EVALUATION OF ONLINE TEACHING OF MATHEMATICS AND STATISTICS AND THE RESULTS OF UNIVERSITY STUDENTS

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ABSTRACT

We analyze here the online and face-to-face teaching of mathematics and statistics at the university level and compare the results of students from two courses of applied mathematics. We examine the influence of online teaching on the performance of students with the help of grades from five consecutive years. A questionnaire on satisfaction with online teaching was also administered to the students. We show that online teaching has a positive impact on the successful results of students if we provide them with video recordings created for all lectures and seminars. We present some opinions of students on this type of teaching.

Keywords: *online teaching, mathematics, questionnaires, linear regression, success at exams, student satisfaction*

INTRODUCTION

During the Covid-19 pandemic, schools in many countries were forced to switch from traditional teaching to online teaching due to schools closing. As probably at many universities all around the world, and not only universities, we asked ourselves the question of how to deal with online teaching. The main aim of our study was to find out how students react to online teaching, how it affects their performance, how satisfied they are and how they cope with the change in teaching. Last but not least, the question arises as to whether it would not be appropriate to include some positively evaluated elements of online education in standard education as well.

LITERATURE REVIEW

While during the Covid-19 pandemic online teaching and online education became a highly relevant issue, online teaching is nothing new to the world of education. There are a large number of books and articles concerning online teaching spanning a long period, as seen below. Conrad (2004) contains reflections of instructors on their first online teaching experiences; McShane (2004) explores the integration of face-to-face and online teaching, including the experiences of university lecturers; Kim et al. (2005) showed the perceptions of online learning, including its benefits, challenges, and suggestions that students found the online experience valuable; and Ke (2010) examined online teaching, especially cognitive and social presence for adult students, and concluded that high social presence and self-disclosure of teachers is required.

More recently, Quinn & Kennedy-Clark (2015) studied the adoption of online lecturing for improved learning in with the integration of video lectures and students' reactions to them. Kauffman (2015) studied the predictive factors of student success in and satisfaction with online learning and identified particular characteristics that contribute to online success versus failure while documenting that online teaching can lead to success if there is a good interaction between learner, instructor,

and technology. McGee et al. (2017) examined the experiences of online instructors. Bettinger and Loeb (2017) researched the promises and pitfalls of online education, listing and discussing positives and negatives of online education. Rose (2018) investigated the key attributes of effective online teachers in New Zealand and Australia and recommended avoiding a didactic approach, varying the pedagogy, or the using productive failure. Yang et al. (2018) discussed online collaboration in a large university class that supported quality teaching, focusing on blending of standard teaching with online elements. Bauer (2019) researched translating a successful lecture into an online course and provided a list of positives and negatives, claiming that online teaching is not for everyone. Elsewhere, Martin et al. (2019) evaluated faculty online teaching practices, course design, assessment and evaluation, and facilitation through instructor interviews and their experiences.

Online university teaching in Rapanta et al. (2020) may serve as the most recent source of information and educational advice concerning online teaching. They interviewed experts on online teaching. The advantages, limitations, and recommendations of online learning in Pakistan at a medical university are discussed in Mukhtar et al. (2020), who recommended reduced cognitive lead and increased interactivities. Jesuiya and Priyadarshani (2020) inspected the impact of the online teaching and the learning process in Sri Lanka and showed that 85% of students are satisfied with online learning but 50% have technical problems. Aduba and Mayowa-Adebara (2020) evaluated online platforms used for teaching and learning and recommended the use of social media platforms. Jayara (2020) researched the advantages and disadvantages of online teaching in medical education. Langford and Damşa (2020) discussed online teaching in Norway and included experience and advice.

Further, Hodges et al. (2020) was concerned with the difference between emergency remote teaching and online learning, Giatman et al. (2020) showed that online learning quality control in Indonesia were necessary to improve the technological approach to education, increase the quality of instructional learning, and provide credit subsidies for students.; König et al. (2020), emphasized that for successfully adapting to online teaching, the IT competencies of teachers are instrumental. The challenges and innovations of online teaching are discussed in Zhu et al. (2020). They showed that online learning is a good substitute for face-to-face learning. Chen et al. (2020) also analyzed user satisfaction with online education platforms in China. Darby (2019) discussed methods on how to be a better online teacher. Lazarevic and Bentz (2020) studied student perception and the impact of stress in online and face-to-face learning at a university in the USA.

Then there are articles dealing with lecture capture contribution to the development of a community of inquiry in online learning. Wood et al. (2021) found there is no substantial increase in cognitive, social, or teaching presence for online students. Jiang et al. (2021) discussed tips and practices for teaching medical students online, and García-Peñalvo et al. (2021) made recommendations for mandatory online assessments. Wang et al. (2021) provided strategies for online teachers transitioning to online teaching. Mittal et al. (2021) compared two teacher surveys with a time gap between them to present a unified perspective on the adoption of online teaching. McCarthy et al. (2021) evaluated transitioning to online teaching through a phenomenological analysis of social work educator perspectives by providing interviews with instructors from various schools across the United States. Modality motivation, selection effects, and motivational differences in students who take courses online, including demographics, were studied in McPartlan et al. (2021).

Mahmood (2021) presented instructional strategies for online teaching, while Ansari et al. (2021) examined the perception of online teaching and learning among health sciences students in Saudi Arabia and Morreale et al. (2021) discussed online teaching challenges and opportunities. Gobbi and Rovea (2020) critically analyzed online teaching and did not recommend it for the near future. Musunuru et al. (2021) used randomized controlled studies to compare traditional lectures versus online modules at a biochemistry course, which showed no difference in students' performance whether online sessions or prerecorded videos were used.

There were already several similar studies of evaluations of student preferences concerning comparison of online and face-to-face teaching or just

online teaching, such as Oliver (2000). Mahoney et al. (2005) assessed the design and evaluation of an online teaching strategy in an undergraduate psychiatric nursing course while Harrington and Reasons (2005) considered online student evaluation of teaching for distance education, and Gamliel and Davidovitz (2005) surveyed online versus traditional teaching evaluation in online education.

The future of online teaching and learning in higher education is discussed in Kim and Bonk (2006), including the experiences of teachers and administrators. Siebert et al. (2006) evaluated teaching clinical social work skills primarily online, and students reported increased skills when studying online but course scores are similar. A comparative analysis by Rovai et al. (2006) of student evaluations of teaching over four academic years in the virtual and traditional classrooms found more negative perceptions of students towards online courses. The development and validation of the student evaluation of online teaching effectiveness are researched in Bangert (2008). Khorsandi et al. (2012) explored online versus traditional teaching evaluation in a cross-sectional study, and Weng et al. (2014) analyzed the theory of planned behavior and online learning teaching evaluation in Taiwan.

More recently there are student learning evaluations during the pandemic, such as Lee et al. (2021), which showed that students coped well with the transition to online leaning; Walker and Koralesky (2021) studied student and instructor perceptions of engagement, and behavioral responses and cognitive components, after the rapid online transition of teaching at a Canadian university; and Maison et al. (2021) explored perceptions, attitudes, and student awareness in working on online tasks and showed that students were able to adapt much better than expected.

BACKGROUND

In our article we focus on two courses of applied mathematics, probability, and statistics (hereinafter referred to as M1 and M2) taught online using distance learning due to the Covid-19 pandemic during the 2020/21 winter semester at the Faculty of Business and Economics at Mendel University in Brno. Each course was taught by a different lecturer (the two coauthors of this paper). The M1 course dealt with differential and integral calculus and linear algebra, the M2 course followed up on the previous course and covered infinite series, differential equations, and the basics of probability and statistics. Both courses are taught for the bachelor's degree, the M1 course in the 1st year and the M2 course in the 2nd year of study.

In both courses, we used Microsoft Teams to keep students connected in the virtual classroom. Students were provided with presentations of lectures and seminars, which contained the relevant theory together with explanatory examples. M1 course presentations were created using the Beamer LaTeX document class; PowerPoint was used for M2 course presentations. The teacher commented on the presentations with verbal explanations. For students to be able to see the procedure for solving examples step-by-step on their computer, the teachers used a Wacom graphics tablet and software that enables graphical work with the whiteboard, which in our case was Microsoft OneNote for creating notes, which helped us communicate with students and illustrate the methods. However, the online teaching of the M1 and M2 courses took place in different ways.

The M1 course was taught through MS Teams directly, exactly at the time scheduled, i.e., synchronously. The teacher shared his lecture presentations with the connected students on the screen using Microsoft OneNote and commented on them verbally, writing any comments needed via a tablet in a window next to the presentation. During the exercises, the teacher calculated the examples, wrote down their procedure with a pen on the OneNote form, commented on the individual steps, and used different colors and thicknesses of the pen to emphasize the text. At the same time, he continuously asked students about partial steps and intermediate results during the calculation. All these online lectures and seminar meetings were recorded in the MS Teams platform. The videos were then saved in the MS Teams channel of the ongoing course to help students review, understand more, and remember the presented material. During the online meetings students could ask questions about the issues being discussed.

The online teaching of the M2 course took place asynchronously, in which all the lectures and seminars were recorded in advance. The teacher used OBS Studio (Open Broadcaster Software)

to create videos as well as a graphics tablet and Microsoft OneNote. He wrote notes in his presentations, directly solved examples, and commented on everything by speaking, the sound also being recorded. The videos created in this way were made available to students for download on the MS Teams platform. Then students watched these video recordings at the scheduled time or at any other time they wanted. A consultation meeting with the lecturer was held in MS Teams for each lecture and each seminar, so the students could discuss with the teacher what they learned from the recorded materials and ask him about anything they didn't understand in the videos. In addition, students could replay the recordings as many times as they wished.

In both courses the tests and final exams were performed through MS Teams meetings. For identification and supervision, the students needed active cameras and microphones suitably set up, so the cameras captured their faces, writing boards, and the monitors of their computers. Students received test assignments or exams by email just before the start (for the M2 course) or the assignment was shared directly on the screen (for the M1 course). Teachers watched students on the screen during the exam and could see if they were cheating. Then the students uploaded photocopies of their work in the form of PDF files to the submission pane for correction by teacher.

It should be noted that during offline teaching both mathematics courses were taught in the traditional face-to-face way. The lecturers showed the same presentations as online teaching and these were commented on and supplemented by solved examples. The examples related to the previous lecture were solved in the seminars. Students were encouraged to go to the board to solve a given example. Any errors by the student were corrected and commented on by the teacher, who also briefly explained the procedure necessary for the calculation at the beginning of the exercise. Written work for tests and exams took place in face-to-face teaching exclusively in writing.

MATERIAL AND METHODS

These two courses were delivered by us for at least five academic years in a relatively stable form and their content changed only slightly during that time. Thus, we were able to collect student grades of these five consecutive years and use them for our computations. It should be emphasized that both courses were held online only in the 2020/21 academic year and in normal face-to-face form for the previous four years.

In our research we collected the final grades of students from both courses, which are normally named A to F, but for computation we numbered them 1 to 6, respectively. An F, or 6, mark means the student failed the exam.

The FF index was computed as

$$FF = 100 \cdot \frac{number\ of\ all\ F\ grades}{number\ of\ students}$$

For our regression model the significance level was set to 5% and Statistica software used for statistical computation and Excel software for drawing regression graphs. The data used in this article were collected by us. We analyzed the grades of the two courses mentioned above over five consecutive academic years, starting with 2016/17 up to 2020/21.

Also, we sent a questionnaire to the students at the end of the online courses in the 2020/21winter semester, from which answers were gathered. The purpose of the questionnaire was to find the opinions of students on the form of online teaching. For the same reason, the answers from student evaluations of both courses, which are performed regularly every semester throughout the university, were also analyzed in 2020/21.

RESULTS

Comparison of Students Final Grades

The total number of students who completed both courses was 440 (288 for M1 and 152 for M2) over a period of five years. In the end, most students received D or E grades. The minimum level for successful final evaluations of both courses was changed and increased from 50% to 60% due to faculty regulations in the 2020/21 winter semester. Concerning the M1, course and unlike previous years, not only did the level of minimum successful evaluation increase but also other activities such as homework, an individual project, and a test that may have been included in the final evaluation.

Despite this fact, student performance was better in the online form of teaching than traditional.

The grades of students were recomputed as averages, as seen in Tables 1 and 2. In these tables, only those students were included who fulfilled all conditions for the final exam and were able to sit the exam, i.e., students with a successfully passed test during the semester (test results over 50%). There were also a number of other students who were not accepted for the exams, since they did not meet all the requirements.

Table 1. Average M1 Grades over Five Years

M1	A	B	C	D	E	F
2016/17	6.87	10.34	13.79	13.79	37.93	17.24
2017/18	5.56	11.11	16.67	33.33	11.11	22.22
2018/19	13.79	13.79	13.79	10.34	44.83	3.45
2019/20	9.52	9.52	9.52	9.52	52.38	9.52
2020/21	4.35	0	19.57	19.57	39.13	17.39

Table 2. Average M2 Grades over Five Years

M2	A	B	C	D	E	F
2016/17	5.56	0	11.11	33.33	39.89	11.11
2017/18	11.11	5.56	5.56	33.33	27.78	16.67
2018/19	0	13.33	13.33	33.33	33.33	6.67
2019/20	10	5	0	30	25	30
2020/21	3.57	3.57	25	21.43	32.14	14.29

We analyzed student success in exams for the selected five years, as seen in Table 3, with one column for M1, and another for M2. There is a weighted average of grades for the first column, Average Grade. The next column shows the percentage of students who were successful in exams, meaning their final grade was A to E (1 to 5). There were 206 such students for both groups (123 in M1 and 83 in M2). The next column (Not Admitted) contains the percentage of students who did not meet the conditions required for admission to the exams. The last column shows the index that indicates how often students resat exams, recomputed on averages (a higher number means more frequent resits). From these data we see that in general M2 course students resat their exams more often than M1students. In particular, for both courses students resat the exams more often during the online form of learning in the 2020/21 academic year.

There is an interesting result in that for all those years and for both courses the final grade was still around a 4 (or D). Moreover, it can be seen that in 2020/21, which was held online, students achieved somewhat better results than in the other four years, meaning that not just grades but both admission to the exams and success in the exams were up. The results of both courses taught online are similar, although the teaching took place in a different way. Also, the success of M2 students was higher than those of M1, which is probably because M1 students were in their first year of study and in the M2 course there were only selected students who had successfully completed the previous M1 course, and they were already more experienced students in terms of their university studies.

In Table 4 there are similar trends to Table 3 but recomputed as weighted averages for both courses together.

Figures 1–3 show graphs for final exam success by year with the linear trend for M1 (see Figure 1), for M2 (see Figure 2), and for both courses (see Figure 3).

We computed the regression lines using Statistica software, which are drawn on all three

Table 3. A Comparison of Average Grades, Exam Success, Not Admitted to Exams, and Exams Repeated for M1 and M2

	M1				M2			
	Average Grade	Exam Success	Not Admitted	Exams Repeated	Average Grade	Exam Success	Not Admitted	Exams Repeated
2016/17	4.17	38.71	53.26	37.09	4.33	51.61	41.94	61.29
2017/18	4	31.81	59.09	38.64	4.11	48.39	41.94	38.7
2018/19	3.69	47.46	50.85	30.5	4.07	58.33	37.5	37.5
2019/20	4.12	36.54	59.62	32.69	4.45	43.75	37.5	75.0
2020/21	4.41	53.52	35.21	60.56	4.18	70.59	17.65	82.35

Table 4. Average Grades, Success, Nonadmission to Exams, Exam Resits for both Course

M1+M2	Average Grade	Exam Success	Not Admitted	Exams Repeated
2016/17	4.23	43.01	49.46	45.16
2017/18	4.06	38.67	52	38.67
2018/19	3.82	50.6	46.99	32.53
2019/20	4.29	39.29	51.19	48.8
2020/21	4.32	59.04	29.52	67.61

*Figure 1. Graph Success by Year for M1 with Linear Trend; Regression Line 3.435*x-6890.222*

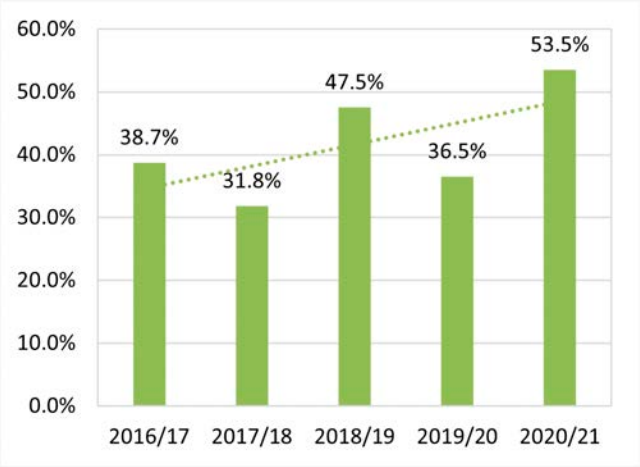
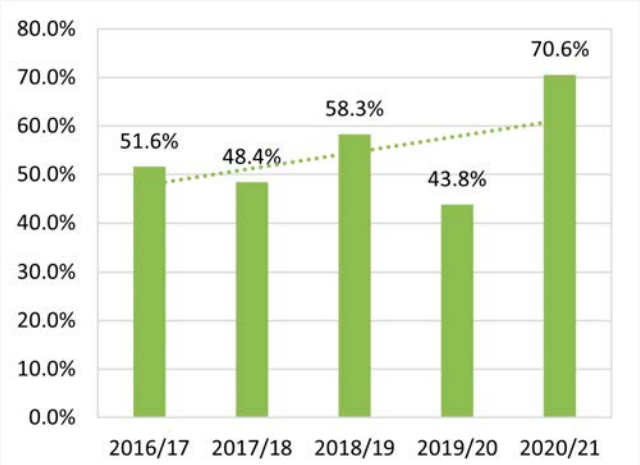


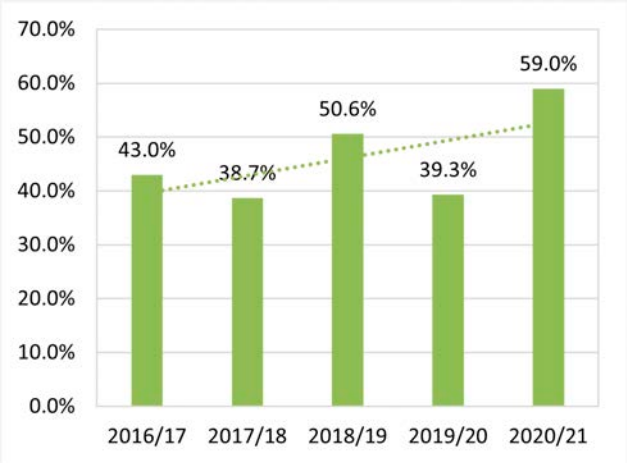
*Figure 2. Graph Success by Year for M2 with Linear Trend; Regression Line 3.332*x-6669.442*



figures (with the relevant formulae) and are rising for all three cases. The coefficients of the regression lines are positive in the range of 3.268–3.435.

Figure 4 shows the linear trend for the previous four years, for which teaching had taken place face-to-face and not online. The coefficient of this

*Figure 3. Graph Success by Year for both M1 and M2 with Linear Trend; Regression Line 3.268*x-6548.702*



regression line is 0.077, which is close to zero; this linear trend is therefore almost constant. Comparing Figure 3 and Figure 4 shows how strong the influence of online teaching was on the performance of students in Year 5. It is interesting that this shows an improvement and not a deterioration. It is quite obvious that the results would be very similar for Figure 1 and Figure 2 without having to provide a graph for the previous four years for each.

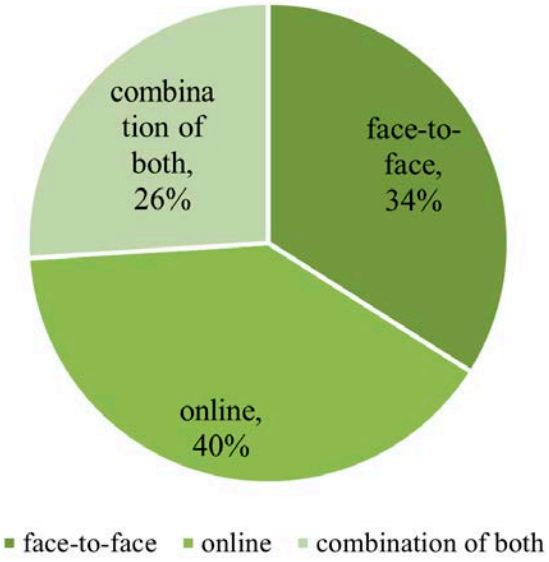
*Figure 4. Graph Success by Year for both M1 and M2 for the Previous Four Years with Linear Trend; Regression Line 0.077*x-112.455*

Results of the Questionnaire

At the end of the 2020/21 winter semester we developed a questionnaire concerning online teaching, which students of both courses could answer voluntarily. Almost 55% of the students who took part in exams responded to the

questionnaire, with 54% of respondents answering for M1 and 46% for M2. In terms of gender, the vast majority of students in these subjects were men. The questionnaire consisted of 20 questions, half of which had multiple-choice answers, with students writing their answers to the remaining open-ended questions. The questionnaire included questions concerning students' views on the online teaching of both subjects, an evaluation of the general advantages and disadvantages of this form of teaching, its comparison with traditional contact teaching, and also whether online mathematics teaching is appropriate for this subject. In addition to their opinions on the teaching, the students were also asked to assess the online exam.

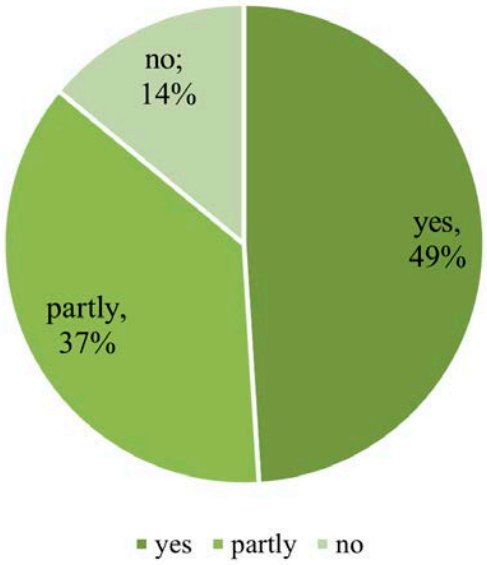
Figure 5. Which Type of Teaching Do You Prefer?



From the results obtained from the questionnaire, most of the students did not prefer face-to-face teaching to online teaching, as 40% of students preferred online learning and 34% preferred face-to-face learning (see Figure 5) and did not find a significant difference between these two forms of teaching. A total of 49% of students considered online teaching to be a complete substitute for face-to-face teaching and 37% considered it a partial substitute, as shown in Figure 6.

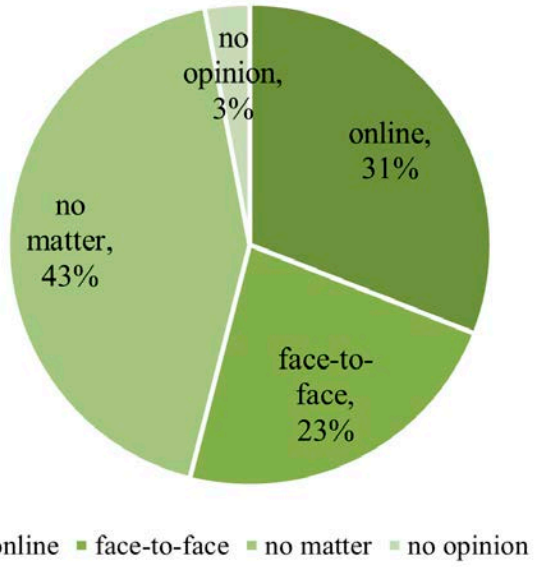
As seen in Figure 7, many students did not care about the online or face-to-face form of test or final exam (43% of respondents). For 31% of students, the online form of examination was more suitable than the face-to-face examination, which was preferred by 23%. In online testing, students were most

Figure 6. Is Online Teaching Equivalent to Face-to-Face?



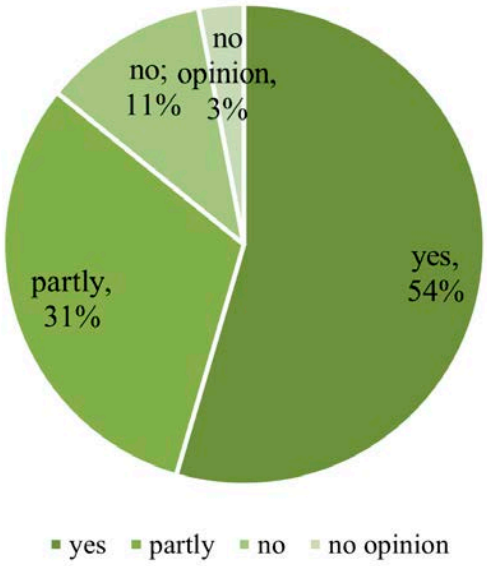
stressed by possible technical problems, and indeed, Figure 8 shows that 54% of students, more than half, considered university teaching of mathematics suitable online and 31% considered this method partially suitable, although mathematics is one of those subjects for which self-study is quite difficult.

Figure 7. Test and Written Exam are More Suitable for Me



Furthermore, students believed the main advantages of online teaching to be the convenience of viewing lessons from home, saving time not travelling to school, and flexibility of when to access the class. The main advantage was the

Figure 8. Is Online Teaching Suitable for Mathematics?

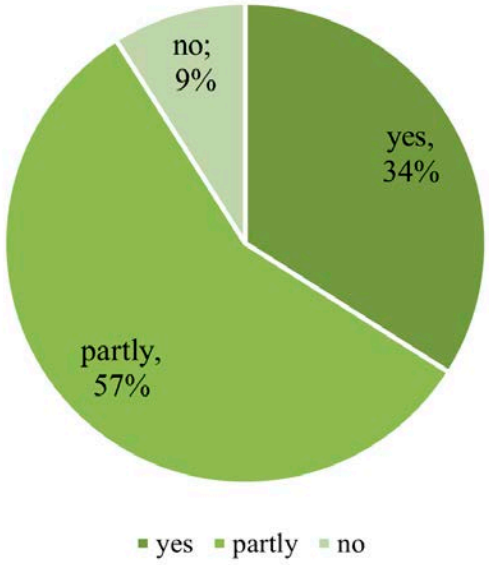


availability of video recordings of all the lectures and seminars, which allowed students to replay them several times. They could stop the recordings and watch them again for better understanding. This possibility to repeat playback basically substituted for the absence of direct contact with the teacher. In the opinion of one of the respondents: "The main advantage is, in my opinion, that if you do not understand the material it is not necessary to arrange a consultation, but you can simply watch the video again, and in most cases that is enough to understand the material," or "It is possible to repeatedly watch a lecture or exercise, which is invaluable; this cannot be done during face-to-face teaching."

According to the answers of the respondents, it did not matter whether the video recordings were made directly during the class meetings in the MS Teams platform or were created in advance. Prerecorded videos with the possibility of online consultations were appreciated by 51% of respondents, and online teaching at the same time as the scheduled recording was preferred by 46% of respondents, which are comparably sized groups. The greater popularity of prerecorded videos may be a result of the feeling of greater freedom in education and the possibility of organizing more self-study according to one's needs. Students also positively evaluated other learning materials provided, such as texts of lectures and solved examples from seminars. Overall, online teaching was evaluated positively and nearly 86% of students rated this form of teaching with a 1 or 2 (A or B). Only two respondents rated it as insufficient with a 6 (F).

On the other hand, students also mentioned the following disadvantages: a lack of contact with the teacher, the limited possibility of communication, lower concentration and maintaining attention, lower motivation when studying at home, and missing their social contacts with classmates. For example, "In online teaching, I was not so motivated to be at lectures and seminars, I was just looking at the recordings," or "I can't bring myself to concentrate, I am less driven by time, I postpone everything." It was also stated that students understand problems better while calculating by themselves at the blackboard in class and they learn more continuously in face-to-face teaching. Here are some of the comments: "After all, at school you ask when you don't understand something, and when you go to school, you also remember more, because at home it's harder to talk myself into staying at a lecture and being focused," and "There's no contact with the teacher, it's such a psychic disconnection from school, you don't feel like you're there." During online teaching, the teacher does not get to know the students personally and does not see their strengths and weaknesses. The students also mentioned technical problems with internet connection and speed, poor computer performance,

Figure 9. Can Online Teaching Replace Face-to-Face Teaching?



low mobile phone battery, and the need to purchase a webcam.

If students could choose the teaching method, most of them would prefer the form of online lectures and face-to-face seminars. One of the respondents said: "I think it would be best to have the lectures completely online and have the exercises recorded, but also to hold them in person and leave it to each student to choose the form that suits him."

In conclusion, 91% of students could imagine that online teaching will someday completely or partially replace face-to-face teaching at universities, and only three respondents answered negatively (see Figure 9).

Comparing the answers of students with better and worse exam results, students who did better at the exam did not care about the form of test or exam. They found it convenient to be at home during lectures, seminars, tests or exams, and were pleased with the time saved, which they would normally need to go to or from school or be at school itself. The other students with poor results at exams preferred the online form of test or exam but stated they found the limited communication with the teacher inconvenient. They suffered from low concentration and a lack of motivation during online teaching, and they missed the work at the blackboard in the classroom, through which they believed they learned more.

In terms of courses where M1 is included at the very beginning of the bachelor's program, while M2 is in the second year, it might be expected that the more experienced M2 students of would prefer online teaching and that, vice versa, M1 students would prefer face-to-face teaching. However, the results of the questionnaire show that students' views on online teaching and its preferences, and especially on the online teaching of mathematics, were essentially similar in both groups.

We also analyzed both course evaluations from the 2020/21 academic year, which provided us with quite similar results to the aforementioned questionnaire. Students greatly appreciated the good organization of both courses and especially the video recordings of all lectures and seminars that were available to them. Finally, from the teachers' point of view, the students were somewhat passive during online teaching. They communicated little with teachers and if they did ask questions, it was often only about the organization of the courses.

Analysis of the Obtained Data

For discussion there is the question of what causes greater success in exams during the online form of teaching of mathematics and statistics. As the university evaluation and the questionnaire showed, the recorded lectures and seminars had a very positive influence on the performance of students, even when such a form of teaching somehow lacked the interactive methods, and especially contact with lecturer, that are used in normal face-to-face teaching.

The reason for better study results during online teaching may be the fact that in the classic form of face-to-face teaching during a seminar, only one student solves the example at the board, while other students calculate the example alone and check the progress with the board, and some weaker students only wrote down the solution. If a student skilled at math was calculating on the whiteboard, the students saw the correct procedure, but the weaker ones often did not understand the methods. Although teachers tried to comment on the solution of examples, weaker students were not able to understand everything at once, nor could they capture all the additional verbal explanations in writing, let alone memorize it all.

The possibility to replay the recordings provided as many times as needed was a great advantage compared with normal face-to-face teaching and the students appreciated it. If a student did not understand something while watching the video, they could stop the video and go back a few steps, then watch the solution again until they understood it. Many students stated in the questionnaire that it was thanks to the possibility of replaying the videos that they were able to understand all the steps for solving the examples. This had the effect that even students lacking the good logical and abstract thinking necessary to study mathematics gained knowledge and skills by repeatedly watching the recordings, which they could then use to prepare for the final tests and exams. Although they spent more time watching the videos than in face-to-face teaching, the result was a better and deeper understanding of the subject matter. And this better success of students in exams in online teaching was achieved despite the increased evaluation scale.

On the other hand it should also be noted that

during online testing it was very difficult to check the students through the camera, so there was a larger opportunity for students to use nonpermitted techniques, such as cheating or breaking rules, even when teachers did their best to prevent this. Therefore, the possibility of cheating could also have contributed to the better learning outcomes.

The question of how much influence the aforementioned recordings or possible cheating had on better results still remains open. But the results are quite clear, since we provided an index of resits of exams, which is higher during the online form of teaching than for other years, which diminishes to a certain extent the influence of cheating. The raised minimal level of final successful evaluation may have had some influence on the higher index of resits of exams. The responses of the students confirmed for us that even mathematics and statistics, which are difficult subjects for self-study, can be taught online.

DISCUSSION

According to our findings, the students valued positively the prerecorded videos, as seen in Wood et al. (2021), and coped with the transition to the online form of study without profound problems, as seen in Lee et al. (2021). They found online learning a good substitute for classical face-to-face teaching, as found in Zhu et al. (2020). Of course, our investigation shows that negative factors, such as stress, technical problems, or missing social contact either among students or between students and lecturer, might also play a role, which is consistent with Rovai et al. (2006). Some factors also depended on the personality of students, especially students' lack of autonomy or the need for deeper leadership by a lecturer, which in the case of online teaching may be more difficult (Gobbi and Rovea, 2020).

The positives and negatives of both forms of study were identified and similar to Aduba and Mayowa-Adebara (2020), Giatman et al. (2020), and Bettinger and Loeb (2017), so online teaching may have a positive effect but is not suitable for very student, as seen in Bauer (2019). This may be followed by a deeper analysis concerning the demographics of students, cf. McPartlan et al. (2021), or translating the method into other courses (Maison et al., 2021; Mukhtar et al., 2020; or Musunuru, 2021), or even enlarging the concept across more universities (Ansari et al., 2021; or McCarthy et al., 2021).

CONCLUSION

Seeing the results and reactions of students in the questionnaire or student evaluations of both courses, we conclude that online teaching has a positive effect on students' performance where video recordings are provided, although there are some negatives also present. It would, of course, be appropriate to expand this research to other mathematically oriented courses or to deal with online teaching in the subjects of other disciplines that are taught at our faculty and to compare these results with each other. It would be also very interesting to repeat this survey in the next academic year, when we hope we return to face-to-face teaching, and find out whether the trend we observed will return to the norm of previous years.

The popularity of online teaching as shown by the questionnaire results may be caused not only by the possibility of repeated playback of videos, which contributed to a better understanding of the material, but also the factor of being at home, feeling comfort, having freedom and time for further activities, reduced stress when passing exams, etc. This is despite the fact that online teaching is less personal and more anonymous, and students miss their social contacts.

Our study, together with a range of other studies, shows that students are able to adapt to online teaching if there is a willingness to do so. Our study shows that students coped well with online teaching, were able to study even under these special conditions, and that online teaching did not bring any fundamental fluctuations in their performance. A positive finding was that the students' reactions and the overall data have shown that online learning suits students to a certain extent, and some of its elements, such as video prerecordings and online lectures, would be particularly beneficial for them in terms of time flexibility. On the other hand, it is advisable to leave the seminars in the standard face-to-face format, especially for students who need closer guidance and greater supervision by a teacher.

An appropriate combination of online teaching and face-to-face teaching may become the reality and foundation stone of teaching even for classic universities sometime in the future, as the pandemic has showed us quite clearly.

The limits of this study are that it was carried out only on two courses with a limited number of

students; it would be appropriate to further expand it to other courses, possibly also to a master's degree program.

DECLARATIONS

- Funding—not applicable
- Conflicts of interest/Competing interests—not applicable
- Availability of data and material: https://uloz.to/tamhle/EhOYwRPglKeT#!ZGZmMwR2AGyyZTD0BGSyZwEzAQuvZyEyF2k+pzgupRH4pQDmLt==
- Code availability—not applicable

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