2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37426

Effects of Covid-19 Pandemic and Response on Student Performance in Large Foundational Mechanics Courses

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Abstract

In Spring 2020, institutions were forced to make rapid changes to their teaching, attendance, assessment, and academic relief policies. Our institution moved all classes and assessment online, removed most attendance policies, extended the drop deadline, and allowed students to alter their grading system from A-F to credit/no-credit. Most classes and assessments continued to be online in Fall 2020 and Spring 2021, before returning to typical pre-pandemic scheduling in Fall 2021. These accommodations were necessary to respond to public health advice, student and faculty illness, and ongoing uncertainty at the time. However, there are growing concerns about the effect that the pandemic and associated policies had on student learning and preparation for follow-on courses.

We analyze student grade data and withdrawal rate for three large multi-section foundational mechanics courses between Fall 2015 – Fall 2022: Statics (91 sections), Mechanics of Deformable Bodies ('Deformables') (79 sections), and Dynamics (73 sections). Specifically, we look at Grade Point Average (GPA) and the proportion of students receiving either D grades, F grades, or withdrawing from each course (collectively known as the DFW rate). We separate our data into 4 time periods and compare results across these periods: Fall 2015 – Fall 2019 ('pre-pandemic'), Spring 2020 ('early-pandemic'), Fall 2020 – Spring 2021 ('mid-pandemic'), and Fall 2021 – Fall 2022 ('post-pandemic').

We find a significant increase in GPA and decrease in DFW rate in the Spring 2020 semester when classes were moved online and institutional polices were very lenient around grading and drop policies. Since Fall 2021 (when both course modality and institutional policies largely reverted) GPA and DFW rates in Statics have been virtually identical to pre-pandemic rates. However, we see significant decreases in GPA and significant increases in DFW rate in both Deformables and Dynamics. Statics is a prerequisite for both of these courses.

This general trend was observed for almost all faculty members who taught classes across this time period, although the size of the effect varied. One section of Deformables has been offered asynchronously online since Fall 2015. This class also saw the same trends in GPA and DFW rate across the study period.

We do not explicitly explore the reasons for these changes in this paper, but our experience in these classes suggests that students who took Statics mid-pandemic are not as well prepared for follow-on courses as students were pre-pandemic. The changes in GPA and DFW rate are a concern that is likely to extend to higher level courses. We intend to continue to track student progress through these courses and report on longer-term trends. Larger studies are warranted to help explain these trends.

Background

In Spring 2020, growing cases of COVID-19 forced institutions to make rapid changes to their teaching, attendance, assessment, and academic relief policies. A report from the National Center for Education Statistics estimates that 84% of US undergraduate students had some or all of their classes moved to online-only instruction [1].

Common institutional responses include awarding course grades for the semester on a binary (pass/fail) system, relaxing academic progression and degree award policies, revising extension and deferral policies, and adjusting grades [2]. Our institution moved all classes and assessment online, removed most attendance policies, extended the drop deadline, and allowed students to alter their grading system from A-F to credit/no-credit in Spring 2020. The extension of the drop deadline was also provided in Fall 2020.

Most classes and assessments continued to be online in Fall 2020 and Spring 2021, before returning to typical pre-pandemic scheduling in Fall 2021. These accommodations were necessary to respond to public health advice, student and faculty illness, and ongoing uncertainty at the time. However, there are growing concerns about the effect that the pandemic and associated policies had on student learning and preparation for follow-on courses.

Research on the efficacy of online courses is mixed, with some studies suggesting that students performed better in online courses and some studies suggesting that students performed better in in-person courses. However, the majority of research found that there were no significant differences in performance between delivery modes [3]. Of course, most of this research was conducted pre-COVID-19 and students were generally opting to take online courses that had been carefully designed. In Spring 2020, students (and instructors) were forced into online courses that were largely being designed on the fly and attempting to adapt in-person teaching and assessment to online environments. This creates a number of challenges for both students and faculty [4], and online classes during this time period are not necessarily comparable to online courses pre-COVID-19.

Despite concerns that this environment would harm student performance, several studies show that student performance did not suffer during this time period [3, 5, 6] and that students largely adapted well to the transition [7-9]. This has led to some suggestions that institutions should explore increasing their offering of different delivery modes [3, 5].

However, it has been noted that this effect may not be driven only by student learning. Grades are a reasonable, but imperfect, measure of learning. It has been suggested that instructors may be more lenient with expectations and award higher grades that normal in an attempt to compensate for the negative circumstances [10] and that grades during this time period were inflated [11].

To date, the majority of studies that explore student performance compare performance during the COVID affected semester(s) to performance pre-COVID. We sought to better understand both the immediate and the ongoing effects of the COVID-19 pandemic and the associated institutional response on our engineering students. We explore student performance in three large

multi-section foundational mechanics courses: Statics, Mechanics of Deformable Bodies (Deformables), and Dynamics. These courses are required for the majority of engineering students at our institution and provide a foundation for higher level in-major courses.

We investigate grade point average (GPA) and the percentage of students receiving either D grades, F grades, or withdrawing from the course (collectively known as the DFW rate) for these courses between Fall 2015 to Spring 2022. We look for differences in these measures for courses taught pre-COVID, during the height of COVID when institutional policies and course modalities were heavily affected, and post-COVID when policies and delivery modes have returned to normal.

We seek to understand not only whether there was a change during the height of COVID-19 and the associated institutional response, but also whether there are ongoing differences between recent semesters and pre-COVID semesters.

Methods

We selected three courses for inclusion in this study; Statics, Mechanics of Deformable Bodies, and Dynamics. These are large, multi-section foundational mechanics courses. Statics is a prerequisite to the other two courses. We collected grade distribution data for these courses across a 7-year time period from Fall 2015 to Fall 2022. A total of 15,159 students across 243 course sections are included. Table 1 shows the enrollment and number of class sections for each course over the 15 semesters from Fall 2015 to Fall 2022.

Table 1: Number of class sections and enrollment per semester for each course. Highlighted semesters indicate the 'early-pandemic', 'mid-pandemic', and 'post-pandemic' time periods.

Semester	Class Sections			Total Enrollment		
	Statics	Deformables	Dynamics	Statics	Deformables	Dynamics
F 15	3	3	1	405	176	66
S 16	5	6	5	300	350	342
F 16	4	4	3	521	212	158
S 17	3	8	6	208	567	375
F 17	8	4	3	597	219	134
S 18	3	7	7	210	442	488
F 18	11	3	3	813	122	122
S 19	4	8	8	314	465	499
F 19	9	5	3	734	256	121
S 20	4	6	8	168	247	241
F 20	10	3	3	699	148	121
S 21	3	7	10	196	551	582
F 21	11	4	3	714	190	106
S 22	4	7	7	263	457	364
F 22	9	4	3	606	204	86
Totals	**91**	**79**	**73**	**6748**	**4606**	**3805**

A total of 13 faculty were responsible for teaching these courses during this time period. Most taught multiple courses in this sequence. There were a total of 91 sections of Statics taught by 7 faculty, 79 sections of Deformables taught by 6 faculty, and 73 sections of Dynamics taught by 6 faculty.

For each semester during this time period, we determined the mean Grade Point Average (GPA) and the mean percentage of students receiving either D grades, F grades, or withdrawing from the course each semester (collectively known as DFW rate) for each course.

We compared these measures across 4 time periods: Fall 2015 – Fall 2019 ('pre-pandemic'), Spring 2020 ('early-pandemic'), Fall 2020 – Spring 2021 ('mid-pandemic'), and Fall 2021 – Fall 2022 ('post-pandemic'). Specifically, we looked for differences pre-pandemic to the other 3 time periods to assess whether there were changes in student performance during the immediate-term, short-term, and long-term as a result of the changes brought on by COVID-19. Two-sample t-tests were used to test for statistical significance. We then compared GPA and DFW rate across instructors in the pre-pandemic period to identify any differences. If variability in student performance was partially explained by the instructor, this could affect the results in semesters where certain instructors were teaching and other weren't. After identifying patterns in student performance across the study period, we identified instructors that had taught sections of a class both pre-pandemic and post-pandemic. Where available, we include data for class sections taught by these instructors during the early-pandemic period too. There were 5 instructors that met this criterion for Statics, 5 for Deformables, and 5 for Dynamics. We compared GPA and DFW rate in class sections taught by each of these instructors individually across the study period to determine whether courses taught by all faculty members followed the same overall trend. The number of sections taught by each instructor during each time period is shown in Table 2.

Table 2: Number of course sections taught by each instructor over the study period. Time periods refer to 1 = 'pre-pandemic', 2 = 'early-pandemic', 3 = 'mid-pandemic', 4 = 'post-pandemic'.

	Number of sections taught											
Course	**Statics**				**Deformables**				**Dynamics**			
Period	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Inst. A	-	-	-	1	2	-	1	2	-	-	-	-
Inst. B	-	-	-	-	-	-	-	-	4	1	-	-
Inst. C	-	-	-	2	-	-	-	-	-	-	-	-
Inst. D	10	-	2	3	8	1	2	2	13	2	3	2
Inst. E	8	1	3	4	3	1	3	4	-	-	-	-
Inst. F	4	2	3	4	10	-	2	2	-	-	-	-
Inst. G	16	-	3	8	-	-	-	1	7	2	3	-
Inst. H	6	-	1	-	16	3	2	4	-	-	-	-
Inst. I	3	1	-	2	-	-	-	-	5	1	5	5
Inst. J	1	-	-	-	-	-	-	-	-	-	-	-
Inst. K	2	-	1	-	-	-	-	-	8	1	1	3
Inst. L	-	-	-	-	9	1	-	-	-	-	-	-
Inst. M	-	-	-	-	-	-	-	-	2	1	1	2

One section of the Deformables course has been offered online asynchronously every semester since Fall 2015. This course is taught through a series of pre-recorded videos by one of the authors of this paper, who also regularly teaches in-person sections of this class. Delivery and expectations in this course are therefore highly consistent across semesters. Exams for this course are held in-person, but otherwise the course is entirely online. We compared GPA and DFW rate data for this online course across the study period to see if student performance followed the same trend as the other courses across the four time periods outlined above. We also compared this data to in-person sections taught by the same instructor each semester to identify whether results were similar between the in-person and online sections, and whether they diverged over time across the study period.

Finally, we look at overall grade distributions across the study period in order to better understand any changes in overall GPA and DFW rate.

Results

Mean GPA and mean DFW rate for each course in all semesters across the study period are shown in Figure 1. Corresponding numerical data may be found in the Supplemental Material Table S1. There is natural variation in both measures pre-COVID. There is a significant increase in GPA and significant decrease in DFW rate in Spring 2020, when classes were moved online and the institutional COVID policies described above were implemented. In the following semesters, there is a decrease in mean GPA and increase in mean DFW rate. The measures for Statics stabilize at similar values to pre-pandemic values, while measures for Deformable and Dynamics pass their pre-pandemic values.

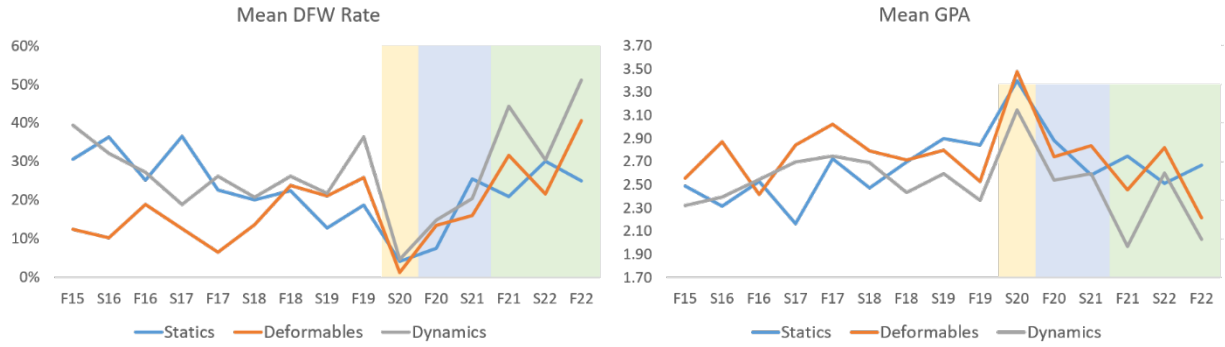

Figure 1: Mean DFW rate and GPA for each course in each semester of the study period. GPA y-axis does not start at 0 in order to improve readability of graph. Highlights signify the 'early-pandemic', 'mid-pandemic', and 'post-pandemic' time periods.

Table 3 presents this data organized across the 4 time periods ('pre-pandemic', 'early pandemic', 'mid-pandemic', and 'post-pandemic') to help visualize the change. Mean GPA and mean DFW rate for the latter 3 time periods (early-, mid-, and post-pandemic) were compared to pre-pandemic values and a series of two-sample t-tests were used to test for statistical significance. Table 3 includes p-values for each time period (except pre-pandemic, as the other time periods were compared to this time period).

The increase in mean GPA and decrease in mean DFW rate during the early-pandemic period were all statistically significant. During the mid-pandemic period, the differences in the measures were statistically significant for Statics, but not for the other two courses. The difference in post-pandemic values were statistically significant for Deformables and Dynamics, but not for Statics. This data is shown graphically in Figure 2.

Table 3: Mean GPA and DFW rate for each course, separated into 4 time periods: 'pre-pandemic', 'early-pandemic', 'mid-pandemic', and 'post-pandemic'. P-values are based on two sample t-tests comparing each data value to 'pre-pandemic' values.

Time period	Mean DFW rate			Mean GPA		
	Statics	Deformables	Dyanmics	Statics	Deformables	Dynamics
Pre-pandemic	24% -	18% -	27% -	2.64 -	2.76 -	2.58 -
Early-pandemic	4% **p < 0.001**	1% **p = 0.001**	7% **p < 0.001**	3.40 **p < 0.001**	3.46 **p < 0.001**	3.15 **p < 0.001**
Mid-pandemic	11% **p < 0.001**	14% p = 0.358	20% p = 0.111	2.82 **p < 0.001**	2.82 p = 0.200	2.59 p = 0.876
Post-pandemic	24% p = 0.944	30% **p = 0.002**	38% **p = 0.046**	2.68 p = 0.193	2.60 **p < 0.001**	2.40 **p < 0.001**

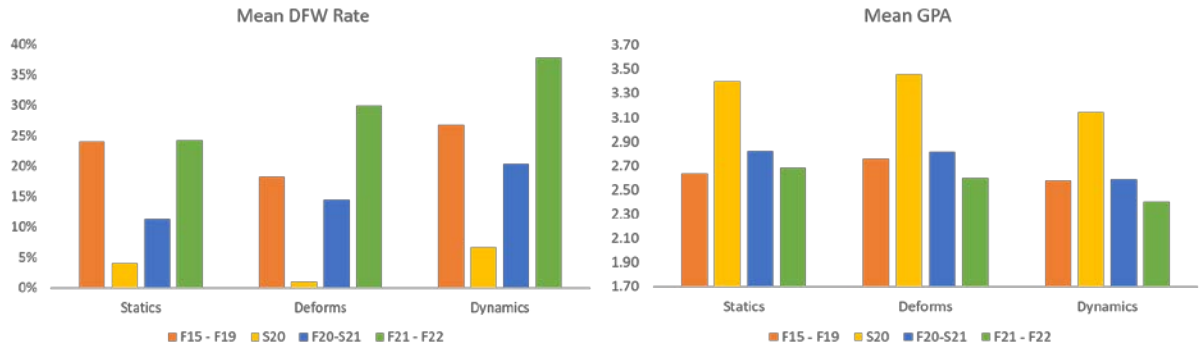

Figure 2: Mean DFW rate and GPA for each course, separated into 4 time periods: 'pre-pandemic', 'early-pandemic', 'mid-pandemic', and 'post-pandemic'. GPA y-axis does not start at 0 in order to improve readability of graph.

Figure 3 shows the same data for the nine faculty members who taught one of the classes pre-pandemic and post-pandemic. Where available, their data for 'early pandemic' is included too. Corresponding numerical data may be found in the Supplemental Material Table S2.

There is significant variation between the faculty members in terms of the mean GPA and DFW rate for their sections. However, in almost all cases the same general pattern is observed. Mean DFW rate decreases sharply in the early-pandemic period before increasing again, typically to levels above the pre-pandemic values. At the same time mean GPA increases sharply during the early-pandemic period before decreasing again, typically to levels below the pre-pandemic values.

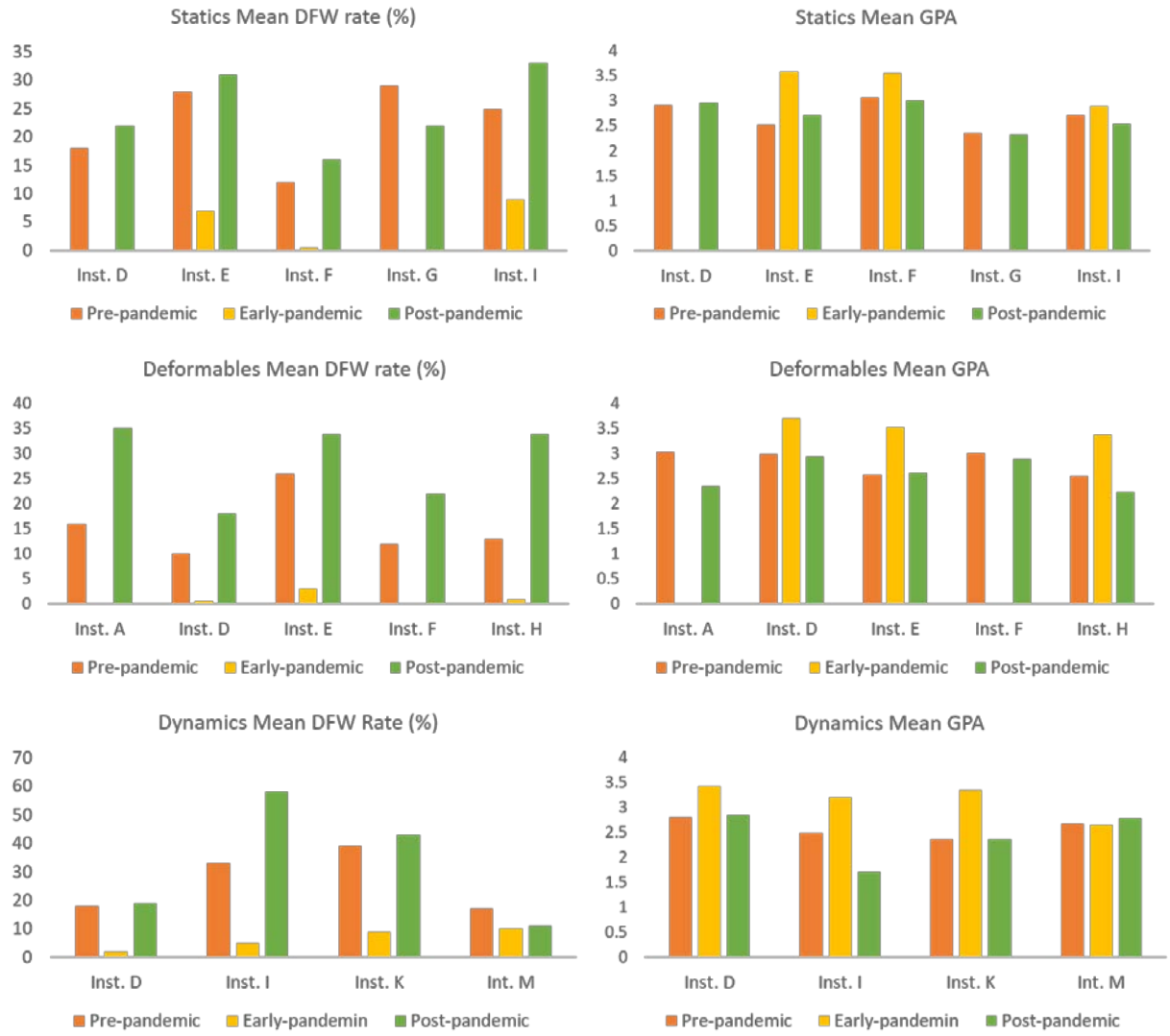

Figure 3: Mean DFW rate and GPA for each course, separated into 3 time periods: 'pre-pandemic', 'early-pandemic', and 'post-pandemic'. Data is separated by instructor and includes only faculty who taught at least one section of a course in both the pre- and post-pandemic time periods.

A comparison of DFW rate and GPA for the online asynchronous and in-person Deformables courses taught by instructor H is shown in Figure 4. Corresponding numerical data may be found in the Supplemental Material Table S3. Pre-pandemic the DFW rate was typically around 10 – 15% for the in-person classes and 15 – 20% for the online class, with the exception of Spring 2018. This was a relatively small class of 38 students (typical enrollment is 55 – 60 for this section), and the high DFW rate is largely driven by the 5 students who earned D+ grades and the additional 5 who earned D grades.

In Spring 2020 the DFW rate dropped significantly, before increasing back to around 10 – 15% for the online class in Fall 2020 and Spring 2021. Following that semester, the DFW rate has

increased noticeably each semester. This instructor has only taught the class in-person once since Spring 2020, and the DFW rate for the class was higher than in previous semesters, although slightly lower than for the online class taught that same semester.

An inverse pattern is observed for GPA. Pre-pandemic the GPA was around 2.4 – 2.7 for the in-person class and 2.3 – 2.6 for the online class, again with the notable exception of Spring 2018. In Spring 2020 the GPA rose noticeably for both the class that began in-person and then transitioned online and the class that was taught online the entire semester. There is a stark decrease in GPA for the online classes in the following semesters, generally below the pre-pandemic values. The single in-person class in this time period also saw a lower GPA than typically expected pre-pandemic, although it was still higher than the online class taught that same semester. We note that generally across the entire study period, outcomes were slightly worse for the online class than for the equivalent in-person class.

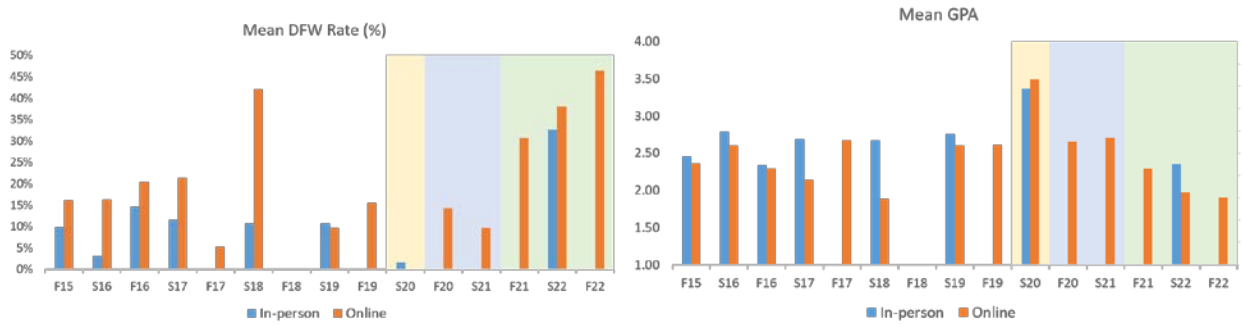

Figure 4: DFW rate and GPA for in-person and asynchronous online sections of Deformables taught by one instructor across the study period. GPA y-axis does not start at 0 in order to improve readability of graph. Highlights signify the 'early-pandemic', 'mid-pandemic', and 'post-pandemic' time periods.

Grade distributions for all three courses in each semester across the study period are shown in Figure 5. There is a clear increase in students earning A grades during Spring 2020. When compared to pre-pandemic values, students in post-pandemic semesters generally earn similar grades in Statics. However, in Deformables and Dynamics a smaller percentage of students earn B and C grades while more earn D and F grades.

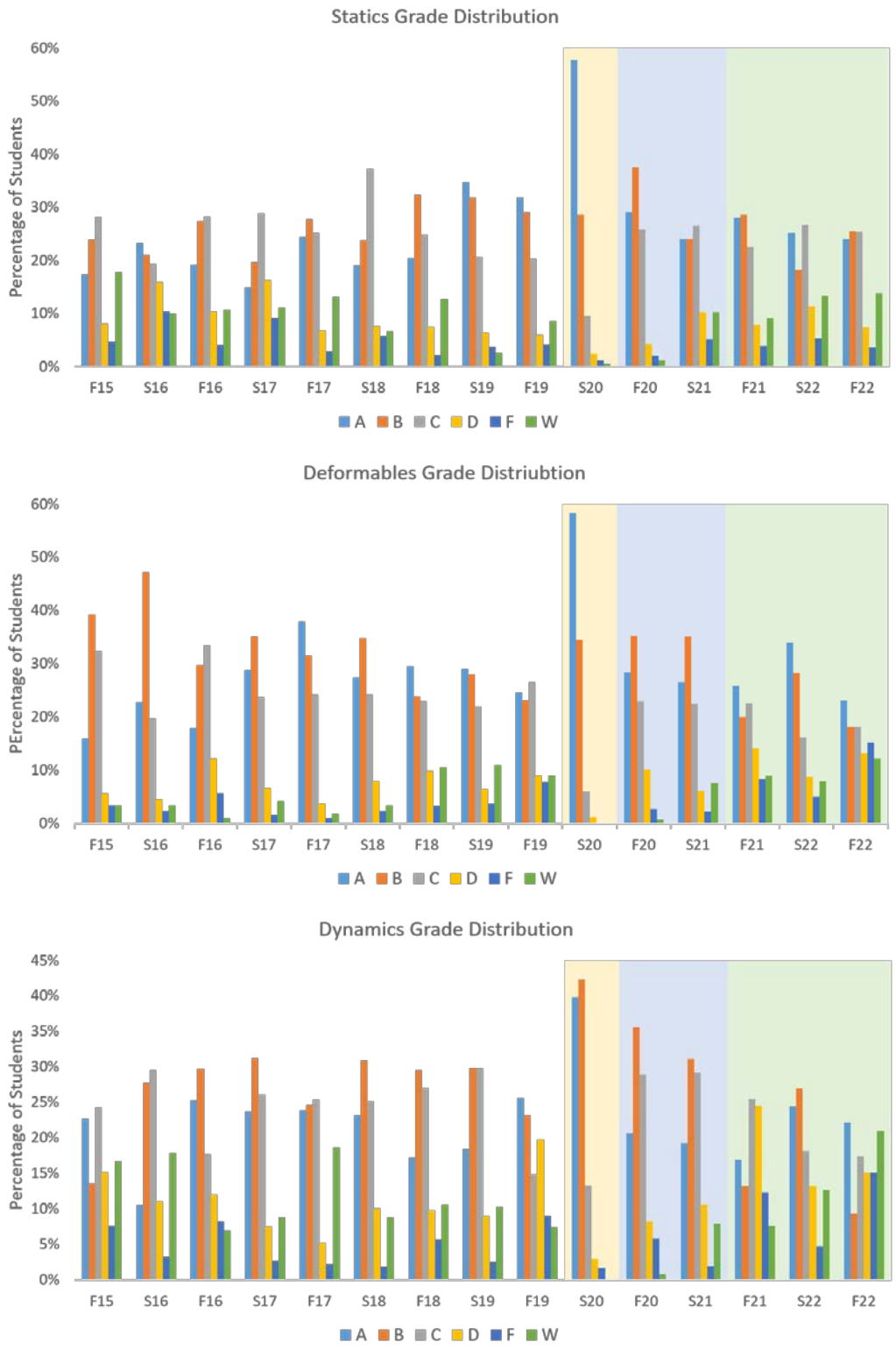

Figure 5: Percentage of students receiving each grade in Statics, Deformables, and Dynamics for each semester during the study period. Highlights signify the 'early-pandemic', 'mid-pandemic', and 'post-pandemic' time periods.

Discussion & Conclusions

The courses included in this study are large foundational courses required for the majority of engineering undergraduates at our institution. Statics is a prerequisite to Deformables and Dynamics, which are themselves prerequisites to several in-major upper division classes around the college. Thus, any deviation in these courses can cause a ripple effect through the rest of the curriculum. It is important that the courses maintain rigor while not acting as “gatekeeping” or “weed out” courses that significantly increase time to graduation for large numbers of students.

In Spring 2020, rapidly increasing cases of COVID-19 forced sudden changes to university courses. A majority of courses transitioned from in-person to online, and many institutions developed policies intended to help students progress through those classes. At our institution, most of those policies were reverted after the Spring 2020 semester, although the majority of classes continued to be taught online through Fall 2020 and Spring 2021.

When these courses moved online in Spring 2020, there was a significant decrease in DFW rate and a significant increase in GPA. This was true even for one course that was already being taught online. However, as courses reverted back to in-person and institutional polices around COVID-19 were relaxed, these effects reversed.

This paper does not explore the reasons for these trends. At present, we can only speculate based on our experience with the curricula in the college and these courses specifically. One policy that was instituted in Spring 2020 and continued in Fall 2020 was a late drop policy that allowed students to drop a course up until the last day of class. Typically students may only drop within ~6 weeks of the start of the (15-week) semester and thereafter may withdraw from the class, but students are only allowed 3 withdrawals during their time in the college. This late drop likely accounts for the significant decrease in DFW rate during the Spring 2020 semester and continued low DFW rate in Fall 2020. Students are unlikely to withdraw from or fail a course if they are able to drop it on the last day instead.

This likely partially explains the increased GPA too, as students with low D or F grades near the end of the course would likely drop the course instead. However, there was another significant change during Spring 2020 that affected grades. When classes were moved online, exams were too. These courses traditionally have proctored in-person exams where students are required to solve workout problems and reach numeric answers. Partial credit is awarded for correct methods. When exams moved online they were proctored remotely using software such as Respondus Monitor Lockdown Browser, if they were proctored at all. Although the format of the exams was largely unchanged faculty reported a noticeable increase in scores on these exams, well above what is typically expected. When exams were held in-person again in subsequent semesters, scores reverted largely back to pre-pandemic levels.

Since Fall 2021, when classes largely reverted back to in-person, there has been a general increase in DFW rate and decrease in GPA when compared to pre-pandemic values. This is true even for the online asynchronous section of the Deformables course, which is expected to have very consistent delivery, standards, and performance each semester. We see significant changes for Deformables and Dynamics, but not for Statics. It is possible that some students who took

Statics in COVID-affected semesters were not fully prepared to build on that foundational material in the follow-on courses. This would also be a concern for students who took Deformables and Dynamics in COVID-affected semesters and may likewise be under-prepared for upper division courses which build on these.

However, this trend was more pronounced for some faculty than others. Some faculty saw very large changes while others saw almost no change. We do not currently have data to explore this disparity. It is possible that some faculty are adapting to post-COVID teaching faster than others. It is also possible that some faculty are simply more lenient. More advanced investigation of student learning in these classes is needed to better understand these effects.

Overall, many students are still performing well in these classes. However, there is a noticeable shift in grade distributions over time. In particular, fewer students in Deformables and Dynamics are earning B and C grades and more are earning D and F grades, or withdrawing from the courses entirely. While we don't currently understand the reason for these trends, they are concerning and warrant further study.

Limitations & Future Work

There are several limitations to this study. First, we focus only on three foundational mechanics courses generally taken in the Sophomore year. A longitudinal study that tracks students through their 1st-year courses and into their upper division in-major courses would provide a more complete picture of any lasting effects of the pandemic. Although Statics is a prerequisite course to Deformables and Dynamics and thus some of our students are captured in multiple courses, our data mostly provides snapshots of these courses over time with different populations. We identify a general change in student performance and grade distribution in these courses, especially Deformables and Dynamics, and make inferences based on our experience in these courses but our data is not able to explain these changes.

It is not clear whether the observed trends are the start of a long-term change or a temporary change. Students at all levels had their education affected to some degree in Spring 2020 and beyond. There have only been three semesters since courses reverted to pre-pandemic modality and policies at our institution, and students that have taken these classes during the study period would have mostly been either 1st-year university students or high-school seniors during the most heavily impacted semesters. Relatedly, our post-COVID data is based on a relatively low number of sections. We intend to continue collecting data in future semesters to identify where student performance stabilizes long-term and whether there looks to be a permanent shift post-COVID.

We saw variations in performance trends for different instructors. For some instructors there are large differences in their students' mean GPA and DFW rate compared to pre-pandemic values, while other instructors see very little change. Our data is not able to explain these differences. A study of instructor attitudes, policy changes, and adaptations post-COVID may provide useful data to explain this.

Finally, we recognize that GPA and DFW rates are imperfect surrogate measures of student learning. The longitudinal study suggested above would allow for additional measures, such as

performance in follow-on courses. This would also help us identify whether differences between instructors are indicative of differences in student learning or differences in instructor expectations.

We identify trends in student performance in our foundational mechanics courses that are cause for concern. We intend to continue to track student progress through these courses and report on longer-term trends. Larger studies are warranted to help explain these trends.

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Supplemental Material

Table S1: Mean GPA and DFW rate for each course in each semester of the study period. Highlighted semesters indicate the 'early-pandemic', 'mid-pandemic', and 'post-pandemic' time periods.

Semester	Mean GPA (standard deviation)			DFW rate		
	Statics	Deformables	Dynamics	Statics	Deformables	Dynamics
F 15	2.49 (1.07)	2.56 (0.93)	2.32 (1.29)	31%	13%	39%
S 16	2.31 (1.31)	2.87 (0.86)	2.39 (0.97)	36%	10%	32%
F 16	2.53 (1.06)	2.42 (1.07)	2.54 (1.24)	25%	19%	27%
S 17	2.16 (1.17)	2.84 (0.95)	2.70 (0.98)	37%	13%	19%
F 17	2.73 (1.02)	3.02 (0.91)	2.75 (0.96)	23%	6%	26%
S 18	2.47 (1.08)	2.73 (1.00)	2.69 (0.98)	20%	14%	21%
F 18	2.70 (0.97)	2.72 (1.13)	2.43 (1.07)	22%	24%	26%
S 19	2.90 (1.05)	2.80 (1.07)	2.60 (0.97)	13%	21%	22%
F 19	2.84 (1.08)	2.53 (1.20)	2.37 (1.33)	19%	26%	36%
S 20	3.40 (0.82)	3.47 (0.63)	3.15 (0.81)	4%	1%	5%
F 20	2.88 (0.92)	2.74 (1.04)	2.54 (1.06)	7%	14%	15%
S 21	2.56 (1.13)	2.84 (0.97)	2.60 (0.97)	26%	16%	20%
F 21	2.75 (1.09)	2.46 (1.28)	1.97 (1.27)	21%	32%	44%
S 22	2.51 (1.19)	2.82 (1.15)	2.60 (1.17)	30%	22%	30%
F 22	2.67 (1.08)	2.22 (1.43)	2.03 (1.48)	25%	41%	51%

Table S2: Mean DFW rate and GPA for each course, separated into 3 time periods: 'pre-pandemic', 'early-pandemic', and 'post-pandemic'. Data is separated by instructor and includes only faculty who taught at least one section of a course in both the pre- and post-pandemic time periods.

	Mean DFW Rate					Mean GPA				
Statics	**Inst. D**	**Inst. E**	**Inst. F**	**Inst. G**	**Inst. I**	**Inst. D**	**Inst. E**	**Inst. F**	**Inst. G**	**Inst. I**
Pre-pandemic	18%	28%	12%	29%	25%	2.92	2.52	3.07	2.35	2.72
Early-pandemic	-	7%	0%	-	9%	-	3.59	3.56	-	2.90
Post-pandemic	22%	31%	16%	22%	33%	2.97	2.71	3.01	2.32	2.54

	Mean DFW Rate					Mean GPA				
Deforms	**Inst. A**	**Inst. D**	**Inst. E**	**Inst. F**	**Inst. H**	**Inst. A**	**Inst. D**	**Inst. E**	**Inst. F**	**Inst. H**
Pre-pandemic	16%	10%	26%	12%	13%	3.04	2.99	2.58	3.01	2.55
Early-pandemic	-	0%	3%	-	1%	-	3.71	3.52	-	3.38
Post-pandemic	35%	18%	34%	22%	34%	2.35	2.94	2.61	2.89	2.24

	Mean DFW Rate				Mean GPA			
Dynamics	**Inst. D**	**Inst. I**	**Inst. K**	**Inst. M**	**Inst. D**	**Inst. I**	**Inst. K**	**Inst. M**
Pre-pandemic	18%	33%	39%	17%	2.80	2.49	2.36	2.67
Early-pandemic	2%	5%	9%	10%	3.42	3.21	3.34	2.65
Post-pandemic	19%	58%	43%	11%	2.85	1.70	2.36	2.79

Table S3: DFW rate and GPA for in-person and asynchronous online sections of Deformables taught by one instructor across the study period. Highlighted semesters indicate the 'early-pandemic', 'mid-pandemic', and 'post-pandemic' time periods.

Semester	DFW Rate		GPA	
	In-person	Online	In-person	Online
F 15	10%	16%	2.46	2.36
S 16	3%	16%	2.79	2.61
F 16	15%	20%	2.34	2.30
S 17	12%	21%	2.69	2.14
F 17	-	5%	-	2.67
S 18	11%	42%	2.67	1.88
F 18	-	-	-	-
S 19	11%	10%	2.76	2.61
F 19	-	16%	-	2.61
S 20	2%	0%	3.36	3.49
F 20	-	14%	-	2.65
S 21	-	10%	-	2.70
F 21	-	31%	-	2.29
S 22	33%	38%	2.35	1.98
F 22	-	46%	-	1.91