INTERVENTION IN ENGINEERING STUDENTS' MATHS EDUCATION TO OVERCOME THE AFTERMATH OF DISTANCE LEARNING

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ABSTRACT

During the pandemic, many people in secondary school failed to acquire solid and profound knowledge. Teaching maths in remote education with distance learning has been a challenge for both teachers and students. In engineering higher education, several years after the pandemic, we are seeing problems that are having an impact on the overall education not only in the basic subjects but in further engineering subjects. There is a need for an intervention programme that can be applied effectively in large-scale courses where the number of students exceeds 100. Recently, we have created supplementary courses to help students learn the advanced Calculus material more effectively, while ensuring that they can catch up with their secondary school knowledge at their own pace.

This research aims to analyse the changes in student performance of first-year student during the first two semesters of university math courses (Calculus 1 and 2). In our research, we investigated three different groups of students: the “2018 group” studied math traditionally, while the “2020 group” took online education at the end of high school and at the beginning of their university studies. Finally, the “2022 group” spent

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two years in high school at home in distance learning but started in-person education at the university and had significant problems during the first semester. Therefore, those students participated in an intervention programme. The performance analysis after Calculus 2 shows that we have succeeded in developing an inclusive pedagogical programme that we intend to further develop in the future to reduce drop-out.

1 INTRODUCTION

The effects of the pandemic were immediately felt in higher technical education. Courses with more practical elements during online education had to be significantly transformed. Laboratory exercises could not be held, so students did not gain hands-on experience. During online education, these exercises were almost completely eliminated, which caused serious difficulties for students. After the end of the quarantine, our university offered students the opportunity to make up missed measurements in certain subjects during the summer, but these blocked classes were less effective. This was also confirmed by several recent studies several studies have been published, and it is widely accepted that lock-down cause significant losses in education, (Kuhfeld and Tarasawa 2020), (Kuhfeld et al. 2020), (Kaffenberger 2021).

Another consequence of the sudden closures was that, on more than one occasion, incomplete, quickly put-together teaching materials were produced, which did not really serve independent distance learning. Many had difficulty in preparing themselves from these materials. There were also students and teachers who did not have adequate technical infrastructure, which also hindered effective learning and teaching.

In addition to the short-term effects of the pandemic, we are also facing very serious long-term effects. It is clear from the results of the usual input measures for first-year students that they are experiencing difficulties that cannot be remedied in a short period of time. We need to use intervention procedures that effectively support students' learning processes and thereby improve educational outcomes. The book, edited by Kelum A.A. Gamage, reviews and synthesizes the findings of the international literature on the impact of COVID-19 on global higher education (Gamage, 2022). In the book containing 18 publications edited by Arday, research and data from 16 countries and 5 continents explore the far-reaching impact of Covid-19 on global higher education (Arday, 2022). While, Katsamunska analyses the reaction of the government and higher education stakeholders to the measures implemented in Bulgaria (Katsamunska, 2023).

Programmes providing targeted assistance need to be those that can be delivered to large student populations. Providing online learning resources is such, but they cannot replace face-to-face teacher-student interaction. Intelligent interactive learning interfaces are particularly useful when they personalise learning material and tasks according to the progress of the students. Providing opportunities for group learning and pair learning is also effective. In 2022, we have designed a new intervention programme for our first-year students to help them better adapt to the academic environment, improve their academic performance, and successfully navigate the educational challenges.

1.1 Motivation and goals

This research project is the continuation of our previous research that was presented in the SEFI conferences in 2022 and 2023 (Sipos, 2022), (Berezvai, 2023). In these studies, we analysed the changes in the learning habits and performance of three groups of students: a pre-Covid, a Covid and a post-Covid groups, respectively. It was concluded that in the post-Covid group a significant change was observed in the online learning habits, namely that students spent more time on online learning, but a significant increase in poor results is clearly detectable. Calculus is the most important undergraduate mathematics course in all engineering programmes in Hungary, which aims to ensure the required mathematical foundation for the further engineering subjects. It should be noted that Calculus is typically is taught over 3-4 semesters and includes the topics of algebra, linear algebra and differential equations (see Table 1). Therefore, we found it essential to give a response for the decreasing student performances in Calculus 1 course in order to avoid the drop-out for the Calculus 2 course. The main goal of this contribution is to present the intervention that was applied in the "2022 group" during the Calculus 2 course and to analyse its effect on the performance of students.

Table 1. Curriculum of Calculus 1 and 2 courses

	Calculus 1	**Calculus 2**
Topics	Complex numbers Spatial geometry Numerical series Functions Differentiation Integral calculus	Linear algebra Function series Multivariable functions Multivariable calculus

2 DATA

In this study, three different classes of the mechatronics and energy engineering courses were investigated. The number of groups and the results of the admission and entrance tests are summarised in Table 2 and Fig. 1.

Table 2. Participants of the investigated courses

		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
Test 0	Mean and standard deviation	39.38±10.71	46.02±8.84	36.14±12.04
	Percentage of Passed	88%	97%	81.5%
	Percentage of Failed	12%	3%	18.5%

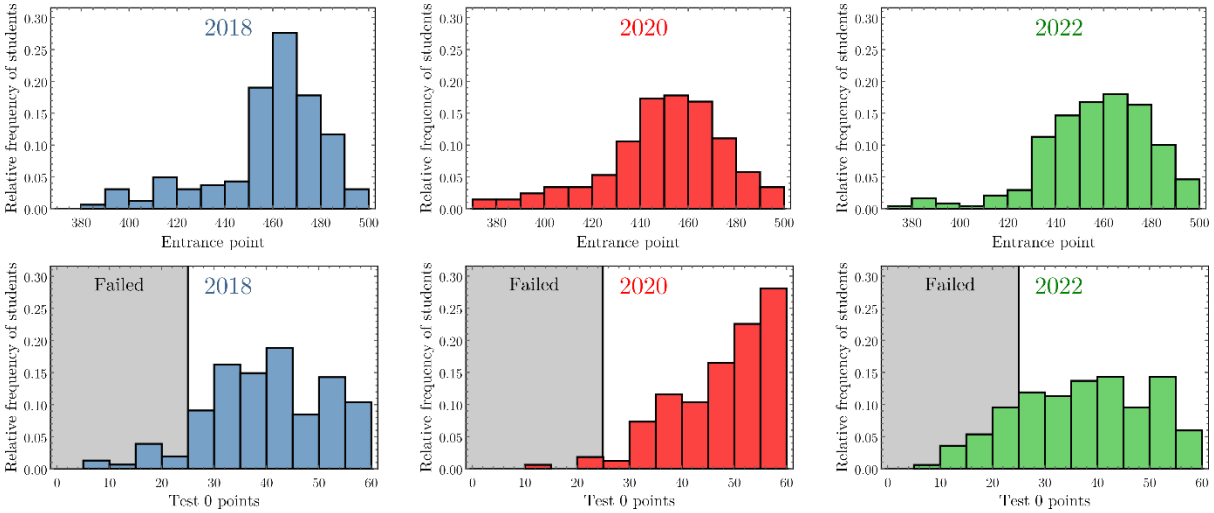

Fig. 1. Relative frequency of a) entrance points (out of 500) and b) entrance test (Test 0) results (out of 60) or all classes 2018, 2020 and 2022 (Berezvai, 2023)

2.1 The investigated groups

In our research three different classes were analysed: the “2018 group” studied math traditionally, while the “2020 group” took online education at the end of high school and at the beginning of their university studies. Finally, the “2022 group” spent two years in high school at home in distance learning but started in-person education at the university and had significant problems during the first semester.

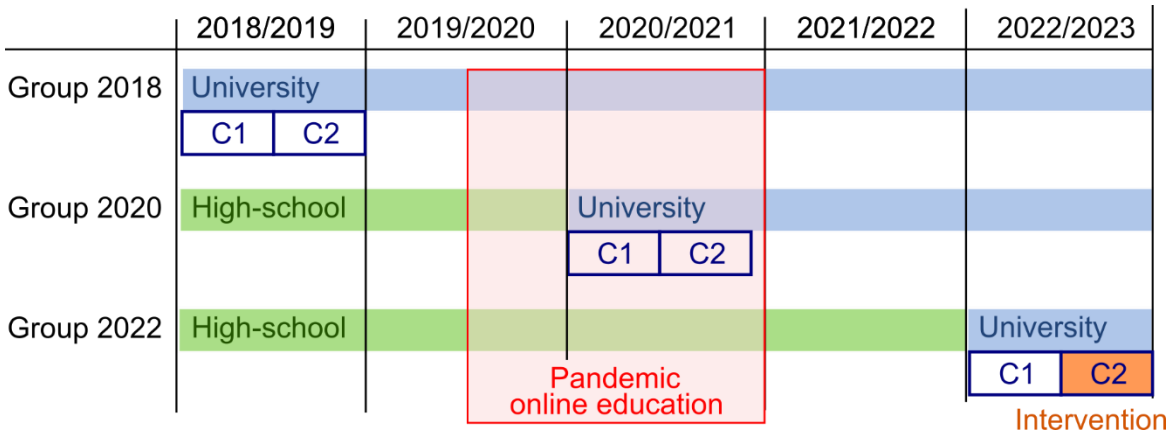

Fig. 2. The temporal distribution of the three groups and the pandemic.
(C1 – Calculus 1 course, C2 – Calculus 2 course)

- **The “2018 group” – pre-Covid**

The class of 2018 consists of 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.

- **The “2020 group” – Covid**

The class of 2020 consists of 134 students with an average admission score of 445.96 points and a standard deviation of 30.20 points. This class received online education

from March to May in their final year of high school, and this continued in their first year of university in remote education. Therefore, the pandemic had very minor effect on their high-school backgrounds.

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.

- **The "2022 group" – post-Covid**

The class of 2022 consists of 173 students with an average admission score of 454.71 points and a standard deviation of 26.78 points. They 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 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. For this group, the Calculus 1 results (see Fig. 3.) showed significant decline, so for the Calculus 2 course an intervention was applied.

3 METHODOLOGY

The failure of a significant proportion of our students to acquire a solid grounding in mathematics during the pandemic in public education was already apparent from the results of the input measures. This was confirmed by both midterm tests written in the first semester (see Fig. 3) and then by the exam results. The failure rate in Calculus 1 test was significantly higher than in previous years, while expectations of students remained unchanged, with a slight decrease. At the same time, the system of university examinations allows you to retake the midterm-tests more than once. In addition, Calculus 2 can be taken by students who have passed all their midterm tests with at least 40% marks, without the need to pass the exam in the exam period.

Since 2016, the Edubase online learning platform serves the basis of our education (www.edubase.net 2024), (Szilagyi, 2020), (Berezvai, 2019). In EduBase students are assigned weekly homework, interactive exercises and also have the option to engage in additional exercises. With parameterized exercises, there is a technically infinite number of exercises available for practising the different topics throughout the semesters.

Despite the availability of much material to help students catch up individually, including the interactive online practice areas with step-by-step guides, students found it difficult to cope. Catching up and keeping up with current material at the same time proved to be too much of a burden. Where individual difficulties varied, it was practical to use online material supplemented by personal consultations, as there was no way to involve more teachers.

The key solution of the intervention was to reinforce the learning, the understanding and mastering of new (previously unfamiliar) topics. For this, a 90-minute extra course per week was scheduled and offered parallel to the regular Calculus 2 course, which was called as Calculus2+. The Calculus 1 and 2 courses consists of 2x90 minutes of lectures a week and a 90-minute-long practical lesson of problem-solving.

For the Calculus2+ course, we have developed a material that helps to illustrate the theory taught in the lecture through example solutions. In these classes, all students of the class participated together, the lecturer showed examples related to the weekly curriculum and explained the methodology of problem solving. Thus, the students arrived at the problem-solving practical lessons much better prepared, with more opportunity to work independently or in pairs. Group work and pair work help to increase learning efficiency, help students overcome anxiety, motivate them to talk, increase their confidence and develop their social skills. Students can discuss ideas, share knowledge and learn from each other. This can lead to a deeper understanding of the subject matter (McDowel, 2003) (Williams, 2000).

Previously, we had to use face-to-face, frontal teaching on these occasions, because the large amount of material only allowed the instructor to present the basic types of problems that were to be solved each week. The students were then rather passive participants in the lessons. With the new extra Calculus2+ lessons, the additional 90 minutes served as a slower-paced presentation of the similar problems.

4 RESULTS

In the following the statistical summary of the Test results are presented for Calculus 1 and Calculus 2 courses for the three investigated classes (see Table 3. and Fig. 3). The number of students in each course shows that, although there is a high failure rate on the first attempts, only a small number of students dropped out and failed to continue in Calculus 2 due to the many remediation opportunities. Thus, improvement in results is attributed to the outcome of the intervention, not the filtering in Calculus 1.

In Figure 3, 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 Calculus 2. The results clearly show, that after the well-observable decline of performance in 2022 for Calculus 1 course, a significant improvement of results were detected as result of the intervention. This not only means that the mean value of the tests are improved, but also the standard deviation decreased compared to the Calculus 1 results. This means that the extra Calculus2+ course also had beneficial effects on the heterogeneity of the group.

Table 3. Statistics of the Calculus 1 and Calculus 2 results for all investigated classes

			2018	**2020**	**2022**
Calculus 1	Number of students		120	181	191
	Test 1	Average and SD	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%
	Test 2	Average and SD	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%
Calculus 2	Number of students		112	161	161
	Test 1	Average and SD	59.76±16.72	58.22±15.61	65.27±16.38
		Failed	12.5%	15.61%	9.31%
		Good result	21.42%	23.61%	41.61%
	Test 2	Average and SD	69.68±19.08	45.04±15.33	65.33±20.24
		Failed	4.46%	31.67%	8.69%
		Good result	48.21%	3.1%	47.82%

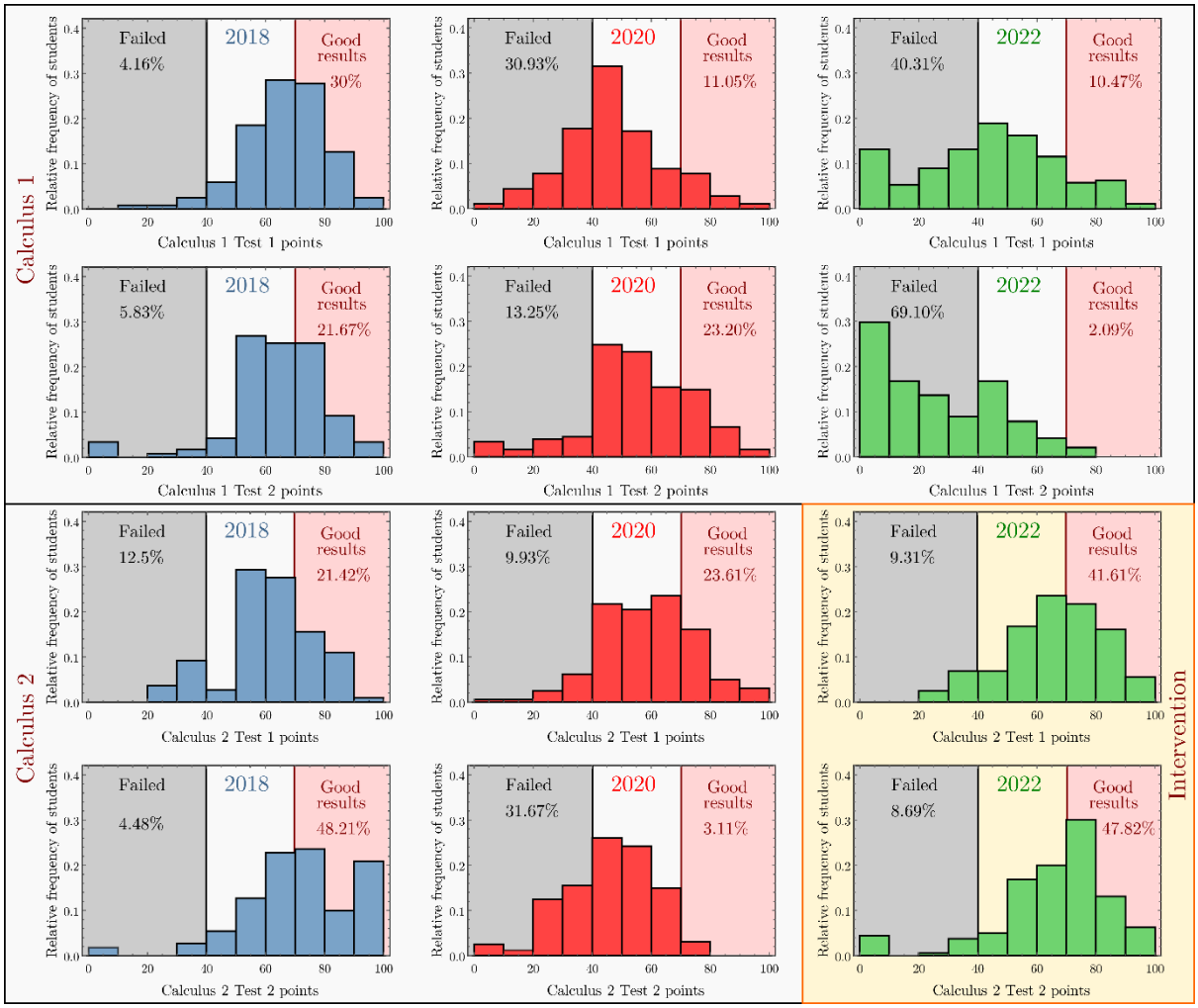

Fig. 3. Relative frequency of Test 1 and 2 in the Calculus 1 and 2 subjects.

5 CONCLUSION

The results illustrate the effectiveness of our intervention programme. It is natural that by increasing the time spent on lectures and learning, our students will achieve better results. However, what makes our results worth mentioning is to show that such a simple intervention can make a difference. Nowadays, frontal teaching is almost a buzzword, even though in many higher education institutions there is no way to provide assistance in small courses, there are not enough instructors and facilities to provide additional small classes. In a university where there are thousands of students per year to be taught effectively, economic issues become an important aspect to be considered. A good combination of large numbers of students and small numbers of students with the opportunity for greater interactivity can provide an economically optimal solution.

Our experience also highlights the importance of the role of the teacher in education. Mathematics is not easy to learn independently, especially for those who have difficulties. The importance of teacher competence may sound trivial, but it was the pandemic that showed that when students were not allowed to go to school, teachers could not help as much, despite the online learning platforms and available digital

sources. We can say that students must first be prepared to be able to learn independently. The programme we have developed helps them to do that.

By increasing the number of contact hours, students were able to make more effective use of the interactive, online practice materials, and therefore achieved better results. This form of support was more effective than if we had given our students more material to work on independently.

In the future, we see it as an important task to show students the benefits of increased contact hours at the beginning of their programmes. In the future we aim to extend this method by proposing an extra course immediately after the entrance test based on their measured knowledge, and therefore trying to reduce the trauma of initial failure.

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