The Impact of Covid-19 on Online Final Exam Scores Among Computer Science Students

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Abstract: The main goal of this research is to identify the impact of COVID-19 on online final exam scores among Computer Science students. The correlation matrix we used indicates the interrelationships among learning outcomes and student profile, type of classes and student online behaviour. Six courses were taken under consideration: Practical Algorithms, Discrete Mathematics, Software Engineering, Programming, Team Projects and Artificial Intelligence. A total of 4,988 final exam results were examined. After a deep analysis of the literature on the topic, we expected two scenarios. The first scenario constituted a decline in passing grades due to challenges such as: learning platform failures, poor internet connections or poorer quality of lessons due to teachers' lack of online competence. We hypothesized the second scenario as extraordinary student performance compared to their prior exams, but due to their dishonesty. The results of the study revealed that neither of the scenarios took place. It turned out that the challenges that seemed to be the most difficult ultimately did not matter. The present study finds that there is not a significant difference in the students' final exam performance between their online and traditional courses. Our strategy as described in this article has demonstrated a smooth transition from traditional to online teaching and assessment in terms of the final assessment.

Keywords: online exam, assessment, delivering education, e-learning

1. Introduction

Nowadays society has become highly dependent on computer networks, particularly after the Covid-19 crisis demanded it on a global scale.

The development of information technologies not only opens up great opportunities for new ways of delivering education but also provides us with all the tools we need for carrying out higher education fully online. It is clear that successful implementation of university courses is no coincidence, but rather requires great analysis and planning (Rataj & Wojcik, 2020). Every professional learning initiative requires deep analysis to identify the learning needs so as to best shape the proposed solution. This article describes the seventeen-month period of university closure from March 2020 to August 2021, comparing it to the same semester conducted in the traditional form a year earlier. It is worth noting that in both years the subjects were conducted by the same teachers.

Among the many challenges in the transition from face-to-face education to online education, the assessment – namely the switch from oral/written exams to online exams – can be considered as one of the biggest hurdles. The main goal of this research was to identify the impact of the COVID-19 on final exams scores of Computer Science students. Traditionally, these courses were delivered in the classroom: all classes took place face-to-face with the teacher and all exams were fully supervised in person.

Despite the circumstances in 2020 calling for major changes, we were not allowed by the Ministry of Science and Higher Education to change the curriculum or learning outcomes (final grades); we were only allowed to change the form of the exam from open question to multiple-choice question or from solving a task to answering true/false questions. These questions were randomly selected and assigned by the system to each student. The fact that each student received randomly selected questions minimalized the possibility of the exchange of answers among students. We made sure that the difficulty level of the exam was the same for every student, and all students took the exam simultaneously. Students did not have the option to return to previously attempted questions, which also served to minimize the possibility of "collusion" between students. Additionally, students had to have their pc cameras turned on during the exam so as to be supervised. In the case of large groups, they were divided into smaller groups, each of which was supervised by additional teachers. All exams went ahead as planned from home via the Blackboard system.

The authors aimed to use the study results to help to understand the impact of the COVID-19 pandemic on exam results, particularly because they are in charge of implementing new technologies in the teaching process, and have been so for the last 20 years.

The University of Information Technology and Management (UITM) has a practical profile focused on the use of computers, and our priority was to close this divergent academic year with a complete set of exams and credits. Online classes at UITM began three days after the announcement by the Polish Government of the need to suspend classic didactic classes in universities due to the risk of spreading the corona virus. From March 26, diploma exams were also held online in synchronous mode. All sessions were recorded and remain in the resource of the Blackboard platform.

The survey we administered was approved and fully supported by the authorities of the University and by ethics board. Quantitative analysis was used in the calculations of research results, and the conclusions were supported by interviews with teachers. The Statistical Package for the Social Sciences (IBM SPSS Statistics 25) was used to compute all data and analyse the main output. We analysed the data using descriptive statistics and correlational survey research.

2. Literature review

Universities are teaching online on a scale never seen before because of Covid-19, which has led to the emergence of a new term: Emergency Remote Teaching (ERT). In contrast to steps that are planned from scratch and designed for online purposes, emergency remote teaching is a temporary shift to an alternate delivery mode due to crisis circumstances. It involves the use of fully remote teaching solutions for instruction or education that would otherwise be carried out in person (e.g., Hodges, 2020).

In order to critically explore the impact of the Covid-19 pandemic on the assessment process and results, we begin by a brief review of the literature. The analysis of literature sources also familiarized us with solutions and strategies, with good practices in online examination, and with the current state of research into online exams worldwide.

Literature that documents online assessments has to date dealt with courses such as: mathematics (Jungic, 2020), medicine (Birch & Wolf, 2020; e.g., Choi, 2020), digital electronics (George, 2020), STEM education (Sintema, 2020), chemistry (Bopegedera, 2020), environment and chemical engineering (e.g., Dietrich, 2020) criminology (Stack, 2015), microeconomics (Gratton-Lavoie & Stanley, 2009) gerontology (Kearns, 2012).

Many countries postponed examinations that were to take place in April, May and June until later in the year (e.g., Liberman, 2020; Daniel, 2020). However, as universities move to new ways of assessing final-year students during the coronavirus shutdown, there are also universities that decided to transfer the exams to the Internet.

Imperial College London, for instance, put 280 sixth-year medicine undergraduates through unsupervised exams from. Open-book exams allow students access to any resource material they may need during the exam (e.g., Tapper, 2020). The success of this strategy indicates that lockdown does not need to lead to a total suspension of university education. On the other hand, one must account for differences in access to the tools needed for online education. According to a study done by Sintema (2020) there is a drop in the percentage of students passing national examinations in Zambia. The main reason for this is "a lack of e-learning facilities that students could have been using to interact with their teachers."

According to George (2020), however, students' test scores in the 2020 final examinations at the University of the West Indies were consistent with those of the previous academic years. Moreover, students ultimately indicated that the support they received via the Internet eliminated their fears of failing the exam. The main concern in the switch to online exams is how to maintain the same high academic standards of examination (Jungic, 2020). Lockdowns due to the COVID-19 made the monitoring of exams difficult; it is difficult to ensure that students are not cheating during online tests (Watson & Sottile, 2010). Bilen and Matros (2020) noticed in their research that the final scores show extraordinary performance among students compared to their prior exams. Gratton-Lavoie and Stanley (2009) had noticed a similar phenomenon in their research ten years earlier.

There is little research available that analyses the quality of online teaching in the context of assessment (Senel & Senel, 2021; Hollister & Berensons, 2009). Few studies also address the impact of Covid-19 on online final exam scores (e.g., Cygan, 2021; e.g., Chen, 2021). The analysis showed that there were no significant differences for the final course grade between the semesters before and during pandemic. This is also confirmed by our research results, which we describe in more detail in the Results section.

Online exams have many challenges. Two of them are the dishonesty of students and the [lack of] technological skills among teachers. Regarding the first, online students have more opportunities for cheating. Bilen and Matros (2020) proved that students in large public universities were generally dishonest during the online exam. During online exam students can use their notes, do internet searches, and ask for assistance in solving exam problems. Students can also collaborate during the exam, for example via teleconference, or even use a solution key for the exams found online. Regarding the second challenge mentioned, teachers' online competences or lack, can seriously affect students' final exam results. Our discussions with teachers revealed that online examination is a stressful experience for them. Other issues mentioned in the literature about on online assessment included the importance of the relation between teacher IT skills and students' final scores. Brown and Liedholm (2002) had observed that learning outcomes in online classes and traditional classes depend on "teacher effects rather than mode of delivery effects".

3. Method

3.1 Data collection

To answer the research questions, a database with a total of 8,671 records was downloaded from the Dean's Office System that included album number, semester number, faculty, type of study, field of study, gender, citizenship, nationality, date of birth, age, number of corrections in the course of studies, second term exams, grade average, grade, subject, form of classes. In addition, we were able to make use of the BlackBoard platform, which gave access to values calculated on the basis of information about individual sessions: total number of joins to platform per semester, total time spent on the online classes per semester, percentage of presence, number of online sessions.

During the online semester, the university integrated its Blackboard Collaborate platform with its Blackboard Learn platform. Classes were held in accordance with a previously agreed schedule of classes in a synchronous mode.

To prepare the database for analysis some records were deleted, such as 82 records of students who had been removed from the student list and 596 records of students who did not attend classes regularly because they had to pass program differences or got credit in advance. Finally, when prepared for analysis, the database consisted of 7,993 records from when classes were provided online during the pandemic (summer semester March to July 2020 as well as winter and summer semester 2021) and records from when classes were provided traditionally at the University in a lecture hall or laboratory (summer semester March to July 2019).

The following courses were taken under consideration: Practical algorithmic, Discrete Mathematics, Software Engineering, Programming, Team Project and Artificial Intelligence. These were carried out in various forms: 42.9%, laboratory 25%, recitation class 9.2%, project 22.9%. All of them occurred in the summer semesters of 2019 and 2020, but due to changes in study plans the practical algorithmics did not appear in the summer semester 2021. Figure 1 shows the number of students assigned to particular courses in the online compared to the traditional learning paths.
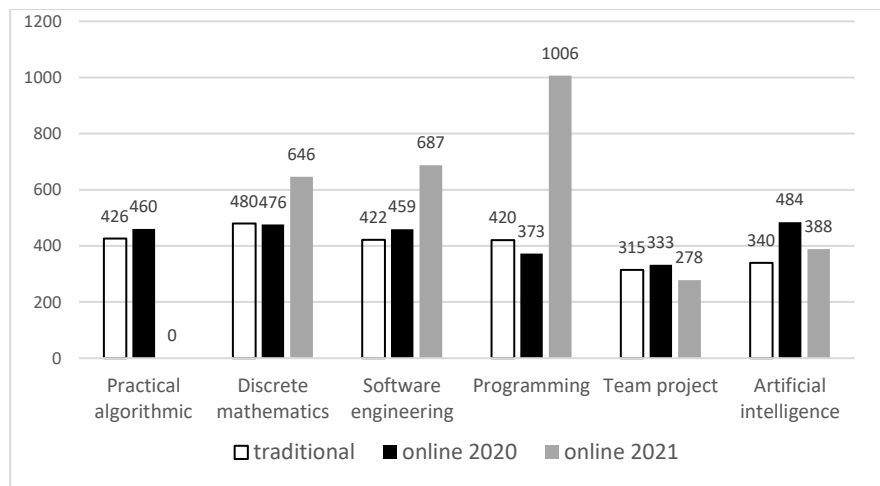
Figure 1: Courses: numbers of online vs. traditional students

The overall greater number of students in the online courses is due to the university's recruiting success.

3.2 Participants

The research population consisted of two groups of students that totaled 7,993 and ranged in age between 18 and 50.

The first group comprised 2,403 students (58.1 % full-time and 41.9% part-time) who had studied in the traditional manner at the university – in lecture halls or laboratories – during the summer semester of 2019. In total, 266 (11.1%) female and 2137 (88.9%) male students participated in the survey. Regarding nationality, 72.9% came from Poland, 22.6% from Ukraine, 1.5.% from Kazakhstan, and 3.0% from other countries: Bangladesh, China, India, Malaysia, Nigeria, Russia, USA, Thailand, Vietnam, Italy, Kyrgyzstan, Azerbaijan, Malaysia, Japan. A total of 90.5% are studying at bachelor's level and just 9.5% at master's level.

The second group consisted of 2,585 students (58.6% full-time and 41.4% part-time) who had attended courses online during the pandemic summer semester of 2020. In total, 230 (8.9%) female and 2,355 (91.1%) male students participated in the survey. Regarding nationality, 72.8% came from Poland, 15.4% from Ukraine, 5.4% from Kazakhstan, and 6.3% from other countries: Bangladesh, China, Egypt, India, Malaysia, Morocco, Nigeria, Russia, USA, Thailand, Tajikistan, Vietnam, Zimbabwe, Italy, Kyrgyzstan, Papua New Guinea, Azerbaijan, Gambia, Rwanda, Japan, Malaysia, and Zambia. A total of 92.8% are studying at the bachelor's level and just 7.2% at master's level.

The third group comprised 3005 students (58.1 % full-time and 41.9% part-time) who had attended courses online during the pandemic summer semester of 2021. In total, 248 (8.3%) female and 2757 (91.7%) male students participated in the survey. Regarding nationality, 71.9% came from Poland, 10.2% from Ukraine, 8.7.% from Kazakhstan, and 9.2% from other countries: Bangladesh, China, India, Malaysia, Nigeria, Russia, USA, Thailand, Vietnam, Italy, Kyrgyzstan, Azerbaijan, Malaysia, Germany.

A total of 97.7% are studying at bachelor's level and just 2.3% at master's level.

4. Research structure

In this research we try to outline how learning outcomes and student profile, type of classes and student online behaviour all interrelate. Details of the research structure are presented on Diagram 1.
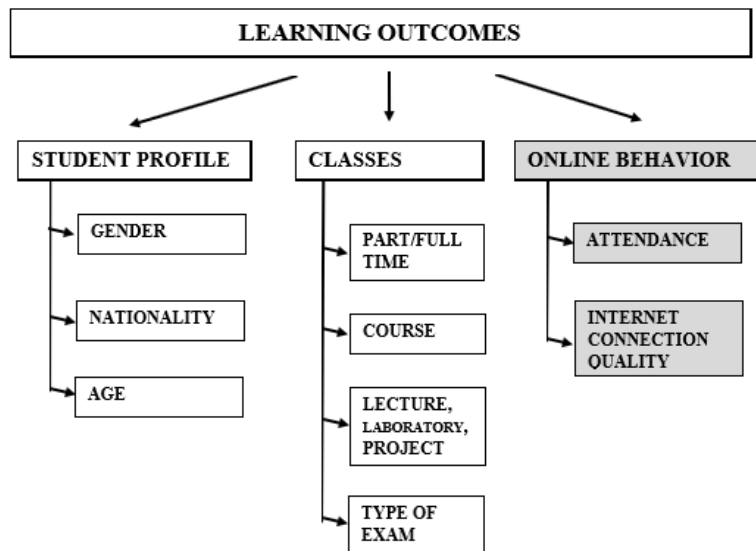
Diagram 1: Research structure

5. Data analysis

The average score on the spring 2020 online exam was 3.16, which is almost the same as the average score of 3.15 during the spring 2019 traditional exam.

After checking how many students did not take the exam, it turned out that in both study groups this percentage ranged from 5.3% to 8.7%. After analysing the database, it turned out that the students who did not take the exam were the Software Engineering students. After analysing the issue, we came to the conclusion that the problem was either the particular teacher or the poorly constructed syllabus.

The grading scale in university education ranges between 5.0 and 2.0, where 5.0 is very good and 2.0 is a failing grade. Figure 2 represents the scores of students from the surveyed courses: Practical Algorithmics, Discrete Mathematics, Software Engineering, Programming, Team Project and Artificial Intelligence.
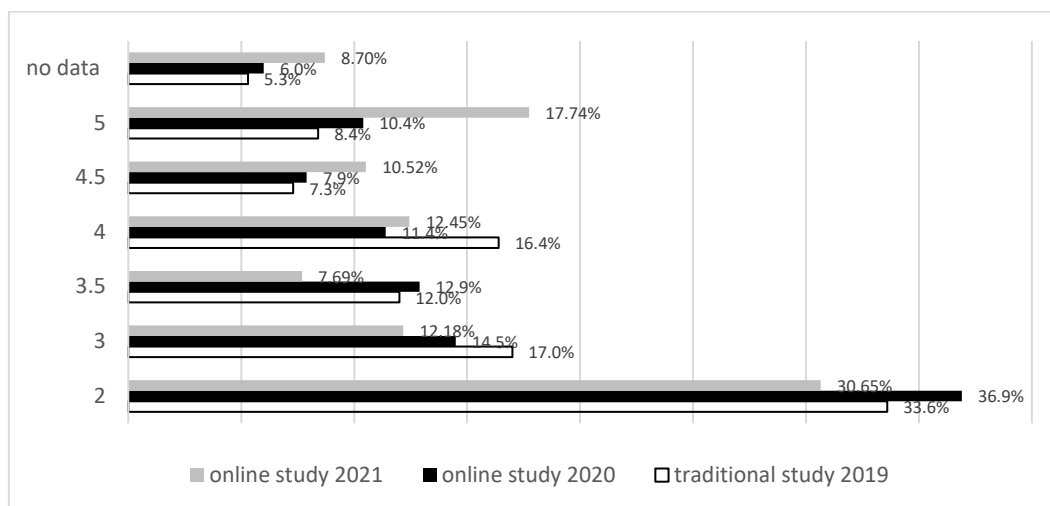
Figure 2: Exams results: online study vs. traditional study

In line with the literature on the subject (Bilen and Matros 2020) we expected fewer failing grades. Although the number of failed online exams is high, as presented in Figure 2, it is just insignificantly higher during a pandemic. The number of failed online exams proves the reliability of the examinations the well-tailored content of the courses and well selected forms of the examination. This conclusion could be supported by the fact that each of the exam questions needed complex problem-solving skills. What is more, the question had not trivial answers such as "100", "350", "yes", "no", which would make it easy randomly guess the correct answer.

5.1 Student profile

Gender. Our research has shown that women pass the exams better. While the number of women at Computer Science faculty in Poland is small (9% - 11%), they are more determined to prepare well for the profession during their studies, and thus achieve better grades on exams. Our results are in line with general statistics in education, which shows that women outperform men (Carvalho, 2016; Voyer &Voyer 2014).

Nationality. Among 25 nationalities, only the students of one nationality (we do not specify which for ethical reasons) have significant problems passing the exams, regardless of the form (online or traditional studies). The problem may lie in the quality of educational background in that country.

Age. The age of the students ranged from 17 to 51 years old. In Poland college-aged students are 18 years old. But UITM has students from Kazakhstan are 17 years old, because they have passed matura exam in their home country and in accordance with Polish law they are entitled to study at the University.

The highest number of failing exams occurred among the oldest students aged 37 to 51. This result is most likely related to technological problems, like the necessity of sending photos of exam papers, as the test does not allow backtracking. Interestingly, the smallest number of failing exams was not among the youngest students, but in the group aged 32 to 36. The explanation may be the great responsibility students must take up to organize and execute their own learning process. Students of this age study usually in part-time mode, which means they have to juggle their work schedules with studying.

5.2 Classes

Course. After checking the exam results from the e-learning platform, it was noticeable that students had more problems passing the online exams in the subjects Discrete Mathematics and Artificial Intelligence – in comparison with traditional exam form. Both subjects have open-ended questions during the exam, and in the traditional form of the exam it was possible to return to previous questions and rethink them. The traditional form of the exam also requires fewer steps. During the online exam, for example, students need to take a photo of the solution and send it by e-mail, which is associated with more stress. We did receive a few complaints about the assessment, but in general, students demonstrated a good grasp of technological skills. On the other hand, several of students sent messages commenting positively about their experience in the online course.

Part/full time. There were no differences in exam results between full-time and part-time students. It should be appreciated that part-time students who attend fewer class hours than full-time students achieved the same learning outcomes.

Lecture, laboratory, project. The difficulty with passing a lecture online had to do with the technical issue with the online platform. There is no difference in the laboratory or project results. Hence, the distribution of grades did not differ significantly from the grades obtained in traditional education (Figure 2). Regardless of the chosen form of exam, the lecturers tried to make individual tasks for almost each student. This hindered the students from sharing answers or asking third part for help. The biggest problems occurred with the exams with multiple answer portions. The difficulties here can be explained by the very short response time given or the inability to change the answers already given.

Type of exam. As only the Department of Applied Computer Science was analysed, all exams and credits were more or less computational. There was no need to change exam methodology after March 2020. Even when taking the exams, it was necessary to perform computational tasks, execute a mini-project, and the test questions contained references to the practice. We can claim that exams in 2019 and 2020 were equivalent and it makes sense to compare the results of these exams. The difficulty level of the exams in the summer semester of 2019 and 2020 was the same. The content of the tasks required students to have a deep understanding of the subject. Detailed information by type of exam and grades can be found in Table 1. When analysing the types of exams available to students, there are several basic types (used regardless of the form of classes):

- typically, computational exams (problems to be solved);
- mixed, consisting of a theoretical part, usually in the form of a single or multiple-choice test, and short tasks to be solved; problem tasks usually in the form of one major problem along with sub-problems to be solved;
- descriptive questions, which, however, try not to reflect directly the content of the lecture;

- quite rare single or multiple-choice tests, usually embedding fragments of practical tasks into the content of the questions;
- one large-scale project spread over the entire semester, requiring individual parts to be delivered on time; a project carried out throughout the semester and an additional theoretical knowledge test.

Table 1: Percentage representation of grades by type of exam

Grade	Calculated	Mixed	Problem solved	Descriptive	Long term project	Test	Project+test
2	50.90%	9.10%	35.50%	26.20%	21.90%	58.00%	43.60%
3	21.70%	40.50%	5.20%	11.80%	3.70%	10.30%	15.20%
3.5	9.80%	19.80%	14.80%	38.50%	8.00%	16.70%	14.00%
4	10.30%	14.90%	14.80%	13.60%	15.10%	8.00%	11.50%
4.5	2.90%	7.40%	13.50%	5.00%	19.80%	4.60%	10.30%
5	4.40%	8.30%	16.10%	5.00%	31.50%	2.30%	5.30%

5.3 Analysis of the online student behaviour

5.3.1 Attendance
The relatively low percentage of attendance of online classes (37.43% - 51.76%), shown in Figure 3, is surprising. Many students combine professional work with education, and in that type of situation, it is paradoxically easier to take part in online classes than to come to the university in person. Some classes were also recorded (by the teacher or by students on their own). The high percentage of students who did not attend online classes and nevertheless obtained a very good grade is also surprising. In this case, the explanation may be the individual organization of studies (the situation when the student is released from classes and prepares for the exam in consultation with the teacher). The problem of low attendance requires further analysis.
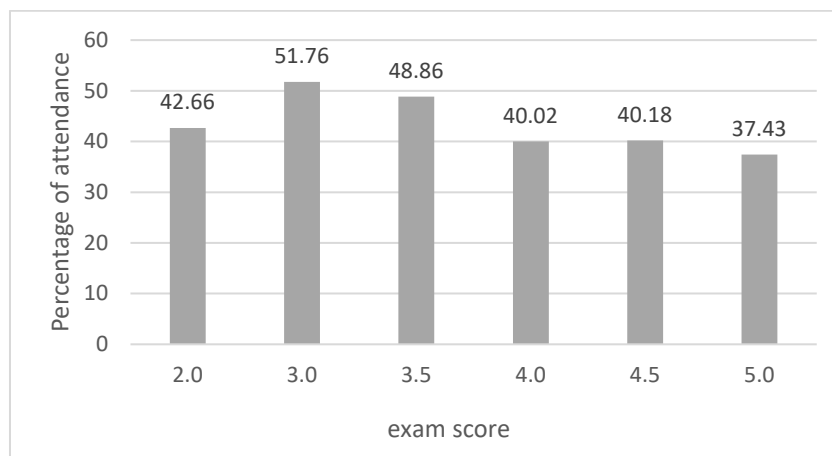
Figure 3: Percentage of attendance vs. exam score

The socioeconomic factor may have an impact on the presence of students during classes. UITM is a private university where students pay tuition every month. After the outbreak of the pandemic, the University prepared a fund of social scholarships for students. However, students paid tuition on time and did not apply for a social scholarship. According to interviews with students, they did not get into financial trouble during the pandemic. Each student had access to a suitable study place. Therefore, in our analysis was not taken into account socioeconomic factor.

5.3.2 Internet connection quality
The quality of the Internet connection was calculated on the basis of the number of connections per session in relation to the number of sessions (Table 2). Absent students were analysed separately because the quality of the connection could not be determined. Due to the synchronous teaching system owned by the university, we did not have detailed data on the quality of the connection. Absent students were thus included separately in the results. Although access to broadband Internet is becoming the norm, a few of the students had a poor internet connection, but we were unable to ascertain any differences in the nationalities of those students with a weak Internet connection.

Table 2: Percentage distribution of grades by Internet connection quality

Grade	Excellent	Very good	Good	Poor	Absent
2	31,8%	8,7%	14,2%	12,9%	32,5%
3	38,9%	12,8%	12,3%	12,5%	23,5%
3.5	22,2%	11,4%	14,1%	18,3%	34,1%
4	26,5%	11,6%	15,3%	12,2%	34,4%
4.5	27,5%	9,3%	13,2%	10,8%	39,2%
5	31,0%	10,4%	14,2%	8,2%	36,2%

As the last part of the research, a correlation matrix was created to find key factors that have a direct impact on final online exam results (Table 3). Given that a correlation matrix is a square, symmetric matrix with all autocorrelations along the main diagonal equal 1 and all the pairwise Pearsonian product moment correlations listed above the main diagonal equal their corresponding row and column placements below the main diagonal. In this table, pairwise correlations that are significant at the .05 alpha level (two-tail) are indicated with an asterisk (∗) and those significant at the .01 level are represented by a double asterisk (∗∗). The Kendall tau coefficient (τ-Kendall) was used in the correlation matrix for the types of variables. This coefficient takes values in the range <-1, 1>. From Table 3 we observe that grade is significantly correlated with several outcome measures like gender, age, course, form of classes (Lecture/Laboratory/Project) and type of exam. Grade is not significantly related to online behaviour measures like attendance and Internet connection quality.

Table 3: Correlation matrix for outcome measure in online classes

	Grade	Gender	Nationality	Age	Course	Part time/Full time	Lecture/Laboratory/Project	Type of exam	Attendance	Internet connection quality
Grade	1,000	-.107**	-0,023	.068**	.037*	-0,031	.113**	.175**	-0,014	0,031
Gender		1,000	-.112**	-.044**	-.036*	0,036	-0,014	-0,026	.047**	-0,030
Nationality			1,000	-.321**	-0,003	-.467**	-0,008	-0,014	-.115**	.056**
Age				1,000	.175**	.423**	.120**	.175**	-.052**	.104**
Course					1,000	0,014	.099**	.568**	-0,020	.120**
Part time/Full time						1,000	0,005	0,026	.062**	-0,005
Lecture/Laboratory/Project							1,000	.044**	-.377**	.245**
Type of exam								1,000	-.091**	.206**
Attendance									1,000	-.483**
Internet connection quality										1,000

6. Results

The results of the present study reveal no significant difference in final exam scores between the students in online classes (summer semester 2020) and those in traditional classes (summer semester 2019).

Undoubtedly, the transition to online learning and online assessment is beset by several challenges such as: learning platform failures, poor Internet connections, poorer quality of lessons due to teachers' lack of online competence, or the dishonesty/cheating among the students. The case study of UITM proved that the challenges that seemed to be the most difficult ultimately did not matter. Of course, this is no accident – we have been using the BlackBoard platform and Blackboard Collaborate system for several years. The research was conducted among students of Computer Science, students who have no problem with the use of modern technologies. Our

fears that teachers might fail during online classes also turned out to be unfounded. We consider that a success that reflects many years of effort in studying, creating a strategy and implementing online and mobile learning classes.

As mentioned in the literature review, we expected increased levels of cheating, but ultimately, no evidence of cheating behaviour was found. During the exams, students were divided into small groups in virtual rooms. All rooms were supervised by teachers' assistants who observed the students and checked their identity.

Interestingly, the results of interviews with teachers show that the pandemic situation made communication with students more intense. Students who did homework and projects at home felt the need to communicate more with teachers outside of classes. From their side, understanding that the situation was difficult for both sides, teachers felt more responsible for the well-being of students. Interestingly, neither the activities of scientific circles nor individual tutoring sessions were suspended during the pandemic.

7. Discussion and Conclusions

The results of our research confirm that the mode of education itself (traditional vs online) does not significantly affect the assessment process. Modern technology used in education enables educators to implement the educational process regardless of the form of communication.

Lecturers who are able to engage students, provide effective feedback, or engage in interactions with students, do it at a comparable level, regardless of the mode of education. With the support of the institution and good infrastructure, the teaching staff can implement the educational procedure both traditionally and online. But there is no doubt that is necessary to constantly develop and support academic staff who feel less confident in online teaching.

Our online students were able to be well assessed by teachers; that is, their exam results did not differ from those before the pandemic period. But were our teachers rated equally well by the students? In a future study we will try to answer that question.

Taking into account the most likely extending period of the pandemic, it is necessary to consider introducing projects or mid-term exams instead of final exams.

Another path for future research would be to investigate why the attendance of the practical courses – where students gain skills required on the labor market - was so low, and how to improve this negative phenomenon. Maybe rewarding student activity in laboratories can increase student involvement and attendance.

The other field of study in which we are interested is to generate a coherent model of strategy implementation for online learning at the university - a model based on our experiences and the experiences of other universities that have been successful in this field.

This study has some limitations. The results of this study cannot be generalised as it was conducted only in one business university. The University of Information Technology in Rzeszow is still a single institution in the context of one country and a particular virtual learning environment. The similar research in another higher education institution could bring completely different results influenced by a different academic staff structure or other infrastructure for distance learning. The research was conducted among students of Computer Science but how would students of another field – perhaps more humanistic – will react? The above points need to be taken into account in future research.

References

Birch, E. and Wolf, M. (2020) "A novel approach to medical school examinations during the Covid-19 pandemic", *Medical education,* [online] https://doi.org/10.1080.10872981.2020.1785680

Bilena, E. and Matrosa, A. (2020) "Online Cheating Amid COVID-19", [online] https://ernbilen.github.io/pdfs/Cheating.pdf

Bopegedera, A. M. R. P. (2020) "Using Familiar and New Assessment Tools in Physical Chemistry Courses During COVID-19", *American Chemical Society and Division of Chemical Education, Inc.* [online] https://doi.org/10.1021/acs.jchemed.0c00789

Brown, B. and Liedholm C. (2002) "Can Web Courses Replace the Classroom in Principles of Microeconomics?" *American Economic Review*, No.92(2), pp. 444-448

Carvalho, R. (2016) "Gender differences in academic achievement: The mediating role of personality", *Personality and Individual Differences,* No. 94, pp. 54–58, [online] https://doi.org/10.1016/j.paid.2016.01.011

Chen, Z., Jiao, J., Hu, K. (2021) "Formative Assessment as an Online Instruction Intervention: Student Engagement, Outcomes, and Perceptions", *International Journal of Distance Education Technologies,* [online] doi: 10.4018/IJDET.20210101.oa1

Choi, B., Jegatheeswaran, L., Minocha, A., Alhilani, M., Nakhoul, M. , Mutengesa, E. (2020) "The impact of the COVID-19 pandemic on final year medical students in the United Kingdom: a national survey", *BMC Medical Education*, [online] https://doi.org/10.1186/s12909-020-02117-1

Cygan, H., Bejster, M., Tribbia, C., Vondracek H. (2021) "Impact of COVID-19 on public health nursing student learning outcomes", *Public Health Nurs,* [online] https://doi.org/10.1111/phn.12978

Daniel, J. (2020) "Education and the COVID-19 pandemic", *PROSPECTS Comparative Journal of Curriculum, Learning, and Assessment*, No. 49, pp. 91–96

Dietrich, N., Kentheswaran, K., Ahmadi, A., Teychené, J., Yolaine, B., Sandrine, A., Laborie, S., Bastoul, D., Loubière, K., Guigui, Ch., Sperandio, M., Barna, L., Etienne, P., Cabassud, C., Liné, A., Hébrard, G. (2020) "Attempts, Successes, and Failures of Distance Learning in the Time of COVID-19", *Journal of Chemical Education* 2020, No. 97 (9), pp. 2448-2457

George, M. (2020) "Effective Teaching and examination Strategies for undergraduate Learning during COVID-19 School Restrictions", *Journal of educational technology*, [online] https://doi.org/10.1177/0047239520934017

Gratton-Lavoie, Ch. and Stanley, D. (2009) "Teaching and Learning Principles of Microeconomics Online: An Empirical Assessment", Journal of Economic Education, Vol. 40 Nr.1, pp. 3-25

Hodges, Ch., Moore, S., Lockee, B., Trust, T., Bond, A. (2020) "The Difference Between Emergency Remote Teaching and Online Learning", *EDUCAUSE Review*, March 27, 2020

Hollister, K. and Berenson, M. (2009) "Protocoled versus unprotocoled online exams: studing the impact of exam environment on student performance", *Decision Sciences Journal of Innovative* Education, Vol.7, Nr 1.

Jungic, V. (2020) "Making calculus relevant: final exam in the time of COVID-19", *International Journal of Mathematical Education in Science and Technology*, [online] https://doi.org/10.1080/0020739X.2020.1775903

Kearns L.R., (2012) "Student assessment in online learning: challenges and effective practices", *MERLOT Journal of Online Learning and Teaching*, Vol.8, No 3. [online] https://jolt.merlot.org/vol8no3/kearns_0912.pdf

Levin, V., Luna-Bazaldua, D., Harnisch, M., LIBERMAN J. (2020), "High-stakes school exams during COVID-19 (Coronavirus): What is the best approach?", *Education for Global Development*, April 01, 2020

Rataj, M. and Wojcik, J. (2020) "The Mobile Learning Adoption Model Tailored to the Needs of a Private University", *The Electronic Journal of e-Learning (EJEL)*, [online] doi: 10.34190/EJEL.20.18.4.004Senel S. and Senel H. (2021) "Remote Assessment in Higher Education during COVID-19 Pandemic", *International Journal of Assessment Tools in Education,* [online] https://doi.org/10.21449/ijate.820140

Sintema, J. (2020) "Effect of Covid-19 on the performance of grade 12 students: Implication for STEM education", *EURASIA Journal of Mathematics, Science and Technology Education*, [online] http://doi.org/10.29333/ejmste/7893

Stack, S. (2015) "Learning outcomes in an online vs traditional course", *International journal for the Scholarship of teaching and learning*, Vol. 9, No. 1, [online] https://doi.org/10.20429/ijsotl.2015.090105

Tapper, J., Batty, D., Savage, M. (2020) "Medical students take final exams online for the first time despite student concern", [online] https://www.theguardian.com/education/2020/mar/22/coronavirus-forces-medicalstudents-sit-final-exams-online (accessed on 10.04.2020)

Watson G. and Sottile J. (2010) "Cheating in the digital age: do students cheat more in online courses?", *Online Journal of Distance Learning Administration,* [online] https://www.westga.edu/~distance/ojdla/spring131/watson131.html

Voyer, D. and Voyer, S. D. (2014) "Gender differences in scholastic achievement: A meta-analysis", *Psychological Bulletin*, Nr. 140(4), pp. 1174–1204, [online] https://doi.org/10.1037/a0036620