attractive way to exchange information; gamification of particular course parts and teacher-student co-creation of learning materials.

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