2023-10-10

A Possible Solution To Avoid The Consequences Of The COVID-19 Pandemic And Reduce Dropout In Calculus Education

Brigitta SZILÁGYI
Budapest University of Technology and Economics, Hungary;Corvinus University of Budapest;MTA–ELTE Theory of Learning Mathematics Research Group, szilagyibr@gmail.com

Csaba SZABÓ
Eötvös Lorand University;MTA–ELTE Theory of Learning Mathematics Research Group, csaba@cs.elte.hu

Anna KOÓS
University of Utrecht, panni.koos@gmail.com

See next page for additional authors

A POSSIBLE SOLUTION TO AVOID THE CONSEQUENCES OF THE COVID-19 PANDEMIC AND REDUCE DROPOUT IN CALCULUS EDUCATION

Brigitta Szilágyi[1]
Budapest University of Technology and Economics, Budapest, Hungary
Corvinus University of Budapest Budapest, Hungary
MTA–ELTE Theory of Learning Mathematics Research Group

Csaba Szabó
Eötvös Loránd University
MTA–ELTE Theory of Learning Mathematics Research Group

Anna Koós
Utrecht University

Bence Sipos
Budapest University of Technology and Economics, Budapest, Hungary
MTA–ELTE Theory of Learning Mathematics Research Group

Conference Key Areas*: Mentoring and Tutoring, Fundamentals of Engineering: Mathematics and the Sciences*
Keywords*: catch-up, calculus, drop-out, COVID-19*

ABSTRACT

The effects of the COVID-19 are likely to stay in education for a long time to come. First year students of 2022 have completed the last two years of their high school education, which are the most important for further studies, during the worst period of the pandemic. Compared to previous years, far fewer students were able to meet the requirements of Calculus 1. Although there was a wide range of support material (interactive online interface, films, notes, elaborate calculation exercises) available to the students, they were not able to catch up and progress independently, regardless.
The calculus course consists of 2×90 minutes of lectures and 90 minutes of practice per week. The lectures are attended by all the students in the year's batch - nearly 200 students - while the exercises are done in groups of 35. In the second semester we introduced a new course for Calculus 2. The 90 minute per week course provides an opportunity to introduce routine calculation methods and thus provide more personalised teaching in small group sessions. New course gives a chance to understand Calculus 2, and thus could reduce the dropout rate.

[1] *Corresponding Author: Brigitta Szilágyi*
szilagyi@math.bme.hu

In our research, we investigate the effectiveness of this new intervention. We analyse student satisfaction. We will examine the extent to which such a cost-effective intervention helps students to acquire a solid mathematical foundation so that they can successfully overcome obstacles in their studies with less help in the future.

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1 INTRODUCTION

1.1 Pandemic

Several studies have analyzed the short- and long-term effects of the pandemic. (Kaffenberger 2021, Azevedo et al. 2021, Sipos et al. 2020). We are still faced with the long-term effects. Learning loss is the loss of knowledge and skills that can occur when students are not able to attend school regularly or receive high-quality instruction. During the COVID-19 pandemic, many students around the world were forced to learn remotely or miss school altogether, which could lead to significant learning loss in mathematics and other subjects. The long-term impact of this loss could be felt in lower test scores, reduced opportunities for higher education and career advancement, and increased socioeconomic inequality. The shift to remote learning during the pandemic highlighted existing disparities in access to technology among students. Students from lower-income families or those living in rural areas may not have had access to the same quality of computers, internet connections, or other resources as their wealthier or urban counterparts. This could exacerbate existing inequalities in education and limit opportunities for some students to succeed in mathematics and other subjects. With the pandemic disrupting traditional teaching methods, many schools may have had to make changes to the mathematics curriculum in order to adapt. These changes could have long-term effects on students' understanding of mathematics and their preparedness for future coursework and careers. With remote learning becoming more widespread during the pandemic. This could lead to a more permanent shift towards online learning, which could have both benefits and drawbacks for mathematics education. While online learning can offer greater flexibility and accessibility for some students, it may also change the way mathematics is taught and learned in ways that are not yet fully understood.

Knowing the above, we can formulate the following research questions: *How can the harmful effects of the epidemic be reduced in education? How could the learning and teaching of mathematics be made more effective and dropout rates reduced?*

2 DATA

In our study, we present our efforts to address the decline in student performance, which is likely due, in part, to the pandemic. The subjects of our investigation were students who started their undergraduate studies in mechatronics engineering and energy engineering in 2022. Admission to these programs requires high scores, with mechatronics engineering requiring 429 points and energy engineering 348 points out of a maximum of 500 in 2022. The majority of these students enrolled at the Budapest University of Technology and Economics following

high school graduation. Consequently, their high school education during the 10th and 11th grades was significantly affected by the pandemic, the impacts of which we observed upon their arrival.

Prior to the beginning of the semester, we administered several entrance evaluations, including tests in mathematics, physics, and an assessment of their geometric thinking skills using the van Hiele test. (Usiskin 1982) The outcomes of these tests were substantially lower compared to the scores achieved by students in the same disciplines in previous years. As we commenced the semester, we offered remedial learning opportunities, such as self-paced online materials and structured courses. Nonetheless, students had to engage in these supplementary learning activities alongside their first-semester coursework. This created a substantial workload for some students, as they were required to attend remedial courses in both mathematics and physics.

Consequently, it is not surprising that this cohort also performed considerably weaker in the first-semester calculus course, which includes differential and integral calculus of single-variable functions, compared to previous cohorts. (We have data on mechatronic and energy engineering students who started their university studies in 2018, pre-pandemic, and 2020, during the pandemic.) It's important to mention those students who selected mathematics in the last two years of high school to be studied for five hours a week instead of the regular three, as well as those who attended special curriculum classes in mathematics, had already learned a significant part of the Calculus1 course material in high school. Unfortunately, our experience over the years is that real understanding of the concepts doesn't happen in high school, with students only mastering certain procedural skills. The Calculusn 1 course material is abundant, and the pace is fast. Those who only studied the intermediate level curriculum in high school face serious challenges at the university.

When contemplating how to assist students, we had to keep several considerations in mind. We needed to think about a solution that is sustainable in the long run, and if successful, could be applied to mathematics education for engineers across other departments and faculties of the university. We couldn't, for instance, consider small-group seminars due to constraints in teaching staff and classroom capacity. Our students already have a high weekly workload, which precluded the possibility of offering assistance courses that are longer than 90 minutes or occur more frequently.

We filled out a questionnaire about their satisfaction with the intervention with the student.

3 METHODOLOGY

Recognizing these challenges, we surmised that our students require additional instructional support to compensate for their deficiencies and to successfully overcome these obstacles. Thus, we introduced a 90-minute practice session associated with the second-semester calculus course. In the Calculus 2 course, students learn linear algebra (vector spaces, matrix arithmetic, systems of linear equations, linear transformations), and they become acquainted with sequences and series of functions (Taylor series expansion, Fourier series). The course concludes with differential and integral calculus of multivariable functions. This course is also

considered challenging, with students having to comprehend numerous new concepts in a relatively short span of time and then apply the learned procedures at a skill level. Similar to the Calculus1 course, we provided materials to assist individual preparation for the Calculus 2 course.

In our study, we analyze the effect of supplementing the curriculum with a 90-minute practice session on the study of linear algebra, and whether this aided students in improving their performance. The linear algebra syllabus is taught over a span of six weeks, and it concludes with a test written in the seventh week. Achieving at least 40% on this test is a necessary prerequisite for the student to attempt the Calculus 2 exam. We analyze the results achieved on the linear algebra test in relation to various input parameters.

The mathematics classes are therefore structured as follows in the new system during the semester: there are one and a half hour lectures on Tuesdays and Fridays, for all mechatronics and energy engineering students. Attendance at the lecture is not mandatory, but about 80% of the students are present almost every time. Each student also has a one and a half hour seminar per week, where they practice problem-solving. In these seminars, the students participate in groups of 35. Attendance at the seminars is mandatory. This regular Calculus course was extended with a weekly 90-minute session, which is held immediately after the Friday lecture. The subject is taught by the lecturer. Unfortunately, it was not possible to find a time slot that would have been suitable for the entire cohort, but even so, many students took the supplementary subject.

4 FINDINGS

Figure 1 shows Calculus 1 grades and supplementary course taking. Enrollment in the supplementary course is denoted as follows. The '0' column represents students who didn't meet the preconditions for the Calculus 1 exam, meaning they scored below 40% in the mid-term and end-term tests. As they couldn't register for the Calculus 2 course, the supplementary class (marked as ‘Supplementary course' in the chart below) wasn't pertinent to them. Students who satisfied the prerequisite but earned an unsatisfactory grade in the Calculus 1 exam (denoted in the '1' column) could enroll in Calculus 2, as could those who secured at least a passable grade. In all columns excluding '0', we used blue to indicate students who opted for the supplementary course and red for those who didn't take the supplementary class. While a few students couldn't join the supplementary course due to scheduling conflicts, it's not correct to infer that they were among those who scored unsatisfactory grades. Therefore, the trends suggest that students with lower grades in Calculus1 were more likely to opt out of the practice class. Regrettably, it seems that students who struggle with mathematics were less likely to seize the chance to practice than those who navigated the challenges more successfully. We can further analyze the decision of students to enroll in the practice course based on the grades they received in Calculus 1.

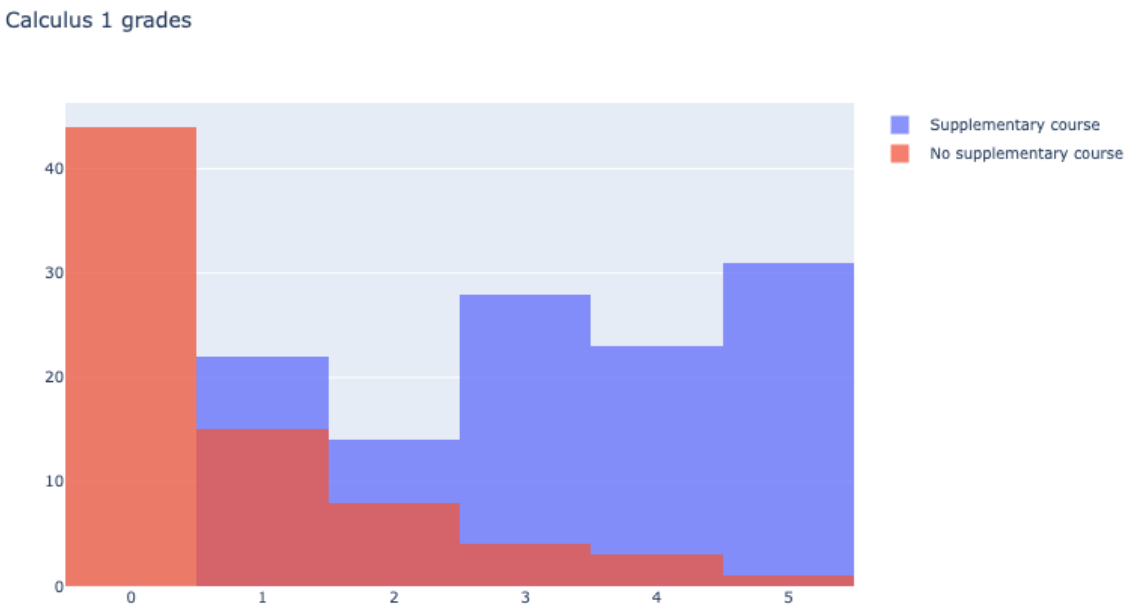

Fig. 1. Calculus 1 grades and supplementary course taking

In this supplementary course, we predominantly present calculation tasks, essentially elaborating on what was covered in the lectures. Our aim was to ensure students attend the seminars having already understood the key concepts, methods, and basic calculation techniques, thereby enabling them to participate more actively, ask questions, and so forth. This course, albeit to a limited extent, also provided an opportunity to make up for past deficiencies. The students tend to attend these sessions in nearly full numbers. Moreover, a few weeks in, there were even some students from parallel calculus courses in other engineering fields who requested permission to attend these sessions.

Students were given the opportunity to provide feedback (3 weeks in) on the supplementary course, including expressing their thoughts in detail and making suggestions. Out of the 41 students who shared their opinions, three did not find the course useful. Two of them believed that it was too demanding to engage with mathematics for another hour and a half after a 90-minute mathematics lecture. One student confessed to not understanding the subject at all. Six students, after three weeks, were still undecided about the usefulness of the supplementary course, though two of them leaned towards finding it beneficial. One student considered the subject too easy. However, 31 students found the course useful. Many of them left detailed comments indicating that they thought the course was a good idea because it helped them understand problem-solving methods better in the seminars.
The linear algebra test took place in the seventh week of teaching. The test was conducted in-person via the cloud-based education platform, EduBase. (Edubase 2023, Szilágyi et al. 2020) The 90-minute test comprised 31 short tasks. It is important for us to track students' progress on each task during online tests, which is why we break down each task into several subtasks. The tasks were varied, testing both calculation skills and theoretical understanding. We deem it important to ensure that the student has understood the teachings. One way of assessing this

is by asking the student to determine whether certain statements are true or false. To deter guessing, incorrect answers attract negative points. Some tasks serve to check basic linear algebra concepts and calculation skills. Achieving 40% was possible just by successfully completing these tasks.

The average score for students attending the supplementary course was 68% (SD 15%), while the average score for those not attending was 53% (SD 13%). The distribution of these results is illustrated in Figure 2. Out of the 143 students who took the test, 116 attended the supplementary course (g2f). Ten students scored below 40%, of which 27 attended the supplementary course. The lowest score was 20.8% and the highest was 82.6%. As can be inferred from the graph, only students who attended the supplementary course achieved scores above 75%.
Using statistical calculations, we proved that the students attending the supplementary course achieved significantly better results on the linear algebra test.

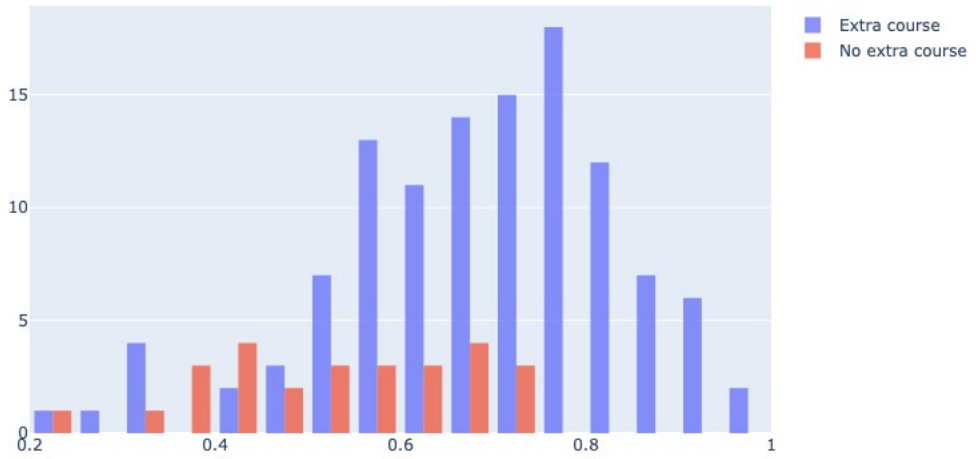

Fig. 2. Calculus 2 first midterm exam results by the groups taking or not taking the supplementary course

It's worth taking a closer look at the academic backgrounds related to the current test results. Figure 3 traces the precursors to the results achieved in the linear algebra test. The graph includes only those students who could take the Calculus2 course. They may have failed Calculus1, but they managed to complete the mid-term tests with at least a 40% score. Each line on the graph symbolizes a single student. The test result can be seen on the right, the Calculus1 grade in the middle, and the entrance points are shown on the left. We are encouraged to see that not only those with the highest entrance points achieved good results in Calculus1. At the same time, it's apparent that even the top-performing entrants could struggle in the first semester, even though they likely covered much of the first semester's material in high school. It's clearly visible that all students with an excellent grade in Calculus1 met the necessary minimum of 40%, and only one student among those with a grade of 4 achieved below-minimum results.

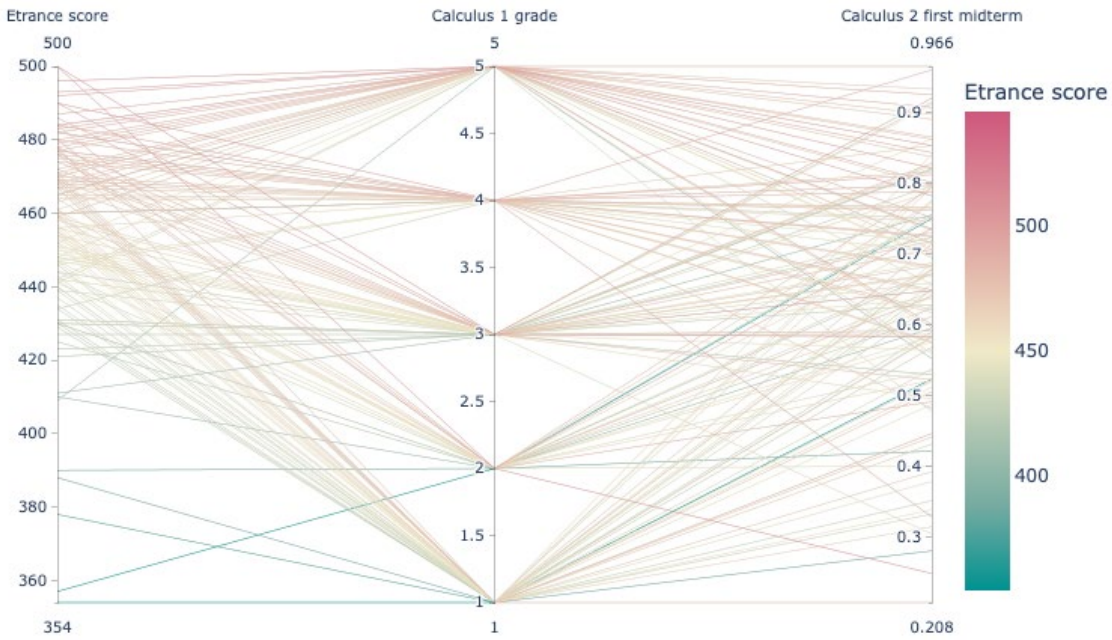

Fig. 3. Entrance score, Calculus 1 grade and Calculus 2 first midterm exam results colored by the entrance score

The notable spread of grades is thought-provoking, and this inspired Figure 4.
Figure 4 examines how test results varied depending on Calculus1 grades and whether or not students attended the supplementary course. The left side of the Sankey diagram shows Calculus1 grades, while the right side represents the converted grades of results achieved in the linear algebra test. The conversion was as follows:

0 – 39%: Fail (1)
40 – 54%: Sufficient (2)
55 – 69%: Average (3)
70 – 84%: Good (4)
85-100%: Excellent (5).

The black color represents students who attended the supplementary course, and gray indicates those who did not. The diagram shows that a larger proportion of students with failing grades in Calculus1 who attended the supplementary course achieved above-minimum test results, with many even obtaining average or good grades. Among students with an average grade in Calculus1, many obtained a good grade (4) on the linear algebra test, and some even reached an excellent (5) level.

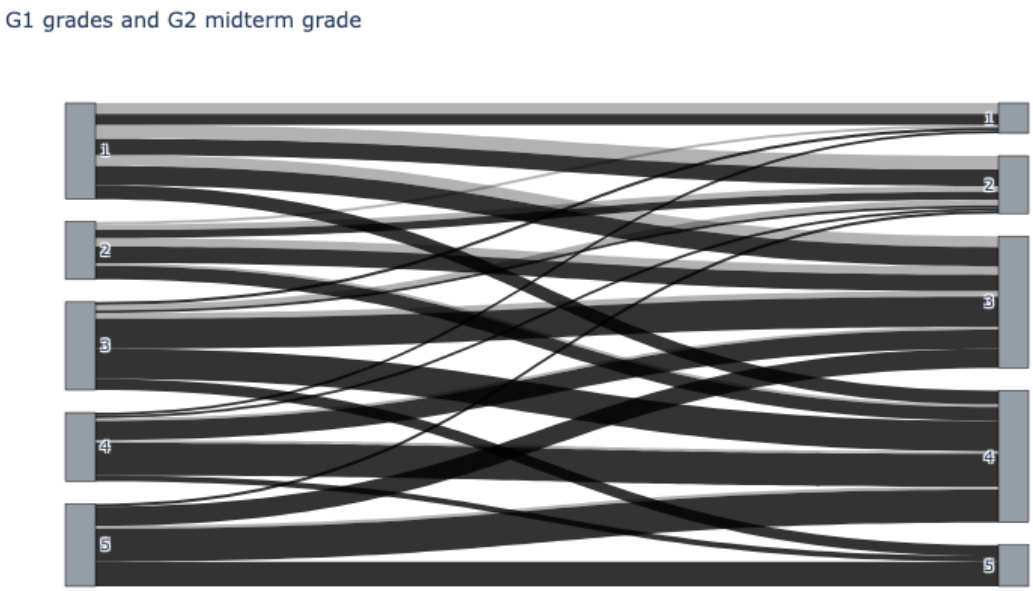

Fig. 4. Calculus 1 final grade and Calculus 2 first midterm exam grade, darker shade is used to represent taking the supplementary class

5 CONCLUSION

Even after analyzing the initial results, we can say that the intervention was successful. We documented the students' attendance at the extra course. At the end of the semester, it will be possible to conduct tests that analyze the relationship between attendance and performance on tests.The number of tests falling below the minimum standard has significantly decreased compared to the first semester, and performances above the minimum level have also improved. We can conclude that a course of this type can greatly assist in reducing student attrition in education, thereby mitigating the impacts of the pandemic. We managed to provide a cost-effective solution that can be easily integrated into any courses to reduce dropout. It is unsurprising that this intervention works. We add more for the students. Increased time on task is widely regarded as greatly beneficial for performance. The full analysis will take place after the semester.

6 ACKNOWLEDGMENTS

The research received funding from the MTA-ELTE Theory of Learning Mathematics Research Group.

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