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THE IMPACT OF EDUCATIONAL TECHNOLOGIES ON LEARNING OUTCOMES IN HIGHER BUSINESS EDUCATION

ABSTRACT: *The paper examines the impact of alternative ways of teaching and the use of various educational technologies on students' performance. Our survey was conducted on a sample of actively enrolled students of Business Informatics at the Faculty of Economics, University of Belgrade, in December 2022. Our results suggest that utilisation of communication and learning platforms (Viber, WhatsApp, Facebook, Moodle and course sites), although widely accepted and favoured by students, has no significant impact on their performance. Students' performance was measured by their average grades and the share of passed examinations in the total number of attended courses (i.e., success rate). We have found evidence that students' performance can be related to the teaching approach. Furthermore, attending classes online worsens students' chances of improving their average grade and their success rate in business informatics courses. On the other hand, the data suggests that students' chances of improving their total average grade improve if they attend classes online.*

KEY WORDS: *business education, educational technologies, learning platforms, distance learning*

JEL CLASSIFICATION: O31, O33, A22, C12, M15

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1. INTRODUCTION

In welfare economics, theoretical education is an important factor for both economic and human development (Barr, 2001). When it comes to prospective economists, modern economic education is faced with numerous challenges due to the global challenges which are emerging in the 21st century (Shakharova et al., 2022). Some of the main issues are: keeping up with the rapidly changing economic trends and technologies, addressing the increasing complexity of global markets, politics and economic factors, adapting new teaching methods and technologies to the teaching process, pedagogical preparations for dealing with new generations and students' new way of life, ensuring that students have the necessary skills to navigate a dynamic and competitive job market, satisfying a growing need for incorporating real-world applications and practical experiences into economic education in order to prepare students for the career challenges they may face in their careers, etc. Over the years there have been many attempts by researchers to address these issues. Our research deals with one of them – utilisation of technologies in the education process.

Since February 2020, the COVID-19 pandemic has had a significant impact on educational systems all over the world, as well as on the global society. The Internet, communication platforms, smart devices and numerous other novel digital and electronic resources (referred to as "Educational Technologies" or "EdTech" – Mirrlees & Alvi, 2019) helped sustain both teaching and learning during the pandemic. Simultaneously, educational technologies brought additional benefits into education (class flexibility, time efficiency, extension of student–teacher communication time, etc.). Nowadays, although the pandemic is over, teachers still use these technologies to supplement traditional teaching. Naturally, the question of how the changes introduced in the educational process affect students as the key beneficiaries of the educational system arises. Addressing this issue is vital for the future of education systems around the world. Given their benefits for the teaching process and positive experiences of students from schools in which some EdTech are already implemented, it is expected that EdTech would have a positive impact on students' performance as well. If this is the case, they should be incorporated into the teaching process globally. Conversely, if EdTech do not contribute to or have a negative effect on students' performance, there is no need to change the existing educational systems. Examining this question could be particularly helpful for the Serbian educational

system, where traditional teaching is still dominant in schools with little to no presence of EdTech. Furthermore, investigating this issue could be beneficial for the future development of Serbian academic business and economic education, especially bearing in mind the fact that in the Serbian context, similar academic surveys and research have not yet been conducted, to the best of our knowledge.

The main goal of this research was to quantify and examine the impact of different EdTech types on students' learning outcomes in Serbian higher business education. More precisely, this paper aims to examine and quantify the impact of three digital resources from the EdTech family on students' performance: communication platforms (Viber, WhatsApp and Facebook), learning platforms (Moodle and course websites) and online education. All of these resources were available to the students of the Business Informatics Department at the Faculty of Economics, University of Belgrade when our survey was conducted in December 2022. Each student had the opportunity to decide whether or not to use these EdTech. It covered a sample of 108 actively enrolled students participating on a voluntary basis who were asked to identify the EdTech they used, their attitudes toward theEdTech and their final performance. The results obtained were analysed using logistic and linear regression along with the Mann-Whitney U test. We found a high level of student satisfaction with implemented EdTech (analysis of student satisfaction was the secondary goal of this research). However, only one of them had a statistically significant impact on students' performance – online education.

The remainder of this paper is organised as follows: Section 2 gives a review of the relevant literature, Section 3 presents the EdTech analysed in this research, Section 4 deals with the data, applied methodology and research hypotheses, while in Section 5 we present our empirical findings. Finally, Section 6 provides the conclusion.

2. LITERATURE REVIEW

A detailed review of the literature on economics students' education was given by Miragaya-Casillas et al. (2023), who discussed 29 studies on this topic and students' self-interest. Among the earliest published papers on the impact of COVID-19 on teaching is Watermeyer et al. (2021), in which the authors discussed the rapid migration to online teaching and utilisation of digital

pedagogy in the UK. 1,148 academics working in the UK universities participated in the research. The results showed that not all fields were equally ready for a quick transition to online teaching. Computer science proved to be the readiest. Birdi et al. (2023) discussed recent economics pedagogy literature in the first period of the pandemic (2020–2021). They noticed a significant impact of the pandemic on scholarly articles, but not to the extent that they expected after 2021. The authors paid special attention to the impact of technologies on overcoming the issues brought on by the pandemic. Zhang and Ramse (2021) also dealt with the impact of the pandemic on economics and handling the problem in teaching practice.

There have been several papers on the impact of the COVID-19 pandemic on education in individual countries. For example, Roman and Plopeanu (2021) discussed the education of economists in Romania. They found that psychological distress and increased concerns about the pandemic had a negative effect on learning effectiveness. They also concluded that the university infrastructure for online activities decreased the likelihood of students perceiving online education as less effective. Conrad et al. (2022) examined education in Canada. They found that students' experience with online education can be negatively affected by information overload and additional technical skill requirements. Their evidence suggested a lack of social interactions, class format and ambiguous communication, which also affected perceived learning. Engel et al. (2023) analysed the situation in Germany. Based on various regression analyses, the results of Engel et al. (2023) show that several (digital) frameworks must be created at both teacher and student levels to achieve sufficient learning success. The strongest predictors of students' learning success were teachers' digital competencies. This supports the argument that teachers must be qualified to address the very specific challenges of teaching in digital contexts and a need for universities to implement more teacher qualification programmes. Rudolph et al. (2023) discussed the situation in Singapore, presenting students', lecturers' and academics' perspectives. They discussed the practical implications of their research for current university students during and after the pandemic. Engzell et al. (2021) analysed a large sample (n=350,000) of pupils in primary schools in the Netherlands. Their findings imply that students made little or no progress while learning from home and suggest even greater losses in countries with weaker infrastructure or school closures of longer durations.

González et al. (2023) showed that teachers who used EdTech to maintain content delivery and promote interaction expanded their understanding of course design and developed an empathetic disposition to understand students' situations. Rapanta et al. (2021) interviewed experts and discussed issues related to the possible role of EdTech and distance learning after the COVID-19 pandemic and what the teachers had learned from it. Engelhardt et al. (2021) compared students' performance in the COVID-19-affected semester to the performance in the previous three semesters. They considered both students' grades and performance on standardised tests in introductory macroeconomics, microeconomics and statistics and concluded that there were no significant differences in performance across the semesters. Orlov et al. (2021) concluded that students' gender, race and first-generation status had no significant association with a decline in students' performance in the pandemic semester. In contrast, they found that prior online teaching experience and teaching methods that encouraged active engagement (e.g., small group activities and projects) played an important role in mitigating negative effects of the pandemic. Adedoyin and Soykan (2023) concluded that online education is different from emergency remote teaching as it is more sustainable while instructional activities are more hybrid. Generally, the literature on the efficacy of online teaching is divided and inconclusive. There are authors claiming that one of two teaching methods is more efficient (online teaching was favoured by Bi et al., 2023; Dutton et al., 2002; Hamdan & Amorri, 2022; Zheng et al., 2021; amongst others; whereas face-to-face teaching was favoured by Brown & Liedholm, 2002; Helms, 2014; Jiang et al., 2021;amongst others), while there are also those who claim that online and face-to-face teaching are equally efficient (e.g., Fisher et al., 2022; Paul & Jefferson, 2019; Westhuis et al., 2006; amongst others).

Researchers apply different methods to analyse the EdTech impact on students' performance. There are also researchers who try to assess the EdTech impact via multiple statistical methods. Here, we will briefly address some of the commonly used methods in the recent literature. Authors such as Rapanta et al. (2021) and González et al. (2023) used qualitative methods based on interviews with research respondents. One such popular method is a hybrid thematic analysis which combines inductive and deductive codes (concepts) in order to draw a common conclusion (i.e., common narrative) from all the held interviews. Some authors tested whether average students' performance would be the same among students

who had been exposed to some EdTech and those who had not via two-independent-samples T-tests (Bi et al., 2023; Fisher et al., 2022; Helms, 2014) or via its non-parametric alternative, the Mann-Whitney U test (Fisher et al., 2022; Westhuis et al., 2006). Some others used other non-parametric tests to check whether the distribution of students' performance among exposed and unexposed students is the same. One of the most commonly applied non-parametric tests is the chi-square test (Dutton et al., 2002; Helms, 2014; Paul & Jefferson, 2019; Zheng et al., 2021). Among parametric statistic procedures, researchers typically use ANOVA or MANOVA depending on the number of students' performance metrics utilised. Some good examples are Bi et al. (2023), Jiang et al. (2021), Paul and Jefferson (2019). Finally, many researchers have used different econometric models to study the impact of EdTech. The most common among them is simple linear regression (Brown & Liedholm, 2022; Dutton et al., 2002; Engelhardt et al., 2021). Authors typically regress students' performance on a dummy variable which indicates whether a student is exposed to EdTech or not and on some controlling variables (such as gender, age, race, previous performance, employment, homework performance, teacher demographics). Apart from linear regression, authors have used the fixed effect panel model to test performance on multiple courses at the same time (Orlov et al., 2021), or logistic regression to model discrete metrics of students' performance (Roman & Plopeanu, 2021).

In analytical terms, the study by Roman and Plopeanu (2021) is closest to our work. The authors used ordinal logistic regression to assess the impact of multiple factors on students' attitudes towards different teaching methods in five major economics faculties in Romania during the COVID-19 pandemic. Thematically, the studies by Valverde-Berrocoso et al. (2022) and Palaroan et al. (2023), who examined the impact of ICT (Information and Communication Technologies) and Viber on students' performance, is the most similar to our work. All of these authors found significant improvement when EdTech were utilised.

3. EDUCATIONAL TECHNOLOGIES

Educational technologies have existed and been in development for many years. However, their use was not so widespread before the pandemic. It was left to teachers and students to use them as they chose. The Business Informatics department at the Faculty of Economics of the University of Belgrade recognised

the potential of EdTech and implemented some of them even before the pandemic. This primarily refers to the course websites and communication platforms for immediate information exchange (Viber, WhatsApp and Facebook). Both resources were initially used solely to supplement the teaching process, but they gained additional importance during the pandemic. Here we will briefly discuss each of them.

Course websites are learning platforms used for dissemination of teaching materials and information. Materials used in classes, additional exercises, notifications, announcements, instructions, relevant updates, etc. are commonly distributed to students via the respective course websites. The sites are not interactive. Consequently, they serve as general support for students in the learning process. Their main advantage lies in their availability since they are easily accessed from any place and any device with an Internet connection. Moreover, when course websites are built, designed, updated and maintained by teachers alone, they are usually better adapted to the needs of a specific course and each individual generation of students.

Viber and WhatsApp are communication platforms for instant information exchange. By using them, students have the opportunity to participate in a direct group conversation. Questions posted by each student can be answered by either a teacher or other students who are group members. Teachers can simultaneously monitor students' common questions, weak points in knowledge, point of interests, etc. In this way, the transmission of incorrect information is significantly reduced, while the response time is significantly shortened. Another important benefit of these platforms is that received information can be in text, audio, image, or video format. A non-negligible advantage of instant messaging applications is their popularity. They represent a preferred way in which students and young people want to communicate these days, which can encourage students to participate in discussions.

Facebook is a specific communication platform. It operates more as a hybrid between a communication platform and a course website. Facebook groups are basically a shared Facebook wall. A person can post content, reply to other posts, create polls and even start live streams. Compared to major community platforms, this is not much. In addition to this, students need to have an account

with Facebook, which reduces the range of students a teacher can reach. In the remainder of this study, Facebook is considered separately from other communication platforms since it is a hybrid platform.

During the pandemic, the exigencies of sustaining the teaching and learning process paved the path for two additional widely accepted EdTech. In the first months of the pandemic, Moodle was the dominant electronic learning platform. Moodle was especially helpful for courses that did not have their own websites and had to be transferred into virtual space in a very short time. Moodle is an open-source electronic learning platform for LMS (Learning Management System). It provides a space for teaching materials, posting information, checking knowledge (sitting tests), etc. Access to the platform is made easy by assigning user access rights.

In the autumn of 2020, using the video conference platform Zoom became the predominant approach for distance teaching and learning. Teachers use Zoom to stream their classes online, allowing the students to attend classes digitally. In addition to streaming, Zoom also offers a large number of supplementary features: direct conversation, messaging, "whiteboard" writing, screen sharing, defining multiple "rooms" for work (breakout rooms), meeting recording, file sharing, among others. Furthermore, Zoom allows large numbers of participants to attend, which sets it apart from its main competitors.

4. METHODOLOGY, DATA AND RESEARCH HYPOTHESES

We surveyed Business Informatics students from the Faculty of Economics of the University of Belgrade who had experience with the EdTech analysed. The research was anonymous and voluntary. The prepared survey consisting of a questionnaire with 15 questions in total was conducted in December 2022. The data was analysed by the commercial statistical software IBM SPSS. The research questionnaire and the dataset of survey results are available upon request.

The question regarding grades is traditionally considered to be a sensitive piece of information among the Serbian student population. Students prefer to keep information about their average grade private and they even tend to lie when asked about it. To avoid receiving false answers to this question, we reduced its sensitivity load by asking students to point out the range in which their average

grade could be found. In the Serbian higher education grading system, grades are awarded on a scale from 5 to 10, with 5 being a failing grade. We decided to group average grades in four intervals: 6–7, 7–8, 8–9 and 9–10. This makes the target (i.e., dependent) variable "average grade" categorical. Consequently, we analysed the EdTech impact on average grade (AG) using the proportional odds ordinal logistic regression model:

$$\ln\left(Odd_k\left(AG_i\right)\right) = \beta_{0,k} + \beta_1 online_i + \beta_2 moodle_i + \beta_3 viber_i + \beta_4 facebook_i + \beta_5 site_i + \varepsilon_i, \quad (1)$$

where $online_i$, $moodle_i$, $viber_i$, $facebook_i$ and $site_i$ are dummy variables indicating whether a student has been exposed to the given EdTech or not, $\beta_{0,k}$ is a regression intercept, β_j represent regression slope parameters and ε_i represent random errors. Note that slope parameters are the same for all categories, while the intercept, $\beta_{0,k}$, varies across categories. In a proportional odds ordinal regression, a dependent variable is a logarithm of category deterioration odds. In our case, it translates into grade deterioration odds, i.e., the ratio of the probability that a student will get the same or worse grade, $P\left(AG_i \le k\right)$, to the probability that a student's grade will be improved, $P(AG_i > k)$:

$$Odd_k\left(AG_i\right) = \frac{P\left(AG_i \le k\right)}{P\left(AG_i > k\right)}, \quad (2)$$

where k is some grade category. The higher this ratio is, the lower the students' chances of getting better grades are, and vice versa.

As suggested by Hosmer and Lemeshow (2000), we tested the model's proportional odds assumption by using a parallel lines test, which compares the log-likelihood function of the given proportional odds model and a baseline ordinal regression model. If the parallel lines assumption is violated, the baseline ordinal regression model is used instead.

$$\ln\left(Odd_k\left(AG_i\right)\right) = \beta_{0,k} + \beta_{1,k} online_i + \beta_{2,k} moodle_i + \beta_{3,k} viber_i + \beta_{4,k} facebook_i + \beta_{5,k} site_i + \varepsilon_i \quad (3)$$

Note that in the baseline model, the slope parameters vary across categories and the odds are defined in a different way. Here, we consider the odds of not belonging to a referent category for each of the dependent variable categories. In other words, the model defines the odds as a ratio of the probability of belonging to the same group, i.e., $p(AG_i = k)$, to the probability of belonging to a chosen reference group, i.e., $p(AG_i = m)$, where *m* is some chosen referent category:

$$Odd_k(AG_i) = \frac{p(AG_i = k)}{p(AG_i = m)}. \quad (4)$$

We use the category 9–10 as the referent category. Consequently, for each student the modelled likelihood will tell us whether it is more probable that the student will have grades in the lower grade ranges (6–7, 7–8 or 8–9) or the highest possible grades (9–10). The higher this likelihood is, the lower the probability of a student having the highest grades. Note that in both models, the increase in the modelled odds indicates a deterioration of the student's performance.

By testing the statistical significance of the regression slope parameters (β_j), we examined whether students' odds of improving (or worsening) grades could be explained by exposure to some EdTech:

$$H_0 : \beta_j = 0$$

$$H_1 : \beta_j \neq 0$$

If slope parameters are statistically significant and positive, the EdTech they represent increase the chances of students' bad performance (since $e^{\beta} > 1$). Conversely, if slope parameters are statistically significant and negative, the EdTech associated with them decrease the chances of students' bad performance (since $e^{\beta} < 1$). EdTech impacts are examined separately for the total average grade (average grade of all courses the students completed) and the Business Informatics average grade (average grade of all Business Informatics courses the students completed).

The second target variable which was considered was the Business Informatics success rate (SRBI). It is a ratio of the total passed (i.e., completed) Business Informatics courses to the total number of Business Informatics courses that students took. The Faculty of Economics at the University of Belgrade allows students to attend up to 10 Business Informatics courses (some courses are elective). To analyse the EdTech impact only on the Business Informatics success rate, we used the multinomial linear regression model, since the dependent variable is continuous.

$$SRBI_i = \beta_0 + \beta_1 online_i + \beta_2 moodle_i + \beta_3 viber_i + \beta_4 facebook_i + \beta_5 site_i + \varepsilon_i \quad (5)$$

Naturally, we used the same set of regressors (i.e., the EdTech) as in the case of the previous ordinal regression. By testing the statistical significance of regression slope parameters, we examined whether students' Business Informatics success rate could be explained by their exposure to some EdTech:

$$H_0 : \beta_j = 0$$

$$H_1 : \beta_j \neq 0$$

In the case of finding a statistically significant result in any of the previous three regressions, a supplementary nonparametric test was to be carried out to strengthen our conclusions. For this purpose, we used the Mann-Whitney U test complemented with the analysis of Cohen's effect size index (Fritz et al., 2012):

$$r = \frac{|Z|}{\sqrt{N}}, \quad (6)$$

where Z represents a standardised test statistic, while N is the total sample size. The idea was to test whether the distribution of the target variable (total average grade, Business Informatics average grade or Business Informatics success rate) was the same for the students who were exposed to some EdTech and for those who were not exposed to it. If the distribution (labelled as F) of the target variable for these two groups of students proved to be the same, then the grouping variable (i.e., EdTech exposure) did not affect the target variable (i.e., students' performance). Formally, we tested the following hypotheses:

$$H_0 : F_{Yes} = F_{No}$$

$$H_1 : F_{Yes} \neq F_{No}$$

Provided this test verified the existence of the identified statistical significance, the impact of the studied EdTech on students' performance was measured by Cohen's effect size index. For $0.1 \leq r < 0.3$, the effect is weak; for $0.3 \leq r < 0.5$, the effect is moderate; for $0.5 \leq r$, the effect is strong.

The secondary goal of our research was to examine the students' attitudes towards the implemented EdTech. The research findings are presented via graphs and descriptive statistics of our survey results.

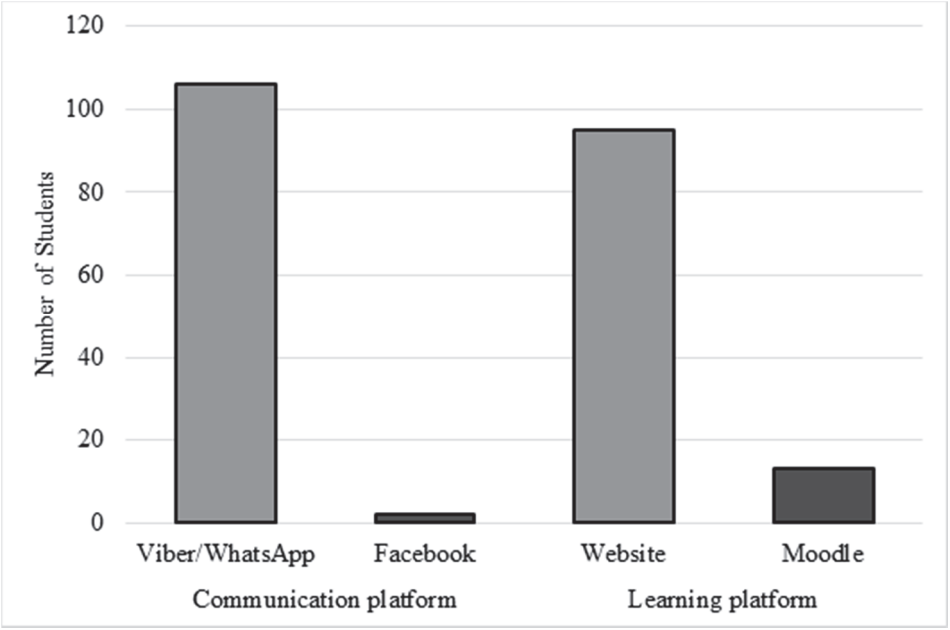
5. RESULTS

108 students (roughly 40% of the student population) voluntarily participated in our survey. The majority of these students were in their final year of studies (66.7%), while the smallest number of participants were in the second year of studies (1.8%). We first focus on examining the students' attitudes towards the utilised EdTech. We then analyse the EdTech impact on the students' performance.

5.1. Students' Attitudes towards Educational Technologies

The end users of the educational process are students, and therefore their opinions on how this process operates are very important. Keeping this in mind, in addition to the benefits of a particular EdTech, it is good to know what students think about them. We asked students to compare the learning and communication platforms used in Business Informatics courses. The results are displayed in Figure 1. In both cases, one of two alternatives is strongly preferred. Regarding the learning platforms, the vast majority of students consider the course website to be a more appealing learning platform than Moodle. One possible explanation for this result is that Moodle is a general, widely accepted learning platform, while course websites are tailor-made. Since the websites considered in this research are specifically designed for the needs of each individual course (i.e., customised), students may find them more helpful in learning a particular subject than Moodle (a more general alternative).

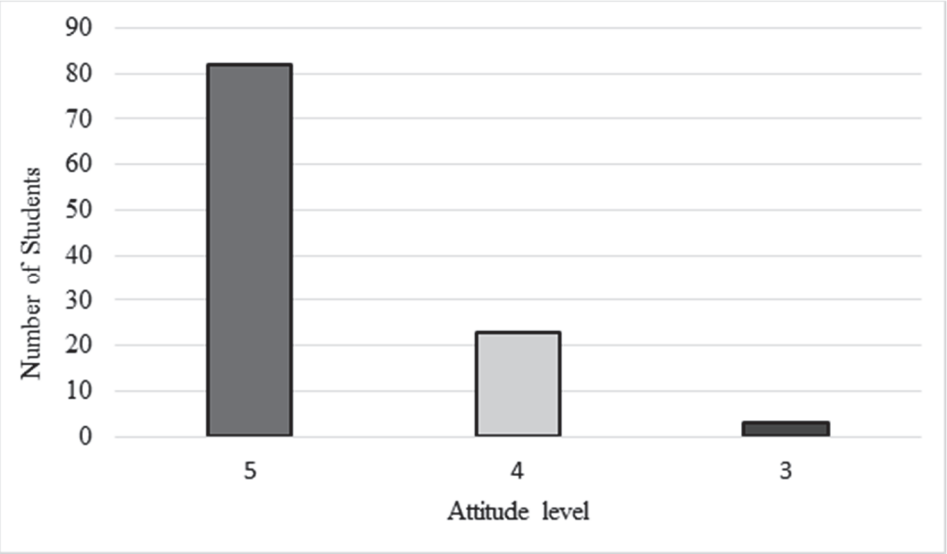
Figure 1. Students' preferred communication and learning platforms



Source: Authors' calculation

Students' preferences concerning communication platforms are shown on the left-hand side of Figure 1. The students almost unanimously selected Viber/WhatsApp as a more useful communication platform than Facebook. We anticipated this result, since teachers have constantly gained positive feedback from students regarding the idea of incorporating Viber/WhatsApp in the educational process. Figure 2 shows the distribution of students' attitudes towards the implementation of Viber and WhatsApp in the educational process. The highest level of satisfaction is associated with grade 5, while the lowest satisfaction level is represented by grade 1. The majority of students displayed the highest level of satisfaction. The average satisfaction level is high (the mean is 4.73) and the students' satisfaction does not vary too much within our sample (standard deviation is 0.5). This proves that a positive attitude is pervasive among students.

Figure 2. Students' attitude towards incorporation of Viber and WhatsApp in educational process



Source: Authors' calculation

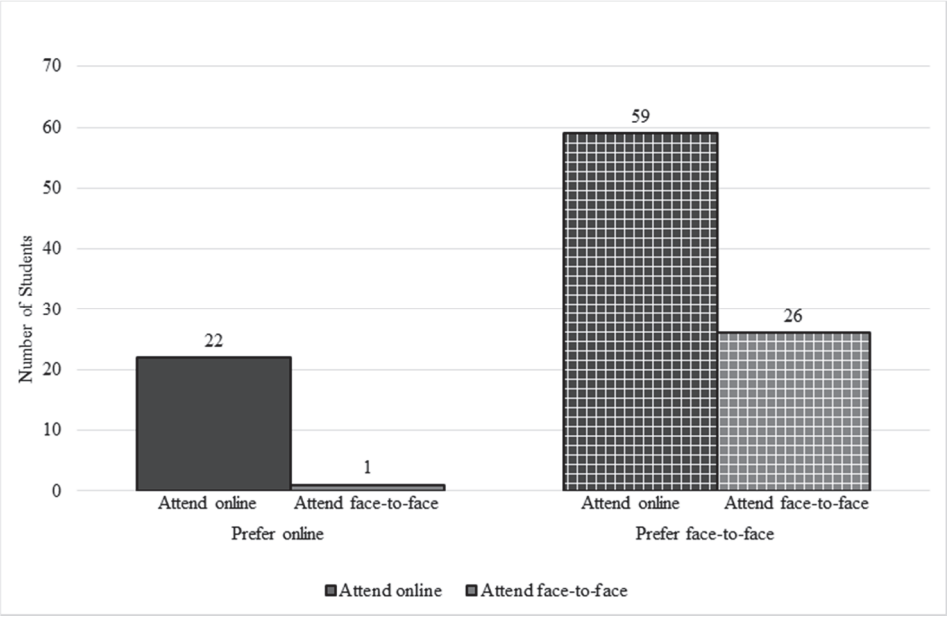
When it comes to teaching methods (online vs. face-to-face), we contrasted students' opinions and choices. More precisely, we examined whether students chose to attend classes online or face-to-face and which of these two was more efficient in their opinion. Our results are summarised in Table 1 and depicted in Figure 3. Interestingly, the majority of students chose to attend classes online (78.7%), while the majority of students considered face-to-face teaching a better teaching method regardless of the way in which they chose to attend classes. The obtained results also indicate that only 25% of the students considered online teaching as a more efficient alternative and they almost unanimously preferred attending classes online. The evidence presented implies that students generally prefer to attend classes online although they consider it to be a less efficient teaching method. One possible explanation for this could be that online education provides students with a certain dose of comfort and flexibility. It would appear that (these) Serbian students were willing to trade their learning efficiency for such benefits.

Table 1. Distribution of students by teaching method and their attitude towards it

		Used method:		Grand total (teaching method)
		Online	F2F	
Preferred method (attitude):	Online	26	1	27
	F2F	59	22	81
Grand total (attitude)		85	23	108

Source: Authors' calculation

Figure 3. Distribution of students by teaching method and their attitude towards it



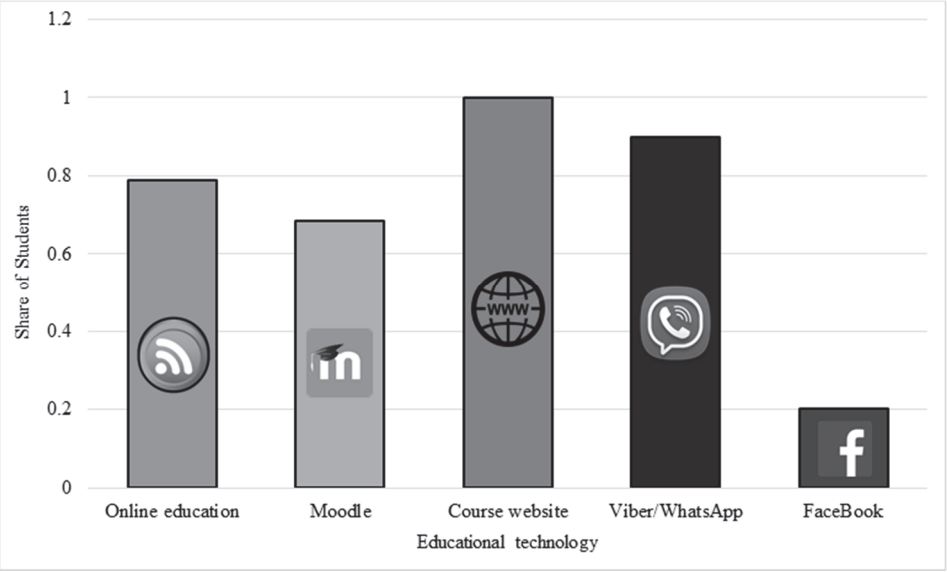
Source: Authors' calculation

5.2. Students' Performance

The primary goal of EdTech is to boost students' performance. This aspect of EdTech is also investigated in our study. Students' performance is measured via the total average grade (TAG), the average grade on Business Informatics courses (BIAG) and the success rate in the Business Informatics Department (SRBI). The examined EdTech included online teaching, Moodle, course websites, Facebook and Viber/WhatsApp. However, we were only able to examine the impact of four of them. After conducting the survey, an issue with the variable "course website"

arose. Namely, it turned out that all participating students used course websites during their learning process. Without the sub-sample of students who did not use course websites, we could not compare performance with and without this EdTech. Alternatively, we can say the utilisation of a course website is not a variable, but rather a constant within our sample. Since students' answers to the question whether they used course websites or not did not vary, we could not use it to explain the variations in students' performance. Furthermore, keeping it within a model would create a perfect multicollinearity issue (the intercept and variable "utilisation of website" are the same). Consequently, we excluded "course website" from this part of the research. The shares of the participating students who had the opportunity to use different EdTech are presented in Figure 4. The majority of the participating students were evidently open to trying the implemented EdTech. The only exception is Facebook, which was utilised by only 20% of students.

Figure 4. Shares of students who experienced different educational technologies

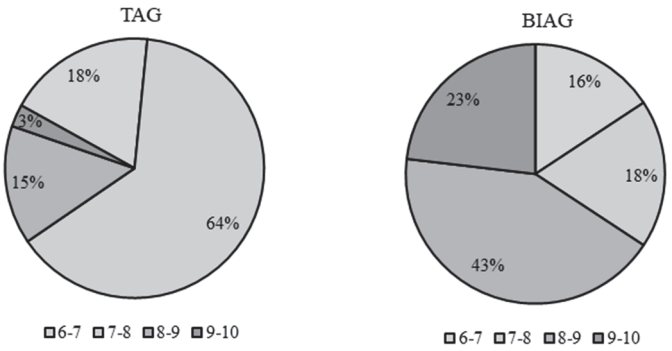


Source: Authors' calculation

The distribution of the first two performance matrices is shown in Figure 5. Interestingly, the results show that a significant number of students had better average grades in the informatics course group. This may indicate that the

EdTech used in the Business Informatics courses helped students master the course requirements more efficiently. Of course, since EdTech are not the only differentiating factors between these two groups and since they are not perfectly separated (BIAG is the subsample of the TAG), this assumption has yet to be verified.

Figure 5. Distribution of average grade (Total and Business Informatics)



Source: Authors' calculation

We first analysed the impact of EdTech on the TAG. With the exception of the teaching method, all other EdTech considered were implemented only in the Business Informatics Department. However, they still had an impact on students' TAG since the grades obtained in Business Informatics courses are included in it. This allowed us to estimate the ordinal logistic regression by regressing the TAG on four selected EdTech. The test of parallel lines asserted the proportional odds model. The results are displayed in Table 2.

Table 2: Test of parallel lines in the case of full model for TAG

-2 Log-likelihood		Chi-Square	df	p-value
Null hypothesis	Proportional odds			
55.961	49.815	6.146	8	.631

Source: Authors' calculation

The estimated model parameters are given in Table 3. Apart from the intercepts, the only statistically significant parameter at the significance level of 10% is the teaching method (i.e., online vs. face-to-face education). However, even the

teaching method is on the very edge of statistical significance. The results lead to the conclusion that the use of the other three EdTech (Moodle, Facebook and Viber/WhatsApp) cannot explain the variations in the students' TAG. Since the full model incorporates irrelevant regressors (which may affect estimates of relevant regressors), the reduced model is estimated prior to interpreting the impact of the teaching method on the TAG.

Table 3: Parameter estimates in case of full model for TAG

Variable	Estimate	Std. error	Wald	p-value
online	-0.805	0.489	2.712	0.100
moodle	0.474	0.433	1.2	0.273
viber	0.357	0.651	0.3	0.584
fb	0.301	0.493	0.373	0.541
Limit points				
[TAG = 1]	-1.460	0.839	3.030	0.082
[TAG = 2]	1.677	0.845	3.937	0.047
[TAG = 3]	3.720	0.994	13.999	0.000

Source: Authors' calculation

In the reduced model, the TAG is regressed only to the teaching method and intercept. The test of parallel lines (reported in Table 4) indicated that the proportional odds model was an appropriate framework for our analysis. This time, the statistical significance was much lower and close to the significance level of 10%.

Table 4: Test of parallel lines in the case of reduced model for TAG

-2 Log-likelihood		Chi-Square	df	p-value
Null hypothesis	Proportional odds			
22.613	18.022	4.591	2	.101

Source: Authors' calculation

Table 5 exhibits the estimates of the parameters in the reduced models. With the irrelevant regressors removed, there was a noticeable improvement of statistical significance for the variable "teaching method", which was previously on the very edge of statistical significance.

Table 5: Parameter estimates in case of reduced model for TAG

Variable	Estimate	Std. error	Wald	p-value
online	-0.823	0.483	2.907	0.088
Limit points				
[TAG = 1]	-2.154	0.479	20.177	0.000
[TAG = 2]	0.938	0.426	4.849	0.028
[TAG = 3]	2.960	0.667	19.693	0.000

Source: Authors' calculation

The negative value of the parameter next to the variable "teaching method" indicates that online teaching enhances students' chances of improving their TAGs. Attending classes online leads to a 0.44 times reduction in the likelihood of a deterioration in grades ($e^{\beta} = e^{-0.823} = 0.44$), *ceteris paribus*. Although there are other studies which found evidence in favour of online teaching efficiency, the obtained result was surprising. Given students' poor attitudes towards online teaching, previous inexperience with it and traditional benefits that face-to-face teaching provides, it was expected that students who attended classes in person would perform better. This issue is addressed later.

The intercept estimates show the chances of grade deterioration for the students who attend classes in person (i.e., face-to-face teaching). The intercepts vary from group to group, thus indicating that different groups of students who attend classes in person have different chances of deteriorating and improving their grades. The chances of grade deterioration for the students who attend classes in person are the lowest among the students who have the lowest grades. In other words, face-to-face teaching is the most beneficial for the students with the lowest grades. The chances of grade deterioration during face-to-face teaching are the highest among students who have high grades. In other words, the better the student, the less face-to-face teaching contributes to their performance.

Table 6: Test of parallel lines in the case of full model for BIAG

-2 Log-likelihood		Chi-Square	df	p-value
Null hypothesis	Proportional odds			
72.655	55.795	16.861	8	0.032

Source: Authors' calculation

Our results suggest that learning and teaching platforms do not affect students' performance as measured via TAG. We examined their effect on Business Informatics courses, i.e., on the students' BIAG, where they are directly implemented. To test whether the proportional odds ordinal logistic regression is an appropriate framework for this analysis, we conducted the test of parallel lines. The test results presented in Table 6 indicate that this is not the case. Consequently, the impact of the utilised EdTech on BIAG was modelled with the baseline ordinal logistic regression model.

Table 7: Parameter estimates in the case of full model for BIAG (reference category: 9–10)

BIAG	Variable	Estimate	Std. error	Wald	p-value
6–7	Intercept	-0.384	1.256	0.094	0.759
	online	1.158	0.770	2.259	0.133
	moodle	-0.784	0.687	1.303	0.254
	viber	-0.521	1.073	0.236	0.627
	fb	0.819	0.869	0.890	0.346
7–8	Intercept	-1.533	1.471	1.086	0.297
	online	2.695	1.116	5.831	0.016
	moodle	0.186	0.727	0.065	0.798
	viber	-1.272	0.963	1.744	0.187
	fb	0.507	0.873	0.337	0.562
8–9	Intercept	-1.062	1.210	0.770	0.380
	online	1.265	0.571	4.903	0.027
	moodle	0.010	0.579	0.000	0.987
	viber	0.691	1.055	0.430	0.512
	fb	0.719	0.733	0.963	0.326

Source: Authors' calculation

The estimated parameters in the case of the full model for the BIAG are given in Table 7. Once again, we have the situation in which the teaching method is the only EdTech with a significant impact. It is significant in two out of three equations. However, even in the first equation it is close to statistical significance. The test's failure to recognise its significance may be due to the presence of the

irrelevant regressors. The other three utilised EdTech (Moodle, Facebook and Viber/WhatsApp) cannot explain the variations in the students' BIAG. Although the participating students showed a high level of satisfaction with the utilised EdTech, their implementation in the educational process did not help the students improve their grades.

Before interpreting the significant parameters, the estimated full model was gradually reduced until the final reduced model with statistically significant parameters alone was obtained. The estimates of its parameters are presented in Table 8. After the impact of the irrelevant regressors is excluded, the teaching method proves to have a statistically significant impact in all three equations. In contrast to the results obtained for the TAG, in this case, online teaching had a positive impact on the modelled odds ratio.

Table 8: Parameter estimates in the case of reduced model for BIAG (reference category: 9–10)

BIAG	Variable	Estimate	Std. error	Wald	p-value
6–7	Intercept	-1.299	0.651	3.979	0.046
	online	1.299	0.753	2.977	0.084
7–8	Intercept	-2.398	1.044	5.271	0.022
	online	2.703	1.102	6.015	0.014
8–9	Intercept	-0.318	0.465	0.470	0.493
	online	1.317	0.560	5.530	0.019

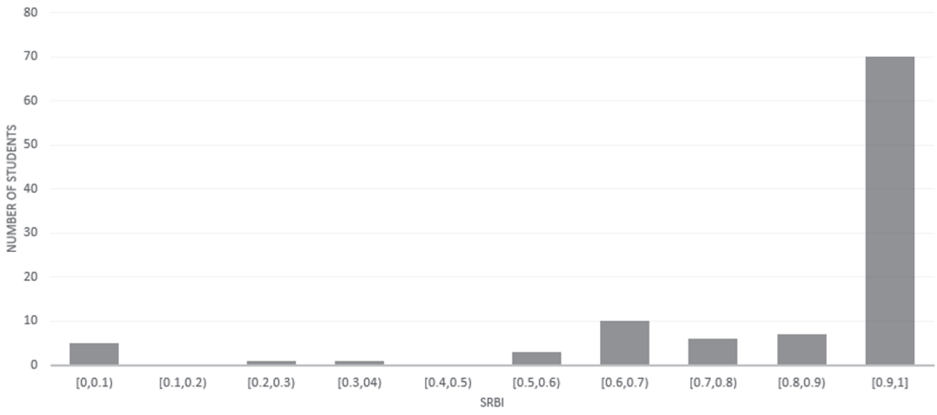
Source: Authors' calculation

In all three equations, the estimated slope parameter was positive. This indicates that attending classes online increases the chances of not getting the highest grade in Business Informatics courses for each group of students. The impact of online teaching on this likelihood was the highest for the students who had a BIAG between 7 and 8. For these students, attending classes online resulted in an almost 15-fold increase in the likelihood of not getting the highest grade in Business Informatics courses ($e^{\beta} = e^{2.703} = 14.929$), *ceteris paribus*. The impact of online teaching on the remaining two groups of students (6–7 and 8–9) was almost the same. In their case, attending classes online led to an almost 3.5 times increase in

the likelihood of not getting the highest grade , *ceteris paribus*. The results obtained in this part of our research are consistent with the findings of the other strand of the current literature.

The intercept estimates show the chances of not getting the highest grades for each group of students who attended classes in person. The students from category 7–8 had the highest likelihood of getting the highest grades (i.e., the lowest likelihood of not getting them) when attending classes in person. This indicates that they benefited the most from face-to-face teaching in Business Informatics courses. Underachievers (students from group 6–7) also felt the benefits of face-to-face teaching, given that their intercept was negative and statistically significant. Students from category 8–9 did not have statistically significant benefits from attending classes in person. However, some small and insignificant benefit still existed since the obtained point estimate was negative.

Figure 6. Distribution of students by their SRBI



Source: Authors' calculation

As the final performance metric, we considered the students' success rate in Business Informatics courses (SRBI). Survey participants typically attended 4 courses (the mean is 3.68 and the median is 4) while only 2 students decided to attend all 10 available Business Informatics courses. When it comes to their success in mastering these courses, the distribution of SRBI is depicted in Figure 6. The majority of 63% were able to pass all courses they attended (SRBI of 1).

The lowest success rate (0) was observed in just 5 cases. In addition, an average SRBI of 0.88, along with a median of 1 and a standard deviation of 0.26, also speaks in favour of excellent student performance in Business Informatics courses. The question remains whether the utilised EdTech had something to do with these students' performance in Business Informatics courses.

Since the success rate is a continuous random variable, here we fitted the linear regression model with the SRBI as a dependent variable and used EdTech as regressors. The estimated regression parameters are displayed in Table 9. Once again, we can observe that all utilised EdTech, with the exception of online teaching, did not have a significant impact on students' performance. We removed them from the model by estimating the reduced model with only significant parameters. The estimates of the reduced model are presented in Table 10.

Table 9: Parameter estimates in the case of full model for SRBI

Variable	Estimate	Std. error	t	p-value
Intercept	1.061	0.111	9.577	0.000
online	-0.131	0.065	-2.017	0.046
moodle	-0.038	0.057	-0.663	0.509
viber	-0.059	0.089	-0.661	0.510
fb	-0.001	0.067	-0.013	0.989

Source: Authors' calculation

The estimated slope parameter in the reduced model is statistically significant and negative. This indicates that online teaching had a negative impact on students' success rate. By attending classes online, students reduced their SRBI by 0.127, *ceteris paribus*. When it comes to the intercept, it was once again associated with the performance in face-to-face teaching. The students who attended classes in person had an average SRBI of 0.978, *ceteris paribus*. This success rate is high and favours face-to-face teaching. Thus, based on our results, face-to-face teaching seems to have had a positive impact on both analysed students' performance metrics.

Table 10: Parameter estimates in case of reduced model for SRBI

Variable	Estimate	Std. error	t	p-value
Intercept	0.978	0.056	17.425	0
online	-0.127	0.063	-2	0.048

Source: Authors' calculation

Finally, we display the statistical properties of the estimated final reduced model. Based on the F-test, the whole regression is statistically significant. The results presented in Table 11 imply that utilisation of the teaching method can explain 3.8% of the variations in students' success rates. When it comes to heteroscedasticity, autocorrelation and normality diagnostics, the usual statistical tests are reported in Tables 11 and 12. There is no heteroscedasticity (based on the Breusch–Pagan and Goldfeld–Quandt tests) nor autocorrelation (the Durbin–Watson test for order 1 and the Box–Ljung test for orders up to 10).

Table 11: Results of F-test for the model's statistical significance along with usual statistical heteroscedasticity, autocorrelation and normality diagnostics

	R^2 (F-test)	Jarque–Bera	Breusch–Pagan	Goldfeld–Quandt	Durbin–Watson
Statistic	0.038	152.664	.148	.904	2.228
p-value	.048	.000	.700	.637	- [a]

a. Critical values (intercept + k=1, n=100): [2.438, 2.478]

Source: Authors' calculation

Table 12: Results of Box–Ljung test

Lag	1	2	3	4	5	6	7	8	9	10
BL	1.406	2.864	2.929	3.311	3.490	4.996	10.596	10.760	12.898	13.075
p-value	.236	.239	.403	.507	.625	.544	.157	.216	.167	.219

Source: Authors' calculation

The only violated assumption is the assumption of normality. Under these circumstances, in order to be able to rely on the results of the statistical tests, we bootstrapped the estimated p-values. The bootstrap results were based on 10,000

bootstrap samples, and they are presented in Table 13. The simulated p-value is still below the significance level of 10%, thus indicating that the statistically significant teaching method can explain the variations in the students' SRBI.

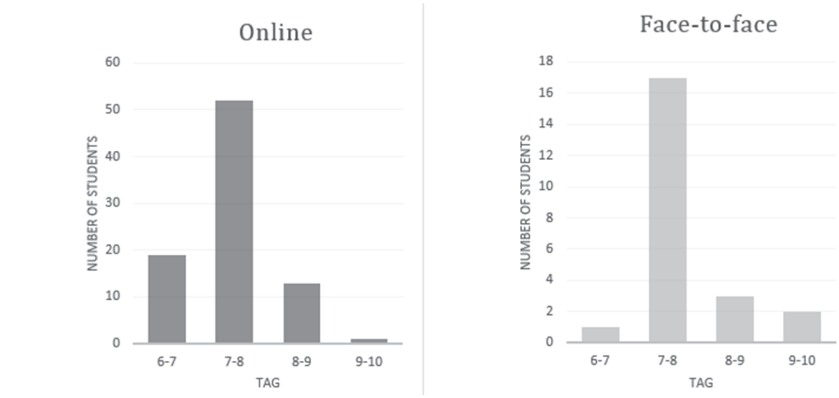
Table 13: Bootstrapped parameter estimates in the case of reduced model for SRBI

Variable	Estimate	Std. error	p-value	90% Confidence interval	
Intercept	0.978	0.061	0	0.874	1.074
online	-0.127	0.067	0.055	-0.235	-0.015

Source: Authors' calculation

In all our models, one EdTech in particular displays a statistically significant impact on the students' performance. In order to verify that result, the nonparametric Mann-Whitney U was carried out. Before the test itself, the distributions of all three performance metrics for online and face-to-face attending students considered were visually analysed in Figures 7 to 9. In each of the three figures, the performance metrics displayed a different distribution for the online and face-to-face attending students. Consider, for example, Figure 8. While the majority of the students who attended classes in person ended up with the BIAG between 9 and 10 and a small number of them ended up with lower grades, this was not the case with the students attending online. Faced with this evidence, we conducted the Mann-Whitney U test accompanied by Cohen's effect size diagnostics. The results are presented in Table 14.

Figure 7. Distribution of Total average grades by teaching method

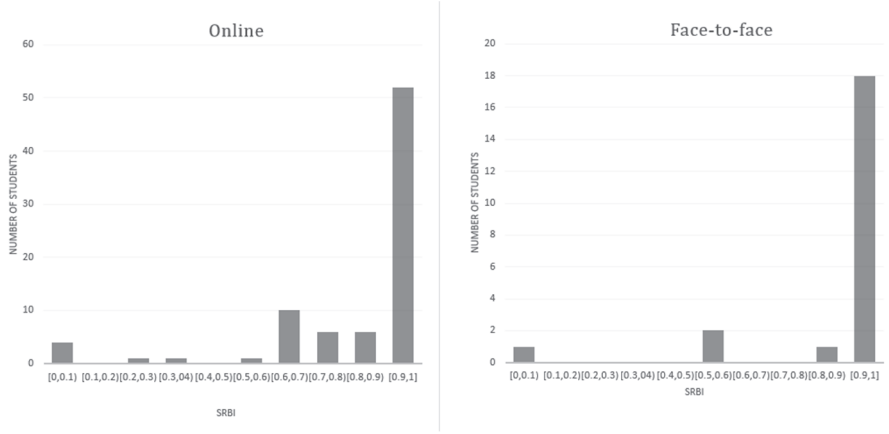


Source: Authors' calculation

Figure 8. Distribution of BI average grade by teaching method

Source: Authors' calculation

Figure 9. Distribution of students' success rates by teaching method



Source: Authors' calculation

In all three cases considered, the Mann-Whitney U test reported a statistically significant impact of the teaching method on the students' performance. Also, the size of this impact was rather small in all three cases based on Cohen's index. However, in the case of SRBI, it was close to the upper bound of 0.3, thus hinting that in some broader research it may show some moderate impact on this performance metric.

Table 14: Results of Mann-Whitney U test for three performance metrics

	TAG	BIAG	SRBI
Mann-Whitney U	779.000	636.500	603.000
Z	-1.744	-2.697	-2.747
Cohen's r	.16782	.25952	.26433
p-value	.081	.006	.005

Source: Authors' calculation

6. CONCLUSION

We conducted an experiment aiming to examine whether the three groups of educational technologies utilised the most during the COVID-19 pandemic affected students' performance (the average grade and success rate). Our paper considered the following EdTech: learning platforms (Moodle and customised

course websites), communication platforms (Facebook and Viber/WhatsApp) and online teaching. We explored their effects on a sample of 108 volunteer students from the Department of Business Informatics at the Faculty of Economics, University of Belgrade.

Our research has shown that students share a high level of affection towards the implemented EdTech. We were also able to identify some of the students' preferences. Students strongly preferred the customised course websites to a more general and widely used Moodle platform. The customised course website was the only EdTech used by all the students in our sample. We have also found that students strongly preferred Viber and WhatsApp to Facebook as communication platforms. Students' level of satisfaction with smartphone messaging (chatting) apps was very high, while the Facebook group was mainly neglected. Furthermore, we have found that the vast majority of students consider face-to-face teaching more efficient than online teaching. However, when it comes to class attendance, most students decided to choose online teaching although they themselves recognised that it is a less efficient learning method. One possible explanation for this result could be that these students were willing to consciously trade their learning efficiency for the comfort of online learning. The factors contributing to this are yet to be explored in some broader research.

Using linear and ordinal regressions, we demonstrated that the use of learning and communication platforms in teaching does not lead to a significant improvement in students' performance. We have found that the teaching method (online vs. face-to-face) is statistically significant and can explain variations in students' performance. Attending classes online boosts students' chances of improving their total average grade, while it worsens their chances of improving their average grade and their success rate in Business Informatics courses. In explaining this we suggest that the nature of the courses might influence the observed difference in the impact of online teaching on students' performance. Most courses in the field of economics are conceptualised as oral presentations of theoretical and empirical facts. On the other hand, informatics courses require practical demonstrations (e.g., working with some software, programming, web design, database editing). Active contact with students and control of their in-class performance is essential under these circumstances. There are also some student-oriented drawbacks. Some students may not possess the necessary

resources to follow informatics courses from their homes (e.g., some software). In addition, it may be difficult for inexperienced students to follow the professor and repeat the same procedure on their own computers at the same time. Consequently, face-to-face teaching might be more relevant for informatics than for classical economics courses. From the students' perspective, face-to-face teaching is recognised as the most beneficial for underachievers (average grade 6–7) and low-to-average-achievers (average grade 7–8). The Mann-Whitney U test provided support for previous claims, confirming that the analysed impacts exist, but are of minor significance.

Finally, we also acknowledge the limitations of this study and identify avenues for future research in this domain. Our study was organised as an anonymous pilot experiment. We decided to use the shortest possible questionnaire and collect the minimal set of information necessary for us to conduct the research. In this way, we obtained just enough data to gain a preliminary picture of the impact of the utilised EdTech on students' performance as a preparation for a wider study that we would like to conduct on this topic. In addition, since students are reluctant to participate in long surveys, one of the goals of giving a short questionnaire was to increase the number of students willing to participate. Finally, the absence of personal and demographic questions contributed to the anonymity of the survey and the establishment of a sense of security and trust among students with the aim of obtaining as honest answers as possible. Unfortunately, the negative side of this trade-off is that we lost controlling variables for our regression models. However, we would like to address this issue once we are able to conduct broader research on this topic by examining EdTech on a larger sample of students and faculties. At this point, a general impression is that communication and learning platforms can be helpful for all students and that overall students' performance does not directly depend on the platform used. In our opinion, it is noticeable that they are all good additions to the teaching process, but that no platform can replace high-quality live teaching for now. We hope that this research will motivate other researchers (from the fields of both economics and pedagogy) to continue in our footsteps and experiment with EdTech, which could prove to be beneficial for Serbian higher education and new generations of students.

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