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A Comparative Study of the Impact of COVID-19 Pandemic on Student Participation and Performance in First-Year Engineering Courses

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Introduction

This full evidence-based paper discusses an elaborate analysis conducted to compare student participation and performance in two courses amidst all the changes and adjustments that took place due to the COVID-19 pandemic. We look at the impact of sudden interruption and transition to remote learning in Spring 2020 and at Fall 2020, which was offered in converged (students can choose to attend class face-to-face or synchronous remotely) and synchronous online mode. Student data from Fall 2019, where the courses were offered in the usual face-to-face setting, is compared to the two abovementioned semesters. This section provides a brief overview on the two courses that were analyzed and their mode of instruction in Fall 2019, Spring 2020 and Fall 2020.

Engineering 101 (ENGR101) is an introductory engineering mathematics course loosely based on the Wright State University (WSU) engineering mathematics education model [1-3]. The course is a 4-credit course meeting for 90 minutes of lecture (common for multiple sections of the course) two times a week, and 90 minutes of recitation and 90 minutes of lab meetings once a week. It is a required course for all engineering students who are taking pre-calculus and are one term behind the expected starting point in mathematics. The lecture component provides an overview of relevant topics in engineering analytical methods that are most heavily used in core engineering courses [4]. These topics are reinforced through solving problems in a lab environment. The lab component is a mix of hands-on labs as well as virtual labs using MATLAB [5,6]. During Fall 2019, lectures and lab were run in the usual format. Spring 2020 started as normal, but all lecture and lab meetings were offered asynchronously after spring break. In Fall 2020, lecture meetings were offered in a hybrid/converged mode, whereas labs were mostly remote. Students broken into smaller groups were brought in twice during the semester to conduct hands-on labs on campus following all safety protocols. The final grade is decided by performance on homework assignments, lab assignments, three midterm exams and one final exam.

Fundamentals of Engineering Design (FED101) is a specially designed course for underprepared (in mathematics, as placed by the placement exam) and undecided students grouped under general engineering. This course combines a lecture (common for all sections of the course) and a laboratory component to help students not only to learn about various major engineering disciplines but also to pick up effective and transferrable skills to become better engineering students. The course covers many important modules necessary for introductory engineering design courses, namely - engineering design, engineering software, engineering research, engineering ethics, using the Makerspace, and evaluation and presentation of engineering data. In addition, many other important skills such as oral and written communication, working in groups, connecting to peers and the institution, self-reflection, and discipline, etc., are embedded throughout the course. The biggest challenge for this course is to give students some insight into multiple engineering disciplines and to help them make an informed decision about their major choice. This course also heavily relied on hands-on and in-person activities until Fall 2019. Midway through Spring 2020, the course was moved to synchronous online mode. In Fall 2020, the common lecture portion of the course was offered in a hybrid/converged mode. Instructors taught from a university classroom and the lecture was simultaneously broadcasted. A limited

number of students (on a rotation basis) had an option to attend the class in-person while all others joined the lecture remotely simultaneously. The lab portion of the course was offered in an asynchronous mode during the latter half of Spring 2020 and synchronously during Fall 2020. Final grade is equally divided into lecture and lab grades. Both lecture and lab grades comprise of formative assignments assigned over the course of the semester as well as a final summative project that utilizes skills learned throughout the semester.

In addition to changes to the course delivery modes, another significant change that was implemented in Spring 2020 and Fall 2020 semesters was a special grading policy. Students were given an option to have multiple course grades changed to Pass (C or better), Academic Credit (D), or Non-Academic Credit (F). This was consistent with what most of the institutions of higher education offered to their students in order protect their GPA under the unprecedented challenges brought on by the COVID-19 pandemic. Authors feel that this policy had a profound effect on student participation and their attitude towards courses they considered as challenging. However, the impact of the grading policy is not within the scope of the analysis presented here.

Comparative Analysis

The enrollment in the two courses for Fall 2019, Spring 2020, and Fall 2020 is shown in Table 1. Spring semester registration for FED 101 is usually much less than fall semester as FED 101 is typically taken by students in their first semester at the university. Spring FED101 is usually populated by students who are spring admits or couldn't fit FED101 in their schedule in the fall semester. ENGR101 class size in spring is also smaller than fall semester. Pre-calculus students who are one semester behind take ENGR101 in the fall semester and students who are two semesters behind in the calculus sequence take ENGR101 during the spring semester, once they reach the one-semester behind pre-calculus course. Student population that is two semesters behind in the calculus sequence is smaller than those that are one semester behind. Fall 2020 saw a drop in the student enrollment for both courses. It can be attributed to some students choosing to take a break during the pandemic and start school 1-2 semesters later. In addition, ENGR101 drop can also be explained by increase in math placement scores as students took the placement exam remotely due to the pandemic.

Table 1: Student Enrollment in ENGR101 and FED101 for the three semesters

Number of Students	Fall 19	Spring 20	Fall 20
ENGR101	106	72	65
FED101	89	66	61

We first look at the impact of mid-semester abruption on attendance in these courses. Figure 1 shows that attendance in Spring 2020 for both classes took a substantial hit right after college moved to remote mode, much more for ENGR101. As can be seen in the figure, attendance during Fall 2019 was similar for both halves of the semester. Attendance during Fall 2019 and pre-COVID Spring 2020 was done using a roll-call. FED101 was run as a synchronous class, so attendance was collected using Cisco WebEx attendance reports. ENGR101 was run asynchronously so students were asked to submit lecture notes to count as attendance. Where just logging into the

online session for FED101 counted as attendance, ENGR101 students had to be actively engaged to get attendance credit. This explains the significant drop for ENGR101 as compared to FED101.

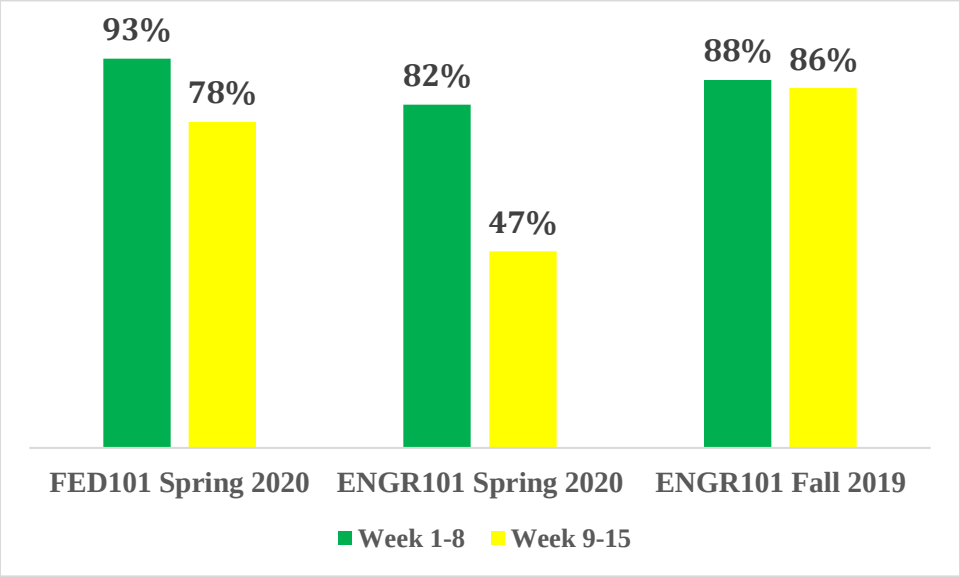

Figure 1: Attendance comparison pre and post COVID for FED101 and ENGR101

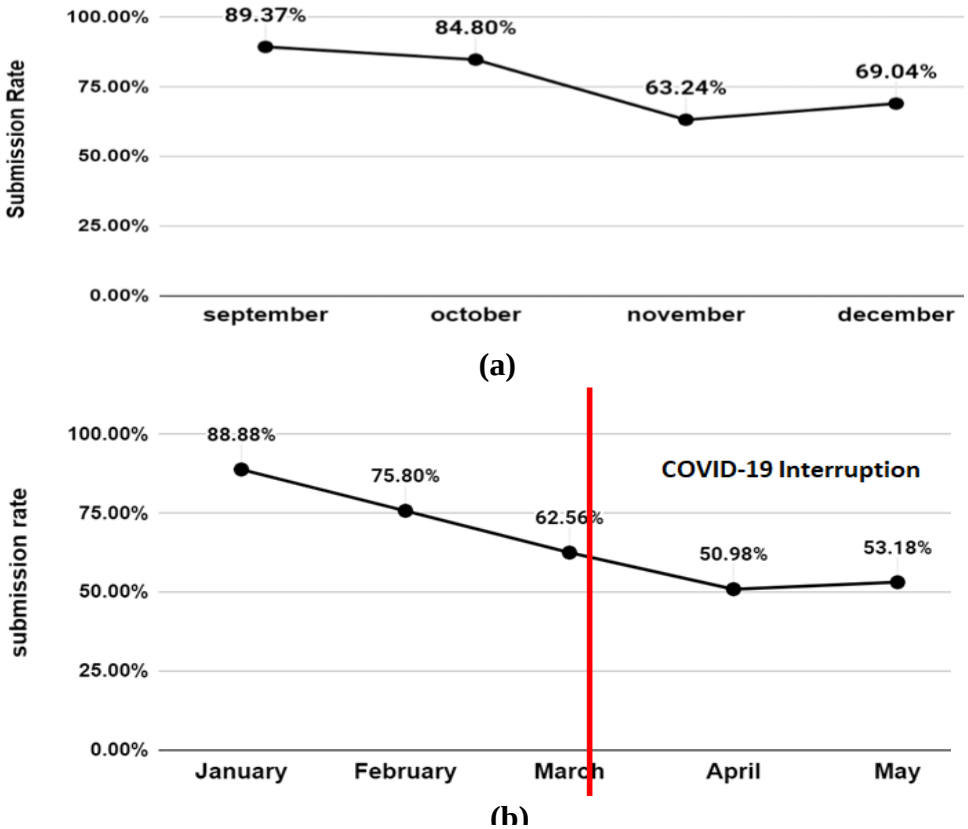

Figure 2: Overall assignment/homework submission rate for FED101 for (a) Fall 2019 and (b) Spring 2020

Figure 2 shows the impact of COVID on the submission rate of assignments for FED101. As seen in Figure 2(a), the general trend of submission for Fall 2019 is downwards, but picks up slightly in the end due to final project and final report submission. In Figure 2(b) depicting Spring 2020, the downward trend is similar, but right after COVID disruption the submission rate drops significantly. A similar observation was made for ENGR101 course as well.

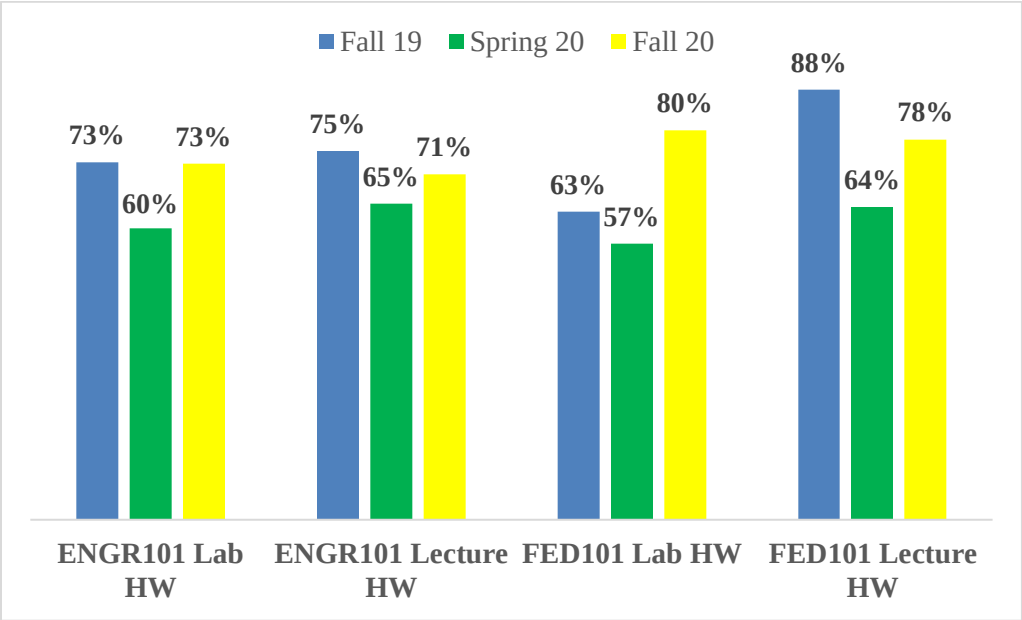

Figure 3: Assignment/homework submission in Lab and Lecture in ENGR101 & FED101

Figure 3 shows the submission rate homework for both the lecture and lab components for both ENGR101 and FED101. For ENGR101, lab and lecture homework submission rates during Spring 2020 saw a significant drop as compared to the fall semesters. For FED101, a similar observation can be made about the submission rate during Spring 2020 semester. Student submission in the latter half of Spring 2020 was significantly low which impacted the overall submission rate. This may be attributed to many reasons including the loss of motivation during the pandemic, financial hardships at home during the pandemic, difficulty in transitioning learning style to match to the remote instruction that all universities and schools transitioned to, students or family members getting sick and even loss of family members, option to use the pass/fail policy etc. . Fall 2020 numbers were very similar to Fall 2019 for ENGR101. For FED101, the submission rates were surprisingly better for the lab. The lab involves learning solid modeling and microcontrollers and its programming. This increase in submission rate can be attributed to the idea that these skills are very hands-on and help keep students engaged. Also by Fall 2020, students were much more familiar and comfortable with the online instruction mode.

Figure 4 shows the grade breakdown for ENGR101. A quarter of the class failed in Spring 2020 and about 6% withdrew from the course. For Fall 2020, 28 withdraw from the course in lieu of their poor performance. Due to the impact of COVID in Spring 2020, the withdrawal deadline for our institution was pushed back significantly and also students planned to utilize the already advertised pass/fail policy. These reasons could seem to explain the low withdrawal rate and high failure rate. In Fall 2020, students were offered to take the pass/fail policy on any two courses, but

this was announced much later in the semester. By then most students had already withdrawn from the course. Figure 5 shows the pass/fail/withdraw grade break down for FED101 for all three semesters. A significant number of students (more than half of the class) failed the class during Spring 2020. Fall semesters overall look similar to each other in terms of students who passed/failed the course.

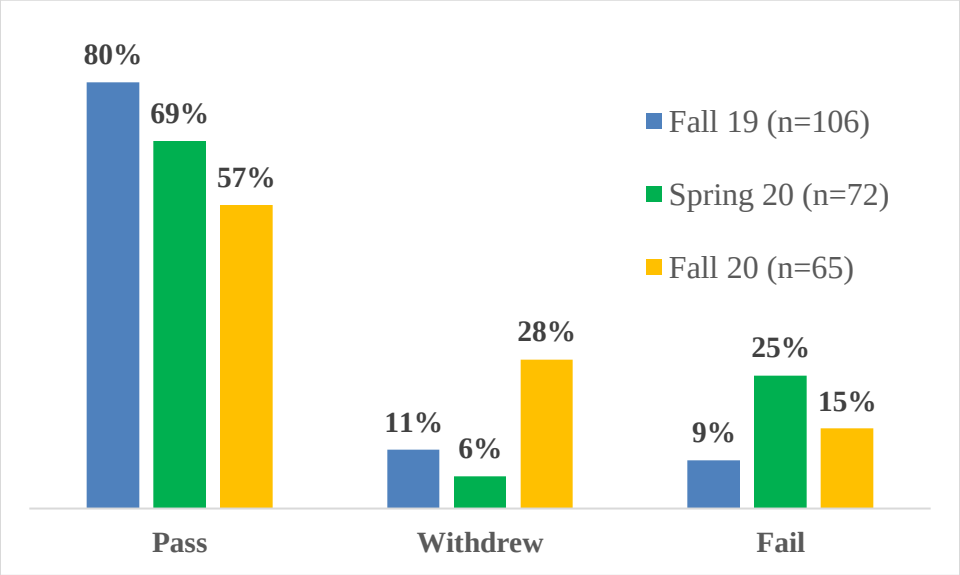

Figure 4: Pass/Withdraw/Fail grade breakup for ENGR101 for Fall 2019, Spring 2020 and Fall 2020 semesters

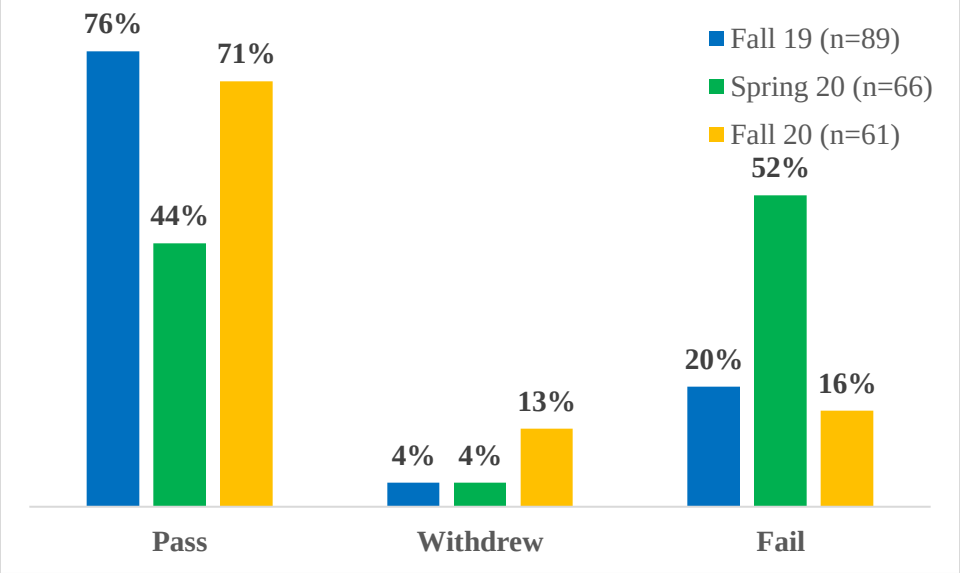

Figure 5: Pass/Withdraw/Fail grade breakup for FED101 for Fall 2019, Spring 2020 and Fall 2020 semesters

Student Reactions and Feedback to the COVID-19 Pandemic Situation

Students took a long time to adjust to the life during the pandemic. In particular, the student population served through the two courses that are the focus of this paper struggled to perform well after the pandemic. These students need extra help, encouragement, and support in order to do well even during a normal semester. All this was made very difficult to manage during the remote learning environment. Even when the classes were offered in a converged learning mode, most students chose to attend remotely and the average performance of the class was below the mark. Some of the difficulties faced by the students include-

- Lack of a reliable internet connection
- Not having access to distraction free environment
- Additional responsibilities to support their families financially as well as emotionally
- Significant disruption brought on to the household when someone is actually or potentially exposed to the virus.
- Having to look after family members including elderly and younger siblings
- Not being able to self-motivate to study and perform well

Overall, it was quite evident that students struggled to adjust to remote learning environment. In Spring 2020, it was more of a shock reaction to what was happening but in Fall 2020, students were openly expressing frustration to lack of hand-on activities, the outside of the classroom difficulties brought on by the pandemic, and challenges in taking online exams. Here are a few comments that represent the general sentiments expressed by the students

  - COVID–19 REALLY MADE EVERYTHING WAY WORSE, AND HARD TO UNDERSTAND
  - There was a minor setback where the virus hampered the class' ability to manage exams. I found the second exam really complicated and I felt that it wasn't well implemented when the setback occurred.
  - Exploring more hands–on labs and the application of mathematical and engineering concepts. Basically, work on projects.
  - More hands–on activities, (hopefully without the worry of COVID–19).

Lessons Learned During the COVID-19 Pandemic

The once-in-a-lifetime disruption brought on by the COVID-19 pandemic had many profound impacts on the way engineering courses are taught in the United States. Even though a lot of initial impact was largely disruptive, sudden, and challenging; there are also a few things that forced instructors to think differently and innovatively in order to engage students in their classrooms. Here are some of the key observations made and lessons learned through the two courses discussed in this paper:

- Both courses were offered in converged mode in Fall 2020 semester, so some activities needed to be modified to include in-person as well as synchronous online students. Even though this was very challenging at first, the instructional team quickly adopted to the need of the hour and learned how to leverage the available technology resources. We learned some best practices about the Learning Management System and many other

tools that we did not know existed before. These lessons will serve all of us for a long time.

- Less exposure to team-based projects/activities – even though the focus shifted from group activities to individual projects at first, we eventually learned to efficiently coordinate small group activities in the remote learning environment as needed.
- Makerspace operated at a very limited capacity so it was not possible to make sure that every student will work in the makerspace at least once during the semester. However, we were very encouraged by the enthusiasm shown by the students to access the makerspace even though they had to abide by rigorous social distancing and safety protocols in place.
- Hands-on activities have serious limitations when some students are attending in-person while others online, but they can still be a part of the course with proper advance planning.
- Converged classroom offers a lot of flexibility for students. This is one aspect embraced during the pandemic that is likely to stay even after the pandemic is long over.
- Interaction with students (the COVID-19 Era Office Hours) can happen at any time you are online. No one is limited by the 9 to 5 mentality anymore. This could be a good thing in terms of availability but at the same time a bad thing in terms of maintaining work life balance. Students took a long time to get used to the virtual office hours. Even though no official data was collected, we noticed a significant drop in number of students showing up when the office hours were offered virtually. This number gradually changed as more and more students got used to the life during the pandemic.
- Guest speakers and other presenters are more available and willing to participate now that they do not have to worry about traveling to the lecture location.

Conclusion

The analysis presented in this paper indicates that student performance and participation was strongly impacted by the COVID-19 interruption. This was not only due to the challenges faced by students but also by the instructional staff who needed time to get a hang of the forced remote learning environment and quick changes that needed to be made to several of the remaining learning modules. However, as people adjusted to life during the pandemic, the overall negative impact reduced. Therefore, Fall 2020 saw much lower negative impact as compared to what happened in Spring 2020. The biggest challenge for introductory first year courses is to find ways to engage and motivate students to participate and perform. Onus lies more on students to take responsibility for their learning than ever before. Finally, there were some positive outcomes from this disruption as well. Several innovative and creative strategies embraced during the forced disruption are likely to stay even after we return to whatever will be the new normal

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