Full research paper

RESULTS OF MATHEMATICS EXAMINATIONS BEFORE, DURING, AND AFTER THE COVID-19 RELATED RESTRICTIONS

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ABSTRACT

The article deals with the results of mathematics examinations at the University of Finance and Administration in Prague before, during, and immediately after the Covid-19 pandemic-related restrictions. The first objective is to evaluate whether the non-standard forms of testing (correspondence and online), used on an emergency basis during the pandemic, were adequate compared to the standard form (face-to-face) applied before the pandemic. The second objective is to assess whether and to what extent the results of the examinations have changed after the return of teaching and testing methods to normal. It turns out that the use of non-standard forms, although more challenging for teachers to control, did not lead to better results – the results in the correspondence form were similar to the standard form and even worse in the online form. The results of examinations administered in the standard form after the return to normal teaching were significantly better than in any of the periods studied, including the standard form of examination before the pandemic. Possible reasons for the results are analysed in the paper.

KEYWORDS

Covid-19 pandemic, form of examination, mathematics, online exam, statistical evaluation, written test

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Highlights

- *Alternative forms of written examinations in mathematics during the Covid-19 pandemic.*
- *Results of written examinations in mathematics after the return to normal teaching mode.*

INTRODUCTION

The Covid-19 pandemic and associated measures have necessitated a change in the approach to teaching and testing in all types of schools. However, as mentioned, for example, by Ho et al. (2021) or Hvorecký et al. (2021), many schools were not prepared for the situation, especially in the first wave of the pandemic, and teaching and examinations were thus "emergency" mode. Many teachers around the world have begun to think about how to replace standard teaching so that students can pass exams (Makamure and Tsakeni, 2020). They believed that using modern technology would help teachers and students overcome problems (Pokorny, 2021). This was also the case at Prague University of Finance and Administration. This article compares the results of mathematics examinations at this school during the pandemic with the results before the pandemic and after the restrictions related to the pandemic. Exam results may depend on many factors. For example, Fajčíková et al. (2020) point out the influence of the field of study, Joyce et al. (2015) study the impact of class time on academic performance, Ulrychová and Bílková (2018) investigate the impact of students' gender on their mathematics exam results, Majovska (2015) deals with the influence of online mathematics programmes on students' results, Darolia (2014) analyses the effect of working on the academic performance.

During the pandemic, additional factors have been added that can affect the outcome of the exam, which is conducted online. Haus et al. (2020) compare the different scenarios of written exams during the pandemic depending on the number of students to be monitored in parallel to avoid cheating. Hartnett et al. (2023) state that most students were positive with online exams, but digital inequalities were found between students' perceptions of digital competence.

Exam results could also be affected by the form of face-to-face or online teaching. Sun et al. (2008) list the main factors influencing students' satisfaction with online learning, both on the part of instructors and students. Issues related

to student satisfaction with online learning have come to the forefront of many scientific publications in recent years due to the restrictions accompanying the Covid-19 pandemic. Aristovnik et al. (2020) found that at the time of the pandemic, students from Europe were more likely to be satisfied with their schooling than students from other continents.

However, many studies report that the form of teaching does not strongly influence learning outcomes. For example, Pasáčková (2021) found that student success rates in mathematics did not change with the conversion from face-to-face to online teaching. Trends examining alternative online education outcomes were already emerging before the COVID-19 pandemic. Thompson and McDowell (2019) conducted a research study at an undergraduate college, comparing student successes in a mathematics course offered fully online, blended, and face-to-face, and concluded that the level of student performance is independent of the form of teaching. In research conducted by Ilgaz and Adanir (2020), there was no statistically significant difference in students' performance in online and traditional exams. Cahapay (2020) states that online or blended learning will become a common part of the curriculum.

The above studies often deal more with the form of teaching, not so much with the form of testing. Our article focuses primarily on the form of testing. Its aim is to compare the results of tests conducted in the standard way with two alternative forms. At the University of Finance and Administration, mathematics is taught as a two-semester course in the first year of study, Mathematics 1 in the winter semester and Mathematics 2 in the summer semester, both of which culminate in an exam. At the time of the Covid-19 pandemic, examinations were conducted by alternative means. The first aim of this paper is to assess whether these alternative forms were an adequate substitute for standard examination and whether the reduced ability to check the authorship of the test did not lead to better results to a greater extent. The summer semesters of three consecutive academic years, when the tests were administered in a different form each time, were chosen to compare the results.

Mathematics examinations are conducted standardly face-to-face at the University of Finance and Administration. In the summer semester of 2019/2020, examinations could not be held in a standard way due to the situation caused by the Covid-19 pandemic, specifically the closure of schools. However, sufficient conditions have not been created to allow the online exams to be conducted in a form that best matches the standard format. Therefore, an "emergency" non-traditional form of testing was chosen: students independently worked out tasks corresponding to the tasks from the regular exam test and sent the finished tasks for evaluation. In the academic year 2020/2021, examinations in both semesters were conducted exclusively online due to the ongoing pandemic.

This article compares the results of mathematics exams in the summer semester 2018/2019, when the standard form was used, with the results in the summer semester 2019/2020, when the correspondence form was used. Further, the results of the standard form in the summer semester 2018/2019 are compared with those of the online form in the summer semester 2020/2021. The results of all three forms, as well as of both alternative forms, are not compared. The main objective is to determine whether the correspondence and online forms are adequate substitutes for the standard form of the examination since the alternative forms do not allow sufficient checking to verify that students are working independently.

In 2021/2022, the academic process returned almost to normal mode. Teaching and examinations were conducted in the standard way. The authors of this article were interested in whether the period of the Covid-19 pandemic had an effect on the exam results. Therefore, after the end of the examination period of the summer semester of the academic year 2021/2022, the mathematics examination results of this semester were compared with the examination results of each of the summer semesters of 2019-2021, i.e., with the period of the last academic year before the Covid-19, when the examination was conducted in the standard form, and the period with Covid-19, when the examinations were conducted in two different alternative forms.

The article extends the paper Ulrychová, Majovská and Tesař (2022) presented at the 19th International Conference on Efficiency and Responsibility in Education (ERIE 2022).

The article is structured as follows. The Materials and Methods section describes the various forms of testing in more detail and specifies the data and statistical methods used. The section Results provides the summary of our research outcomes. The Discussion section compares the results with those of other studies and considers possible reasons for the results. The Conclusion section provides an overall summary of the findings.

MATERIALS AND METHODS

Alternative Teaching and Three Different Forms of Testing

At the University of Finance and Administration, mathematics lessons (lectures and seminars) proceeded in the standard way until the beginning of the summer semester of 2019/2020, when the schools were closed due to the Covid-19 pandemic. Students were then referred to several weeks of guided self-study, for which special study support materials were promptly created. Later, online streaming of standard lectures from empty classrooms without students was enabled. Streaming had the advantage over standard teaching in that recordings were made of the lectures, which students could replay as needed. The disadvantage, however, was that there were no seminars in which students could better understand the material and practice the necessary computational procedures.

In the academic year 2020/2021, both lectures and seminars were conducted online only. The lectures were recorded, as in 2019/2020; the seminars were not recorded. While the lectures were fully comparable to the standard ones, the seminars were more problematic, mainly due to the difficulty of checking the students' work.

In the academic year 2021/2022, teaching and examination returned to their standard form before the pandemic. In addition, learning was supported by providing students with lectures recorded, as during the pandemic.

The curriculum was the same in all considered academic years, regardless of the form of teaching. The exam tests had the same structure in all three forms of examinations (standard, correspondent, and online), which are described in more detail below. They consisted of tasks to calculate exercises from the field of mathematical analysis (behaviour of a function of one variable, Taylor polynomial, an indefinite and definite integral, derivative of a function of two variables). In the standard form of examination, students write the test in a classroom under the direct supervision of examiners. Before the final submission of the tests, the examiners quickly check each student's test, approve the correctly solved tasks, and allow the student to correct the remaining tasks (without the examiner specifying the errors in any way). The test consists of 10 items; to pass the exam, the student must solve at least 50% of them.

In the correspondence form, students prepared written work consisting of exercises corresponding to the standard exam test. However, each student first had to create his or her individual assignment according to precise instructions, which significantly limited the possibility of transferring calculations and results between students. Students could submit their finished work to the university's information system at any time during the exam period; no exam dates were announced. Therefore, this form of the exam gave students a long time to prepare, and students could continuously consult their work with anyone (including teachers). Therefore, the assessment was more rigorous than the standard form of testing. To pass the exam, students had to correctly solve all ten tasks (which corresponded to the regular test). In order to get a better grade, it was necessary to do extra exercises on topics that were not part of the standard test (but were taught in the lessons).

In the online form of the exam, students took the test remotely on the given exam date. Students had to keep the camera and microphone on throughout the exam, and the examiner supervised the exam's correct procedure. The structure of the test and the assessment criteria were the same as for the standard exam. However, compared to the standard exam, students did not have the advantage of a preliminary check of the test by the examiner before the final submission. After completing the test, students photographed or scanned the test and immediately uploaded it to the school information system in the prescribed format. The time to complete and submit the test was extended by ten minutes compared to the standard testing format to make a copy of the test and upload it to the information system. In the case of technical problems during the exam or when submitting the paper, students could promptly solve them with the examiner.

In our study, we purposely worked exclusively with students in the mathematics subject who had the same teachers, examiners, and examination and assessment system. We did not want to compare the results of mathematics exams with results in other subjects, where even the standard way of examination could be quite different. In addition, the demands on students and the rigour of assessment may vary from examiner to examiner, which may bias comparisons of examination results. In this sense, the mathematics subject examiners considered in this study are consistent, so the examination results are well comparable.

Methodology and Research Organization

We conducted our research in two parts. In the first part, we compared the results of the standard testing from the period immediately before the pandemic (academic year 2018/2019) and alternative forms of testing during the pandemic (academic years 2019/2020 and 2020/2021). We wanted to determine whether the alternative testing methods were adequate. In the second part of the research, we compared examination results after the return to the standard teaching and examination regime (academic year 2021/2022) with previous periods (academic years 2018/2019, 2019/2020, 2020/2021). Moreover, we compared the exam results separately for full-time students and for part-time students in the academic year 2021/2022 with the previous years.

We only processed data from the summer semesters of the mentioned academic years, so in the following tables, we denoted the summer semester of the academic year 2018/2019 briefly as S_2019, in other cases analogously. We had 101 results from the standard exam in S_2019, 96 from the correspondence exam in S_2020, 111 from the online exam in S_2021, and 72 from the standard exam in S_2022. The test results were converted to the numerical value: Excellent (A) = 1, Excellent minus (B) = 2, Very good (C) = 3, Very good minus (D) = 4, Good (E) = 5, Failed (F) = 6. For each of the examined groups S_2019 to S_2022, we calculated the sample average value (M), the unbiased estimate for variance (V), skewness (S), and kurtosis (K). The number of tests in a group was denoted by N. We calculated the same parameters separately for full-time students and part-time students. In other cases, we denoted these groups as F_S_2019 (full-time study) and P_S_2019 (part-time study) analogously.

We used the Bowman-Shenton skewness and kurtosis test for normality at a 0.05 significance level (Bowman and Shenton, 1975). In all cases, we compared two groups (hereafter generally referred to as Group_1 and Group_2 in the tables). Specifically, we compared S 2019 (Group_1) sequentially with S_2020 and S_2021 (always Group_2) and then S_2022 (Group_1) sequentially with S_2019, S_2020, S_2021 (always Group_2). Furthermore, F_S_2022 (Group_1) was compared successively with F_S_2019, F_S 2020, F_S 2021 (always Group_2) and P_S_2022 (Group_1) successively with P_S_2019, P_S_2020, P_S_2021 (always Group_2).

Based on our experience and assumptions, we formulated hypotheses:

- H_0: Distribution from which the test results of Group_1 and Group_2 come is the same.
- A_0: Distribution from which the test results of Group_1 and Group_2 come is not the same.

All the hypotheses were tested at the 0.05 significance level using the non-parametric Mann-Whitney U test (Mann and Whitney, 1947).

RESULTS

Table 1 shows the relevant data and calculated values for each group S_2019 to S_2022.

Group	*N*-number	*M*-average	*V*-variance	*S*-skewness	*K*-kurtosis	Normality
S_2019	101	3.545	2.512	-0.074	1.804	No
S_2020	96	3.688	2.765	-0.283	1.837	No
S_2021	111	4.135	2.936	-0.516	2.029	No
S_2022	72	2.944	2.900	0.346	1.797	No

Table 1: Examined data for 2019 - 2022 (source: own)

Group	*N*-number	*M*-average	*V*-variance	*S*-skewness	*K*-kurtosis	Normality
F_S_2019	57	3.509	2.5506	-0.139	1.691	No
F_S_2020	58	3.672	2.6803	-0.237	1.806	No
F_S_2021	85	4.271	2.9141	-0.644	2.197	No
F_S_2022	51	2.922	3.0740	0.368	1.812	No
P_S_2019	44	3.591	2.5739	0.005	1.923	Yes
P_S_2020	38	3.711	2.9681	-0.347	1.874	Yes
P_S_2021	26	3.692	2.8624	-0.162	1.816	Yes
P_S_2022	21	3.000	2.6013	0.293	1.709	Yes

Table 2: Examined data for 2019 - 2022 full-time and part-time students (source: own)

Group_1 / Group_2	Z	*p*-value	Cohen's *d*
S_2019 / S_2020	-0.693	0.488	0.088
F_S_2022 / F_S_2019	-1.803	0.071	0.350
S_2019 / S_2021	-2.686	0.007	0.357
S_2022 / S_2019	-2.347	0.019	0.365
P_S_2022 / P_S_2019	-1.354	0.176	0.367
P_S_2022 / P_S_2021	-1.284	0.199	0.419
P_S_2022 / P_S_2020	-1.449	0.147	0.426
S_2022 / S_2020	-2.759	0.006	0.442
F_S_2022 / F_S_2020	-2.361	0.018	0.442
S_2022 / S_2021	-4.312	0.000	0.697
F_S_2022 / F_S_2021	-4.070	0.000	0.780

Table 3: Results of Mann-Whitney test and Cohen's *d* (source: own)

Table 2 shows the relevant data and calculated values for each group F_S 2019 to F_S_2022 and P_S 2019 to P_S_2022.

Table 3 compares the pairs of groups as described above. It contains results of Mann-Whitney U tests, with the *p*-value estimated by normal approximation with a continuity correction (*Z*). Cohen's *d* was also calculated (Cohen, 1988). The rows of the table are ordered by the size of Cohen's *d*. Cohen's *d* indicates the size of the difference between the groups in terms of standard deviation units.

- A small effect size is usually around 0.2.
- A medium effect size is around 0.5.
- A large effect size is around 0.8 or higher.

In our case, the pairs in the first to fifth rows of Table 3 can be classified as small differences according to Cohen's *d*. The pairs in the sixth to ninth rows have a medium difference according to Cohen's *d*. The last two pairs, representing the results in 2021 (online exam) and the results in 2022 (standard exam), are significantly different. Surprisingly, the results in 2019 (S_2019, standard exam) and 2020 (S_2020, correspondence exam) are almost identical. Possible procedural reasons for these results are discussed in the following section.

DISCUSSION

As mentioned in the introduction, several factors can influence the results of examinations. It is difficult to determine to what extent the teaching method at the University of Finance and Administration contributes to the results. We do not have the opportunity to assess this sufficiently, as a change in the form of testing accompanied the change in the form of teaching. However, in accordance with the articles cited in the introduction, it can be concluded that the online form of teaching mathematics at the University of Finance and Administration may not have had a major impact on the examination results, as online lectures, in particular, correspond well to standard teaching. It is not a big problem to transmit information online (via camera or graphic tablet) from the teacher to the students and answer any questions. In this respect, no major change has occurred, especially in the part-time form of study, with no seminars.

The seminars present a problem because, in the standard form of teaching, students, under the teacher's guidance, solve examples on the blackboard and independently at their desks. In seminars conducted online, checking student work (calculations on paper) was complicated. In the standard form of teaching, students soon realize that the seminars are about student-teacher collaboration, not teacher rehearsal, and are not afraid to show their ignorance. In the academic year 2020/2021, when teaching was entirely online and students did not come into personal contact with the teacher at all, it was

often difficult to establish such cooperation. Students who were interested in mastering the curriculum had the opportunity to have the problematic parts explained to them, just like in the standard form of study, but many tried to hide their ignorance and avoid contact with the teacher. However, a great advantage compared to the past was the recordings of the lectures, which students could replay as needed.

Overall, it appears that students may have been as well prepared for the exam through the online form of instruction as through the standard form. In this paper, however, we consider how exam results may have been influenced by the form of testing, not the form of teaching. In the first phase, we compared the results of standard testing from the period immediately before the pandemic (academic year 2018/2019) with alternative forms of testing during the pandemic (academic years 2019/2020 and 2020/2021) to determine whether the use of alternative testing methods was adequate under the circumstances. Statistical evaluation shows that online testing results are worse than the standard form. The consistency of results in the correspondence and standard forms of testing is rather surprising.

In the correspondence form of the examination, students had the advantage of being allowed to work on the tests for a few months and had the opportunity to consult the tasks with anyone or have them checked before submission. The examiners were concerned that many students would thus obtain an excellent mark in the exam, regardless of their actual knowledge. On the other hand, the students had a more difficult situation with creating their own tasks, especially with the tougher test assessment. It turned out that many students were satisfied with completing the compulsory part of the test (and not always getting it right) – they did not attempt the extra part for a better grade. This may have been because the extra part consisted of tasks that were the content of the unpresented material, where students were referred to self-study, while the compulsory part was largely taught before the schools closed. However, students may have considered it sufficient to pass the exam regardless of the grade. The fact that the students did not have the same assignment may also have played a role. The concern that, in many cases, someone else authored the test instead of the student was not confirmed. In case of doubts about the authorship of the test, students were asked to take an individual online examination, but these cases were quite rare.

In the online form of testing, students were disadvantaged by the fact that they had not experienced face-to-face teaching at all since the beginning of their studies at the university; teaching was only online. Online lectures, transmitted via a camera or a graphic tablet, were an adequate substitute for face-to-face lectures, and students could replay the recording. However, online learning and computer-based testing may not suit all students. Kemp and Grieve (2014) found that students preferred face-to-face rather than online activities, but there was no significant difference in their test performance on the two alternatives. Boevé et al. (2015) concluded that computer-based exam total scores were similar to paper-based exam scores, but only about a quarter of students preferred a computer-based exam. Mendoza et al. (2021) argue that students' increasing anxiety during the pandemic has significantly affected their performance and that the transition to distance learning led to significant differences in students' understanding of mathematical concepts. Fejfar, Jadrná, and Fejfarová (2021), and Dvořáková et al. (2021) assess the advantages and disadvantages of distance education from the student's perspective.

The online form of the examination may have been more stressful for many students than the standard form of testing. In addition to the fact that they may not have been comfortable being watched by a camera, students may also have been nervous about the potential failure of technology, either during the exam or in copying, correctly formatting, and saving the finished test. Nervousness may have negatively affected the outcome of the exam. Elsalem et al. (2020) report that a third of students find online exams and the associated technical problems more stressful than standard exams. Furthermore, a not insignificant number of cheating attempts were detected. In this case, the result of the test was directly assessed as insufficient. When in doubt, students had to take an individual online examination. A significant factor may be that, unlike in the standard exam, students did not have the opportunity to correct some tasks after the examiner had previously checked them.

Among other studies comparing the results of standard and online exams, we mention in particular those conducted at schools whose focus and mathematics curriculum correspond to the University of Finance and Administration. For example, Klůfa (2021) compares the results of the oral part of the mathematics examination at the University of Economics in Prague, Otavová and Sýkorová (2021) from the same university compare the results of midterm tests, final tests, and final grades depending on the form of teaching and examination. Unlike the results presented in our paper, the online form of testing led to better results than the standard form. In the online form of testing, however, it depends very much on the conditions set; these are not specified in the above articles. For example, if the online exam is not monitored by cameras and students only upload a completed test, the results may be highly distorted due to the possibility of cheating.

The problems associated with cheating in online exams have received considerable attention, regarding proctoring during the exam (Atoum et al., 2017) and subsequent detection (D'Souza et al., 2017). Detecting cheating, however, often involves finding matches with other texts. In the mathematics exam, students work out problems using paper and pencil; checking the independence of their work is more difficult.

The results of research by Moravec, Ječmínek and Kukalová (2022) from the University of Life Sciences in Prague also show that the chances of passing the exam are higher with the online testing compared to the standard face-to-face form. The authors consider the higher success rate in online testing to result from online courses being more effective than traditional face-to-face courses, for example, Elfaki, Abdulraheem and Abdulrahim (2019). However, the authors acknowledge that the results of online testing may be biased due to the impaired ability to ensure cheating-free conditions; in designing the tests, they focused on preventing cheating rather than detecting it. Examination results from different classes were studied, but

multiple-choice tests were mostly used, which are not suitable for mathematics examinations. This may also be the reason for the different conclusions presented in our article compared to the articles mentioned above.

In the second phase, we compared examination results after the return to normal teaching and examination mode (academic year 2021/2022) with previous periods. The average grade in the summer semester 2021/2022 was found to be better than in any of the previous terms examined. Particularly in comparison to the year 2020/2021, when the exams were conducted online, the disadvantages mentioned above of this form may have played a role, especially the impossibility of pre-checking the test. During the summer semester 2021/2022 exam period, the examiners were surprised by the small number of students who failed the exam (grade "F"). In this period, however, a high proportion of students were registered to study the subject Mathematics 2 but did not appear for the exam at all (notation "-"). These were probably mostly students who were aware that they had not mastered the subject matter and would likely fail the exam. It is possible that the fact that probably underprepared students did not take the exam at all contributed to a better average grade.

It turned out that the percentages of students who did not appear for the exam were similar in 2018/2019 (47%) and 2021/2022 (49%), when the exams were conducted in the standard way in both years, as well as in 2019/2020 (35%) and 2020/2021 (35%) when the exams were conducted in alternative forms. In 2019/2020 and 2020/2021, i.e., using alternative forms of testing, the proportion of these students was lower than in 2018/2019 and 2021/2022. This confirms what examiners have already observed during the examination process, namely when alternative forms of testing are employed, students are more likely to attempt to pass the exam even if they are not adequately prepared. This may be due to students feeling embarrassed about displaying their lack of knowledge in a face-to-face setting with the examiner. Additionally, students may be hopeful that cheating will enable them to pass the exam through alternative forms, as demonstrated by Harmon and Lambrinos (2008). In fact, detected attempts at cheating, particularly in the online form of testing, were more frequent than in the standard form of testing. While the greater difficulty of detecting such attempts is a disadvantage of alternative forms of testing, the pandemic has fortunately not resulted in students being able to pass exams on a large scale by cheating.

Although the proportions of students who did not appear for the exam were similar in 2018/2019 and 2021/2022 (the standard examination form in both academic years), insufficient mastery of secondary school content may have also contributed to this in 2021/2022. This year followed the school year during which teaching was affected by the Covid-19 pandemic. At the University of Finance and Administration, mathematics is taught in the first year of study, building directly on secondary school mathematics. This is particularly evident in the summer semester when there is a greater need to use secondary school mathematical tools compared to the winter semester. During the academic year 2021/2022, many students complained about inadequate preparation in secondary school mathematics during the pandemic, when classes were conducted online without prior experience. Consequently, some students gave up studying mathematics at the university and did not even attend classes. This likely also contributed to the number of students who did not attempt the exam at the end of the summer semester and, thus probably, to the better average.

In this respect, the situation might be different for full-time versus part-time forms of study: students of the part-time form usually have a longer time gap since graduating from secondary school, and the problems with teaching during the pandemic mostly did not affect them. Therefore, the exam results from 2021/2022 were compared with previous years for full-time and for part-time students separately. For students of the part-time form, the results from 2021/2022 were consistent with all previous years; thus, the pandemic period did not affect the results for this form of study. In contrast, full-time students performed better in 2021/2022 compared to the pandemic period (with alternative forms of testing), probably because unprepared students did not show up for the exam at all.

Compared to 2018/2019, there was also agreement for the full-time form, as opposed to comparing the overall results without differentiating the form of study. If we were working at the 0.01 significance level, then even for the pair 2021/2022 and 2018/2019, the hypothesis H_0 would not be rejected. What is remarkable about the 2021/2022 exam results, in addition to the best average and low proportion of students failing the exam (grade "F": 8% in 2021/2022, 11% in 2018/2019, 14% in 2019/2020, 31% in 2020/2021), is the high proportion of top grades (grade "A": 29% in 2021/2022, 12% in 2018/2019, 16% in 2019/2020, 12% in 2020/2021). In the academic year 2021/2022, the number of "A" grades is the highest of all grades, unlike all previous periods, including the period with the standard form of examination.

The cause must, therefore, be sought elsewhere than in the form of testing. Such a good result could be due to the fact that students had – in contrast to the standard form of examination in 2018/2019 – recordings of lectures, including repetitions for the exam. According to the students' opinion, this helped them a lot in preparing for the exam. However, recordings of all lectures were also available in 2020/2021, but students did not have the opportunity to pre-check the test online as in the standard form. It is also possible that students approached their studies and exam preparation with more vigour after the tiredness and frustration during the pandemic.

Further research could focus more significantly on issues of potential cheating related to the use of ICT in testing. Here, it is necessary to start with the latest cybersecurity research, for example, according to Rahmani et al. (2021). However, there is a need to focus specifically on the conditions that are suitable for testing in mathematics. Multiple-choice tests are not appropriate, and due to the use of specific mathematical symbols, elaboration on a computer is not appropriate either. It is not possible to use automatic correction and scoring as it is possible in some other subjects (Böhmer et al., 2018). It is neither about creating tests suitable for such use (Ardid et al., 2015) nor about automated online exam proctoring (Atoum et al., 2017). The issue is how to achieve the best possible control in a situation where students work out the tasks classically using pencil and paper and immediately upload a copy of

the final product to the university information system, all without the personal supervision of the examiner.

There are many challenges and opportunities ahead for teachers. Malakeh et al. (2022) review and summarise research examining the impact of the pandemic on online examination globally. They highlight challenges and opportunities for policymakers, educators, researchers, and higher education decision-makers regarding online examinations. Teachers should be prepared for online teaching, but especially online testing, which brings more problems (Kyungmee and Fanguy, 2022). Khan et al. (2021) point to the fact that it is important in further research to pay attention to students' opinions about online testing, which can negatively affect the result of the test, for example, due to anxiety and stress. If online testing will continue to be used, teachers should have better technical facilities at their disposal (Abdelwahed, 2023). For example, online proctoring should help teachers in the future. It has become a necessity in online teaching (Waheeb, 2022).

CONCLUSIONS

The first objective of this paper was to determine whether the alternative forms (correspondence and online) of written examinations in mathematics, applied at the University of Finance and Administration during the Covid-19 pandemic, were a suitable substitute for the standard mode of examination. It turned out that the results in the correspondence form of testing, where students wrote the test almost without time limits and stress, were surprisingly very similar to the results in the standard form of testing. The results in the online form were worse than in the standard form. Possible reasons for these results are analysed in the Discussion section.

While alternative forms of testing are less likely to detect potential cheating, the results presented in this paper suggest that alternative methods did not lead to a higher proportion of completely unprepared students passing the exam. Both alternative forms of testing, as they were conducted at the University of Finance and Administration, can, therefore, be considered acceptable substitutes for standard testing in this regard. Although the correspondence form matched the results of the standard examination better than the online form, the correspondence form can only be considered an emergency solution because of the very low possibility of checking for cheating. However, if it is not possible to test in the standard way, the online form of testing is acceptable.

The second objective was to assess the results of the examinations after the return to the normal mode of teaching and the standard method of examination. Our research revealed that during this period, more students did not attempt to pass the exam at all. On the other hand, among the students who did pass the exam, there was a significant preponderance of those who were excellently prepared. The number of students who failed the exam was minimal. It appears that students adopted a more responsible approach to taking exams after returning to normal – those who were unprepared did not try to take the exam, while those who were prepared did so excellently. Although adopting hybrid teaching is likely inevitable in the future and beneficial for many subjects, the standard face-to-face form seems to be the most suitable for the written examination in mathematics.

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