2023-10-10

Changes In First-Year Engineering Students' Performance In Mathematics And Engineering Subjects At Different Stages Of Distance Learning

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CHANGES IN FIRST-YEAR ENGINEERING STUDENTS' PERFORMANCE IN MATHEMATICS AND ENGINEERING SUBJECTS AT DIFFERENT STAGES OF DISTANCE LEARNING

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Conference Key Areas*: Fundamentals of Engineering: Mathematics and the Sciences*
Keywords*: Mathematics in engineering, Covid-19, drop-out, productivity, engineering students*

ABSTRACT

Covid pandemic was unprecedented in modern education but is not expected to be unique, therefore increased attention should be paid to accurately analyse its effects on education. Calculus is an important undergraduate mathematics course in engineering programmes, which gives the foundation for engineering subjects like mechanics or electronics. Unfortunately, recent experiences show that the performance of students admitting after the pandemic has deteriorated dramatically in recent years.
This research aims to analyse the changes in performance and attitudes of first-year students in the aftermath of the pandemic. In our research, we investigated the performance and learning habits of three groups of first-year mechatronics and energy engineering students during Calculus-1 and the related Mechanics subject.
The “2018 group” studied maths traditionally, whereas the “2020 group” took online education in the last months of high school and the first year of university. The “2022 group” spent two years of high school at home in remote learning (the significant 10-11th grades, for maths competence), but received in-person education at the

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university. Learning habit and performance of the students were monitored using EduBase online educational platform.
The results of both the qualitative and quantitative analysis have revealed that online education during the pandemic changed the learning habits of the group in 2020 and had only slight effects on their performance in Calculus and Statics. However, for group 2022, where the pandemic affected high-school maths studies, the performance at the university has fallen dramatically resulting in an increased drop-out rate after the first semester.

1 INTRODUCTION

Covid pandemic was unprecedented in modern education, but is not expected to be unique, therefore increased attention should be paid to analyse its effects on education accurately. At the peak of the Covid-19 pandemic, more than 1.6 billion students were affected by school closures worldwide. Our experiences with the current situation may be helpful in the event of similar cases. As part of the Memory of the World (MoW) Programme, UNESCO (2020) has called on Member States to increase the documentation of information on Covid. Four key areas have been identified: documents based on educational, social, scientific and artistic values. In response to this call, several studies have been published, and it is widely accepted that lock-down cause significant losses in education (UNESCO 2020), (Kuhfeld and Tarasawa 2020), (Kuhfeld et al. 2020).
There are serious concerns that short-term learning losses experienced immediately during the lockdown and online education may continue to accumulate as students return to school, leading to significant and lasting losses. Andrabi et al. analysed the effect of the earthquake of 2015 in Pakistan four years after the earthquake, comparing households close to the fault line with those further away that was not affected by the earthquake. Schools in the affected area were closed for an average of 14 weeks. Four years later, however, children living in the affected areas were not only three months behind but had the equivalent of a 1.5-year lack of schooling (Andrabi et al. 2021)

1.1 The effect of Covid on engineering higher education

Several analyses have also been published on the impact of the COVID-19 epidemic on university education and students' performance. The lockdown and online education have particularly affected engineering programmes with a large number of laboratory and practical subjects, which are effective in a traditional, face-to-face format. One of the most important aftermaths was the decrease in knowledge levels. Online teaching made it difficult for students to concentrate, and many found it difficult to adapt to the digital learning environment. The lack of interactivity and relationships between students also had a negative impact on students’ mental state and learning outcomes. After the lockdown of the dormitories, many students felt isolated and had fewer opportunities for social interaction. Emotional stress and loneliness also affected the students' mental health.
Additionally, institutions were not sufficiently prepared to detect fraud following the sudden changeover. In several cases, this led to exceptionally good results compared to previous years.
However, the impact of the Covid pandemic varied between different groups of students. Students who had financial difficulties or who did not have a suitable learning environment (e.g. internet access, IT devices) at home faced greater challenges than those who had better a comfortable learning environment at home.

In the recent study of Kaffenberger the long-term effects of Covid are investigated on the education system (Kaffenberger 2021). Kaffenberger attempts to make predictions about the long-term consequences that the education system may face due to the learning disruption caused by the pandemic. It is predicted that learning disabilities may have long-term effects on student achievement and social inequality. The article suggests measures that should be taken to avoid such long-term consequences, including digital education, expanding educational services and improving educational infrastructure, which could improve student achievement and reduce social inequalities.

1.2 Motivation and goals

In Hungarian higher education Calculus is the most important undergraduate mathematics course in engineering programmes, which gives the foundation for engineering subjects like mechanics or electronics. It is important to mention that in Hungarian engineering higher education, Calculus is typically taught over 3-4 semesters, and includes also topic of algebra, linear algebra and differential equations. Unfortunately, recent experiences show that the performance of students admitting after the pandemic has deteriorated dramatically in recent years.

In our research, we investigated the results and learning habits of three different groups of first-year mechatronics and energy engineering students during Calculus-1 and the related subjects in Mechanics: i) the “2018 group” called pre-COVID, ii) the “2020 group” called COVID-group with online education and iii) the “2022 group” called post-COVID group.

In 2018 the “pre-Covid” students’ secondary school and first-year university studies were not affected by the pandemic. The class of 2020 received online education from March to May in their final year of high school, and this continued in their first year of university. The third group started university in 2022 in attendance education and received online education in the last two years of high school. These two years are when Hungarian students can choose the two subjects that are relevant for their further studies and study them in higher contact hours in advanced level.

In Hungary, the university admission procedure is partly similar to that in many Central and Eastern European countries, as students take a nationally standardised A-level exam at the end of secondary school. Each university determines which subject results are accepted during the admission process. In engineering higher education, this is typically physics, computer science or chemistry. The aim of the A-level exam is therefore to test the knowledge required for the chosen higher education programme. The A-level exam can be taken at advanced or intermediate level. The results of the A-level exams are converted into points and, together with the additional extra points (e.g. for language certificate, national competitions), are evaluated on a 500-point scale.

In the first week of the semester, first-year students at our university take a mathematics entrance test consisting of 15 four-point multiple-choice questions from the level of the intermediate mathematics examination. For the first semester Calculus in Mechatronics, the minimum score required is 25 points.

2 DATA

In this study, three different classes of the mechatronics and energy engineering courses were investigated through their performance and learning habits in the Calculus 1 course. The number of groups and the results of the admission and entrance tests are summarised in Table 1 and Fig. 1.

Table 1. Participants of the investigated Calculus 1 course

	2018	2020	2022
Number of students	120	134	173
Average entrance points	458.62	445.96	454.71
Standard deviation of entrance point	23.22	30.20	26.78
Average of entrance test (Test 0)	39.38±10.71	46.02±8.84	36.14±12.04
Percentage of Passed at Test 0	12%	97%	18.5%
Percentage of Failed at Test 0	88%	3%	81.5%

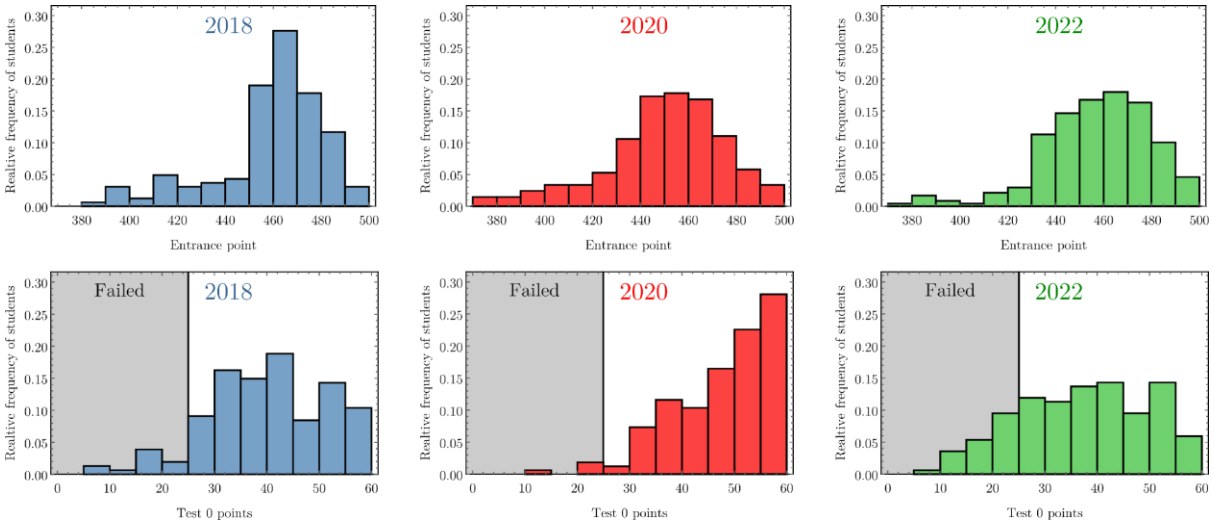

Fig. 1. Relative frequency of a) entrance points and b) entrance test (Test 0) results for all classes 2018, 2020 and 2022

2.1 The "2018 group" – pre-Covid

In the class of 2018, 118 students were admitted to mechatronics (admission point: 451) and 46 to energy engineering (admission point: 389) programmes. The students included in our study are those who took the basic Calculus 1 course. This means 120 students with an average admission score of 458.62 points and a standard deviation of 23.22 points.

Since nearly all students studied mathematics at an advanced level in high school and furthermore, many of them took advanced A-levels, thus they had no problem in meeting the 40% minimum on the entrance test (Test 0). Only 12 students failed to achieve the required 25 points.

2.2 The "2020 group" – Covid

In the class of 2020, 162 students were admitted to mechatronics (admission point: 433) and 77 to energy engineering (admission point: 349) programmes. The students included in our study are those who took the basic Calculus 1 course. This means 134 students with an average admission score of 445.96 points and a standard deviation of 30.20 points.

This year, students took the mathematics entrance test (Test 0) online in their homes using the Moodle system of the University. The results were unlikely too good. More than 50% of students got excellent results (above 85%). Only 4 students scored below 40%, one of whom achieved 100% on the make-up test, also online. The results of this assessment cannot be considered relevant to our study.

2.3 The “2022 group” – post-Covid

In the class of 2022, 227 students were admitted to mechatronics (admission point: 429) and 73 to energy engineering (admission point: 348) programmes. The students included in our study are those who took the basic Calculus 1 course. This means 173 students with an average admission score of 454.71 points and a standard deviation of 26.78 points.
In 2022, the entrance maths test (Test 0) was very poor. Out of 173 students, 32 students failed to score at least 25 points on the in-person test. However, on the several make-up possibilities, most students passed this test. This year was the first time that students who had not studied advanced mathematics in high school.

3 RESULTS

The EduBase online learning platform, which has been used successfully in mathematics education for almost 10 years, allows us to monitor not only the effectiveness of our teaching but also the time students spend learning (www.edubase.net 2023), (Szilágyi et al. 2020), (Berezvai et al. 2019). Both interactive exercises and homework assignments from calculus subjects are available through EduBase. Students receive homework assignments on a weekly basis and also have the possibility to do further exercises. As we have parameterised exercises, a virtually infinite number of exercises are available in any topic of the subject. In a previous study, we analysed the variation of practice time for the first-year class of 2020 and it was found that the average time did not decrease as the semester progressed, in contrast to the pre-pandemic experience, when students did not have enough time to practise in the last weeks of the semester and only did homework (Sipos et al. 2022).

In 2016, with the introduction of EduBase in Calculus education, the aim was to change students' campaign-like learning habits (reduced to the days before tests and exams) and move them towards distributed learning pattern (where the student works on the course material during the whole semester, preferably several days a week).

3.1 Analysis of learning habits

In each of the following figures, the blue colour indicates the “pre-Covid class” starting in 2018, the red colour the “Covid class” starting in 2020 and the green colour the “post-Covid class” starting in 2022. The figures illustrate how the Calculus 1 homework submissions and learning times evolved throughout the three investigated semesters.

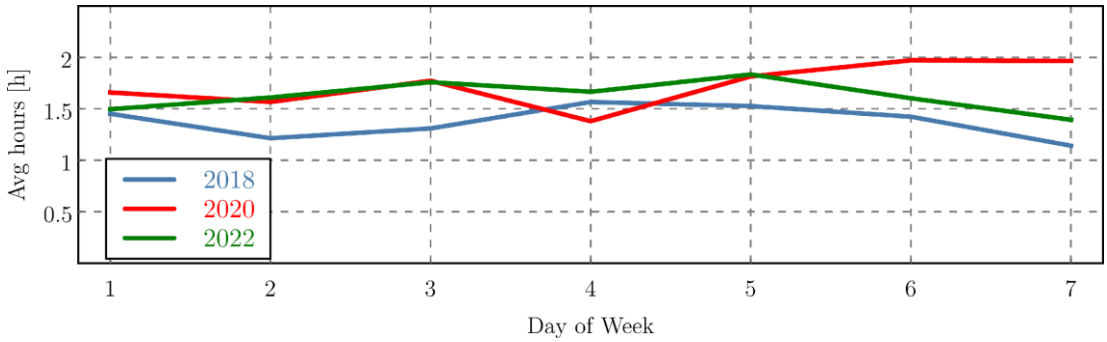

Fig. 2. Average time spent on homework per day of the week for each class

Figure 2 shows the average time spent on solving homework by day of the week. It can be clearly seen that the classes affected by Covid (2020 and 2022) spent more time on solving homework, which can be explained by the weaker input parameters

(incomplete basic knowledge, lower average skills, lower admission scores). Note that the pre-Covid and post-Covid classes show a similar trend. During the pandemic, weekends were merged with weekdays. The elimination of weekend social and family programs increased the probability of solving homework on weekends.

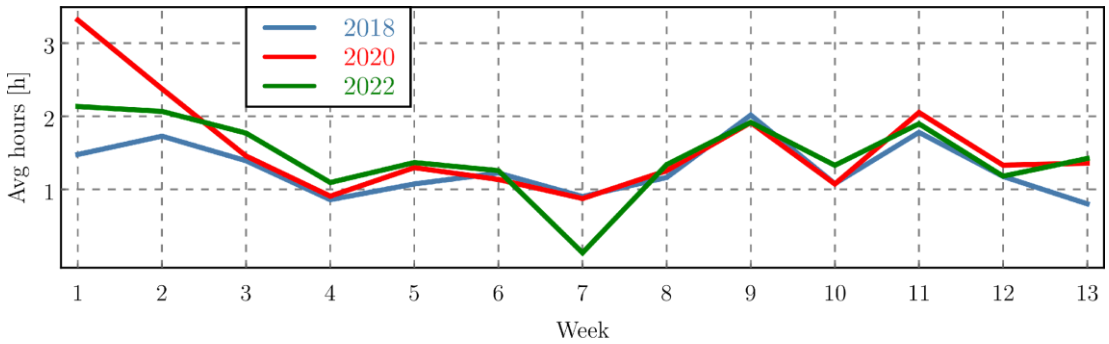

Fig. 3. Average time spent on homework per week of the semester for each class

Figure 3 shows the time spent on solving homework by week during the semester. The high learning time of the first week of the 2020 class (red curve) is related to the topic of Analytic geometry, which covers a lot of the material from high school and which was emphasized in the online high school education and therefore, students needed more time to complete their homework in comparison to the other classes. The low value of the 7th week for the 2022 (green) group can be explained by the fact that there are midterm tests in almost all subjects, and for this group this became so stressful that there was less time to complete regular homework.

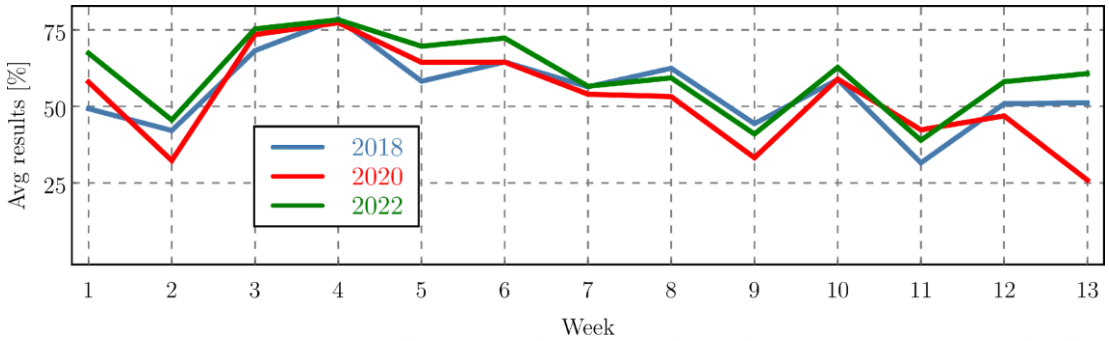

Fig. 4. Average performance of homework per week of the semester for each class

Figure 4 demonstrates the effectiveness and shows interesting results that might seem contradictory. It is perhaps surprising to see the relatively good performance of the "2020 group" most affected by the pandemic. Still, it is worth looking at this in conjunction with Figure 5, which shows the proportion of homework submitters as a function of time. For the Covid group (red curve), it can be seen that the number of submissions is decreasing, and the success rate is also lower. For them, however, we found that the practising throughout the semester was balanced, which may explain the smaller drop in their performance on the tests.

Figure 6 shows the percentage of days on which students submitted the most homework. It can be seen how the pre-Covid (blue) and post-Covid (green) groups tend to deal with homework immediately before the Monday deadline, while the Covid group (red) had a higher submission rate after the seminar days (Wednesday and Thursday). This can be explained by the heavy workload during the year, with many contact hours. During in-person education, our students usually spend a lot of time on campus. Looking also at Figure 2, it can be seen that on a daily basis, students

studying in attendance spent more time completing the homework on weekdays and left the submission for the weekend.

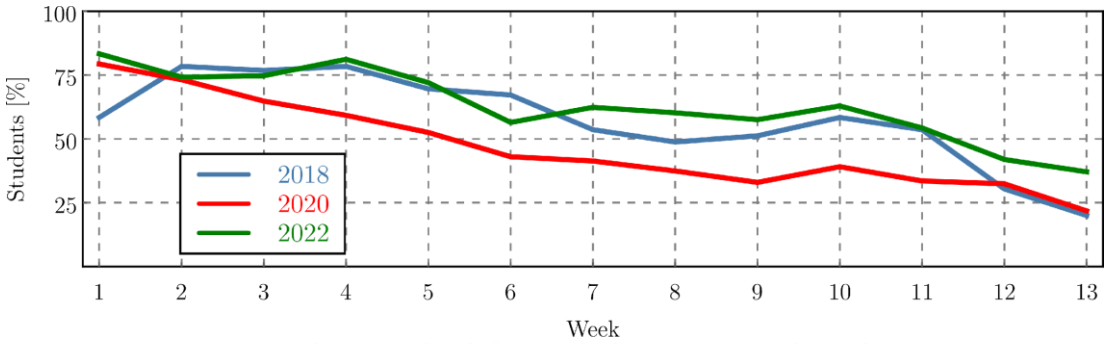

Fig. 5. Percentage of students submitting solutions per week of the semester for each class

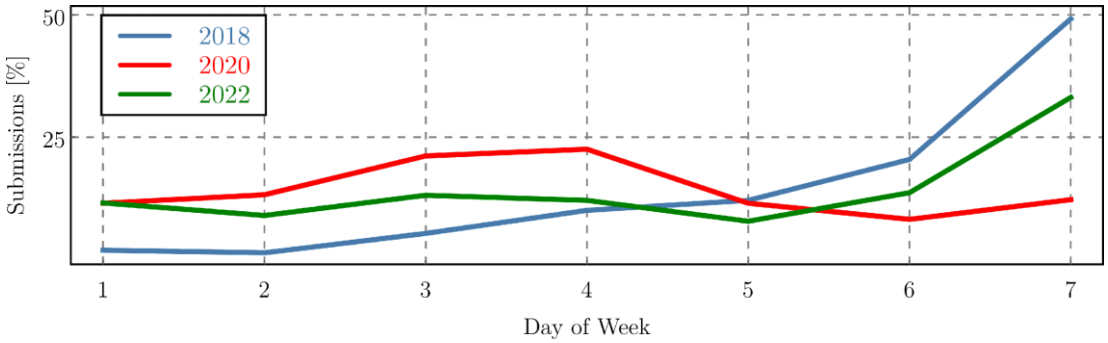

Fig. 6. Percentage homework distribution per day of the week for each class

3.2 Analysis of performance

In the following, the performance of each class was assessed using Calculus and Statics results. Statics is also a mandatory course in the first-year curriculum, which covers the basics of Mechanics including the concept of force-systems, equilibrium, stress-resultants etc. This subject is considered to be most “Math-based subject” as the students are expected to apply the mathematical techniques, they learned in Calculus 1 when solving statics problems, (e.g.: 3D vector operations for force system reduction, differentiation and indefinite integration of stress resultant functions, definite integration for centre of mass calculations). Statics tests always consist exclusively of numerical problems, which can be used to test not only mechanical but also mathematical knowledge. The statistical results of each test are summarized in Table 2. In Figure 7, the first two rows show the results of the first and second tests in Calculus 1, while the last two rows show the results of the first and second tests in Statics (there was no second test in Statics in 2020). If we compare the distribution of the test results and the entrance point distribution in Figure 1, it can be clearly seen that there is an increasing spread in the admission scores, which also means that the knowledge of the cohort is becoming more heterogeneous. The negative effect of the pandemic is clearly visible in the Calculus 1 results. The distribution of the pre-Covid and Covid year classes is still similar, but a slight difference in the mean value is observable. For the post-Covid group, a significant increase in poor results is clearly detectable. For the first Statics test, we also see an increase in the proportion of poorer results. Whereas for Statics Test 2, the results are notably different from the others: the post-covid results show a small improvement compared to the pre-covid results. This deviation is due to two reasons: i) Test 2 usually consists of easily algorithmizable

tasks, and ii) after the failures in Test 1, students were given extra preparation materials and online practicing opportunities as an intervention, which could have helped them to reduce the deterioration of the results.

Table 2. Statistics of the Calculus and Statics test results

		2018	2020	2022
Calculus Test 1	Average	64.14±14.17	47.08±17.29	41.89±24.15
	Failed	4.16%	30.93%	40.31%
	Good result	30%	11.04%	10.47%
Calculus Test 2	Average	61.61±17.43	55.02±18.56	25.07±21.03
	Failed	5.83%	13.25%	69.10%
	Good result	21.66%	23.21%	2.09%
Statics Test 1	Average	68.16±18.82	61.50±26.13	51.27±23.89
	Failed	5%	17.29%	30.81%
	Good result	49%	39.84%	23.25%
Statics Test 2	Average	53.36±27.47	N/A	58.57±29.52
	Failed	27%	N/A	23.12%
	Good result	30%	N/A	45.08%

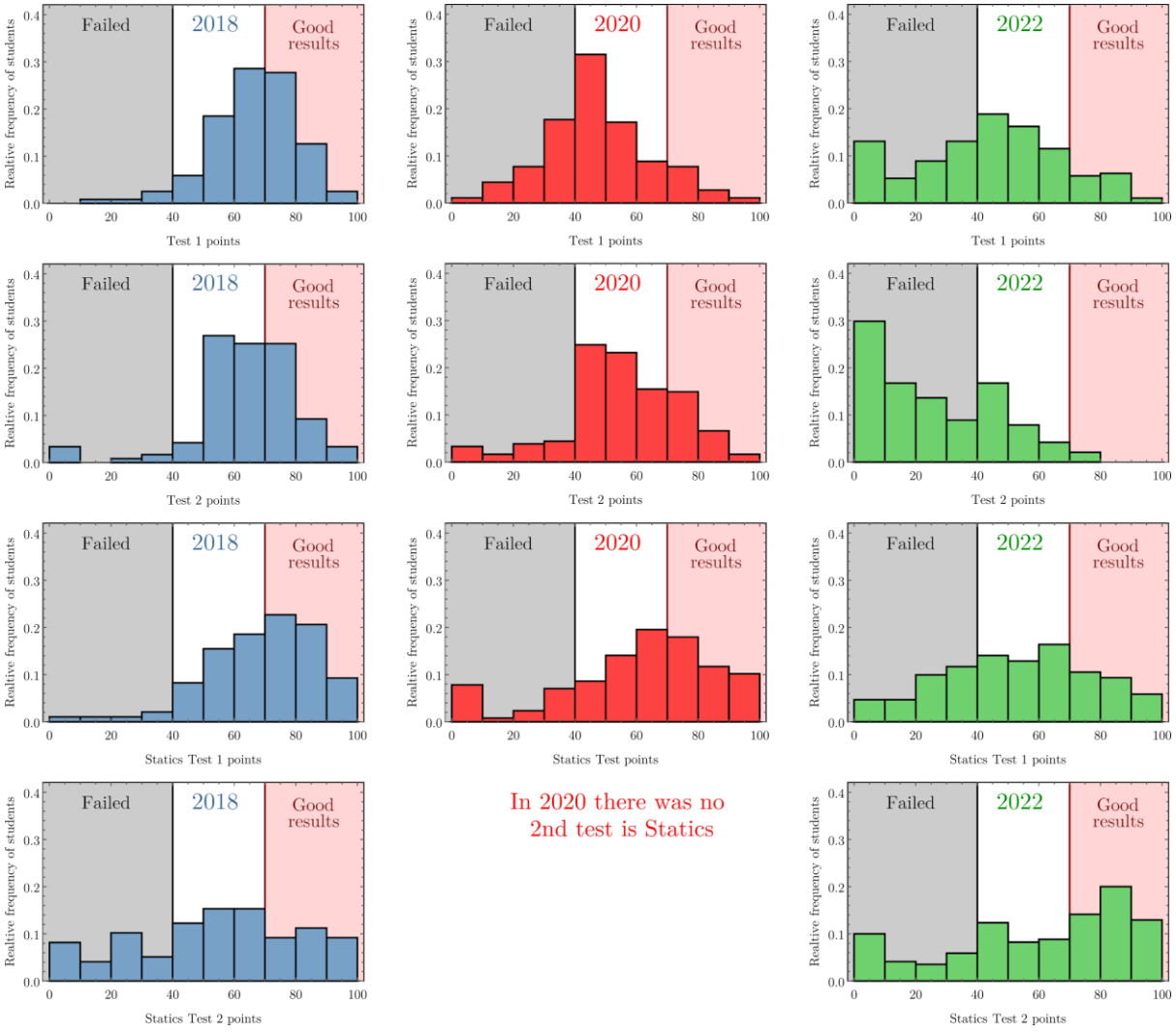

Fig. 7. The relative frequency of Calculus and Statics test results

4 CONCLUSION

In our paper, the impact of the pandemic on three different groups of students was revealed. It can be concluded that Covid has a severe and a long-term impact in engineering higher education. Since online education affected the entire school system, the effect of Covid due to the insufficient mathematical education in elementary or high school will be a long-lasting phenomenon in the future. However, we cannot stop at detecting the effects, and we need to take measures to reduce the negative impacts. At the Budapest University of Technology and Economics, we see the need to provide a catch-up course in addition to the self-study materials, which. have already been implemented in the spring semester of 2023. The analysis of the results is still ongoing as the semester is not finished yet, but the first impressions shows that the intervention had a promising result and seems to be an adequate help to compensate for the handicap caused by the pandemic.

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