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# A Hybrid Mechanics of Materials Course Part 2: Study of the Effect of a Sudden Change to Fully-Online Format

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## Abstract

The recent COVID-19 health crisis caused universities worldwide to move suddenly to an online format during the middle of the spring semester. This change in class format provides a unique opportunity to study the effect of this abrupt shift to online learning on student performance. In order to develop a baseline, the performance of 79 students in two sections of a hybrid Mechanics of Materials course during the face-to-face portion in the spring of 2020 was compared to the past performance of 461 students in 13 sections taught by the same instructor in a similar fashion. Using this comparison as a reference, the effect on student performance after the course transitioned to a fully-online format then was analyzed. In previous face-to-face hybrid sections, the Pearson correlation coefficients between the end-of-semester grade point and the averages for exams given during the first and second halves of the semester were 0.831 and 0.898, respectively. By comparison, the spring 2020 sections had Pearson correlation coefficients for the first and second halves of the semester of 0.825 and 0.932, respectively. This result indicates that the online exams given during the second half of the semester correlated very well with the end-of-semester grades. Some general observations also can be made about the students' ability to adapt to online learning. Not surprisingly, high-performing students generally adapted more rapidly to the online environment and even improved their scores as a result of the open resources that were available in the 50-minute online exams. On the other hand, students who were performing marginally struggled to adapt to the online format, which was less structured than the original format.

## Introduction and Motivation

The recent COVID-19 health crisis caused many countries around the world to lock down their communities as the infection spread from region to region. Universities in these communities ceased face-to-face instruction because large gatherings of students indoors potentially could lead to substantial infection clusters. Within a three-week timespan, colleges across the United States switched to a fully online format by the end of March.[1]

Prior to the present pandemic, only a third of the college students had enrolled in online courses.[1.] Although the number of fully online courses and programs have increased in many disciplines, there are few fully online ABET accredited programs. A recent search of the ABET website[2] shows that while there are hundreds of accredited programs across many different engineering disciplines, only a couple of dozen programs in engineering and engineering technology are accredited as fully online programs. For part of the spring semester, all engineering programs technically became online programs since they were only able to offer online courses for students. This switch to fully online learning midsemester provides a unique opportunity to study the efficacy of the online format.

One common observation made by individuals heavily involved in online education is that a quality online course takes months, if not years, to develop.[3] While the first author was a relatively early adopter of the hybrid format in his Statics and Mechanics of Materials courses in 2009, it took years before the class GPA results were comparable to those of the traditional face-to-face format class.[4] In initial offerings of a hybrid Mechanics of Materials course by the first author, the pass rate decreased by 3.1% from a pass rate of 69.8% in traditional face-to-face classes.[4.] Following the addition of an attendance requirement in spring 2017, Myose *et al.* 2020[4] found that the class GPA for hybrid sessions had improved to 0.14 grade points above the traditional face-to-face class GPA and that the pass rate increased to 79.8%. With the transition to a fully online format in March 2020, which eliminated the in-person attendance requirement, the question became how student performance would be affected.

In Mechanics of Materials, Thomas *et al.*[5] examined a variety of class formats, such as a traditional lecture style with or without the addition of online videos, a fully online format without face-to-face meetings, and a flipped class utilizing online videos outside of class and active learning during face-to-face meetings. Overall student performance was similar, irrespective of class format. However, the comparisons between styles were made with different students taking different versions of the course and not the same students taking different versions of the course.

The health crisis during the spring of 2020 provided an opportunity to compare online and face-to-face formats for the same students in the same course. Students experienced a hybrid format with required attendance in face-to-face meetings during the first half of the semester, while the same students participated in a fully online format during the second half. Past student performance data from previous sections of the first author's Mechanics of Materials hybrid course was used as a baseline to predict the performance of students in the second half of the course if face-to-face meetings had been required for the entire semester. Then, this prediction was compared with the actual performance of the students who completed the second half in online format.

## Change in Course Schedule

During the spring of 2020, the first author taught one section of a hybrid format Mechanics of Materials course that met three times a week for 50 minutes each time and one section that met twice a week for 75 minutes each time. Under normal circumstances, 30 different lessons of topical material are covered in Mechanics of Materials during a 15-week semester. The midpoint for the Mechanics of Materials course in terms of exams occurs during the ninth week of the semester. In 50-minute classes, students take a pre-test, six exams, and a comprehensive final, while students in the 75-minute classes have a pre-test, five exams, and a final. The number of exams taken by the two sections differs since the number of problems that can be reasonably asked during a 50-minute exam is different than for a 75-minute exam. On a 50-minute exam, students are asked three questions that usually involve drawing a free-body diagram, writing out equations, and solving for a numerical quantity with units. Because the 75-minute class has additional time, they are given four such problems on a regular exam as well as four multiple choice questions that measure their conceptual knowledge or understanding of appropriate units and terminology. The topical coverage and exam schedule for the second half of a typical semester is given in Table 1.

Due to the COVID-19 health crisis, universities worldwide abruptly changed to an online format in the middle of the semester. At Wichita State University, the change occurred at the end of the eighth week of the semester. The ninth week of classes was cancelled, and the university converted to a fully online format starting from the tenth week. The change meant that the 50-minute class completed three of their six exams in a face-to-face setting, while the 75-minute class completed two of their five exams face-to-face. The remaining exams and comprehensive final had to be conducted online.

Table 1 – Exam Topical Coverage & Standard Schedule [Abbreviations: Wk for Week, Ex for Exam, Ch for Chapter, L for Lesson, & *con* for continuation of Chapter material]

| Wk | Ex | 50-min Class Topics | 75-min Class Topics | Ex | Wk |
|---|---|---|---|---|---|
| 10 | 4 | Ch 6 Bending (L14-15),<br>Ch 7 Transverse Shear (L16-17) | Ch 5 [*con*] (L12-13),<br>Ch 6 Bending (L14-15),<br>Ch 7 Transverse Shear (L16) | 3 | 9 |
| 10 | | ***Last Day for Withdrawal*** | ***Last Day for Withdrawal*** | | 10 |
| 12 | 5 | Ch 8 Combined Loadings (L18-19),<br>Ch 9 Stress Transformation (L20-22) | Ch 7 [*con*] (L17),<br>Ch 8 Combined Loadings (L18-19),<br>Ch 9 Stress Transformation (L20-22) | 4 | 12 |
| 14 | 6 | Ch 10 Strain Transformation (L23),<br>Ch 12 Beam Deflection (L24-26) | Ch 10 Strain Transformation (L23),<br>Ch 12 Beam Deflection (L24-28) | 5 | 14 |
| 16 | Final | Ch 12 [*con*] (L27-28), Ch 4,5,6 Stress Concentration (L29), Ch 13 Buckling (L30) | Ch 4,5,6 Stress Concentration (L29),<br>Ch13 Buckling (L30) | Final | 16 |

Changes to the schedule as well as to topical content of each exam with reductions shown in blue & additions shown in red are provided in Table 2. As a result of the cancellation of the ninth week of classes, the latter half of the course had to be covered in a shorter time period. Additionally, since students had a two-week break during the transition to a fully online format, the first author created a slow "return to class" with exam-simulating practice before the exam originally scheduled for the ninth week was given in an online format during the end of the eleventh week. It should be noted that while the university moved the last day to withdraw with a grade of W from the tenth week to the twelfth week, the number of exams normally completed before the withdrawal date did not change because the course schedule was restructured.

The format of the online exams planned for the second half of the course were unlike exams that most engineering students usually took, so two exam-simulating homework assignments worth 2% of a student's end-of-semester grade were given during the tenth week and the beginning of the eleventh week of the semester. One of the most notable changes to exams was the conversion of the last three exams in the 75-minute section to 50-minute tests consisting of three problems over a reduced topical coverage on each exam. Although students were given several days to complete and submit their answers on the assignments, they were strongly encouraged to complete them within 50 minutes since online exams would be time-limited. However, this limit was not enforced, and class averages were 2-3% higher on the practice assignments than the subsequent online exam average. This result was not surprising since students had several days to complete the practice assignments, whereas the online exams were time-limited.

Table 2 –Exam Topical Coverage & Schedule after Online Transition [Abbreviations: Wk for Week, Ex for Exam, Ch for Chapter, L for Lesson, & *con* for continuation of Chapter material; color: added or removed]

| Wk | Ex | 50-min Class Topics | 75-min Class Topics | Ex | Wk |
|---|---|---|---|---|---|
| 10 | | Exam-simulating Homework #1 | Exam-simulating Homework #1 | | 10 |
| 11 | | Exam-simulating Homework #2 | Exam-simulating Homework #2 | | 11 |
| **11** | 4 | Ch 6 Bending (L14-15), Ch 7 Transverse Shear (L16-17) | Ch 5 [*con*] (L12-13), Ch 6 Bending (L14-15), Ch 7 Transverse Shear (L16) | 3 | **11** |
| **12** | | ***Last Day for Withdrawal*** | ***Last Day for Withdrawal*** | | **12** |
| **13** | 5 | Ch 8 Combined Loadings (L 18-19), Ch 9 Stress Transformation (L 20-22) | Ch 7 [*con*] (L 17), Ch 8 Combined Loadings (L 18-19), Ch 9 Stress Transformation (L 20-21) | 4 | **13** |
| 14 | 6 | Ch 10 Strain Transformation (L23), Ch 12 Beam Deflection (L24-26) | Ch 9 [*con*] (L 22), Ch 10 Strain Transformation (L 23), Ch 12 Beam Deflection (L 24-26) | 5 | 14 |
| 16 | Final | Ch 12 [*con*] (L27-28), Ch 4,5,6 Stress Concentration (L29), Ch 13 Buckling (L30) | Ch 12 [*con*] (L27-28), Ch 4,5,6 Stress Concentration (L29), Ch 13 Buckling (L30) | Final | 16 |

**Mechanics of Materials Fully Online Teaching and Exam Methods**

In the first author's hybrid class, students are supposed to study on their own outside of class by reading the textbook, watching the lectures and example problems solved on videos posted to the Blackboard Learn™ course website, and then working out the practice problems before coming to class. During face-to-face meetings, the instructor provides a short review and works out an additional problem. Therefore, each lesson consists of three example problems solved in the videos, three problems assigned for practice with solutions provided on the Blackboard course site, and four example problems that are solved in the textbook. Out of the approximately ten problems that are a part of each lesson, one of those problems is chosen semi-randomly for the exam. The potential pool of possible exam problems remains fixed and limited from semester to semester. The same figure and a similar problem statement are used for the exam; however, the starting values are changed. This format means that students have access to the solution methods for all of the problems that potentially might be on the exams. The problem statement and corresponding figure used in the course are incorporated into a Microsoft Excel worksheet so that the instructor can easily change quantities such as the structure's length, width, height as well as external load values to generate exam problems The equations for determining the intermediate and final answers are written as formulas referencing the appropriate cells where the starting values are given in the worksheet. Before the health crisis, the Excel files were not made available to the students.

When the class became a fully online class midsemester, no face-to-face class meetings were held online. Solutions to the example problems that would have been solved in class and other problems were still available in written form on the Blackboard course site along with the lecture videos. In lieu of answering questions during face-to-face class meetings and office hour visits, a discussion board on the course site was created so that students could post questions to the entire class. The first author answered discussion board and e-mail questions typically within 4-8 hours. The number of questions asked on the discussion board was similar to, if not more than, the number of questions normally asked inside and outside of class throughout a semester. In an informal survey conducted at the end of the semester, one question asked whether students preferred to communicate by (1) meeting in-person, (2) discussion board + e-mail, or (3) a Zoom-type class meeting. Most students selected the first option of in-person meeting which was not surprising. Out of the remaining students, they preferred the discussion board + e-mail option by a two-to-one ratio compared to a Zoom-type class meeting.

With the instruction portion of the course already in place online as a result of the hybrid format of the course, the first author focused on online exam development. During the ninth week of the semester when classes were cancelled, faculty in the aerospace engineering department at Wichita State University began discussing online teaching strategies. Based on recommendations from other faculty members who had experience in creating online exams, the first author attempted to create exams using the Blackboard course site's testing software. The system did not have the capability to ask multi-part problems where the numerical answer to one part is used as a starting value for the next part. One strategy employed by some faculty for this type of problem was to make each part a separate, but simpler, problem in the Blackboard test system. However, if the numbers in the each of the separate problems were randomized, students essentially had to solve more problems since one part was not connected to the next part numerically. Consequently, the first author chose to create online exams by modifying the Excel-based problems that were already being used in the course. This strategy allowed essentially the same problem to be asked using a familiar figure from the problem situation. Although each problem was divided into more parts, the starting given values were fixed so that answers from an earlier part still were used in solving for the answer of later parts.

One example that illustrates this method of writing exam questions is a flexural stress problem in which students are given a particular external load, such as a rectangular distributed load, on a simply supported I-beam and asked to determine the maximum tensile and compressive stresses on the beam. For an exam given during a face-to-face meeting, this problem might be divided into three parts: (a) determine the moment of inertia for the entire cross-section, (b) determine the maximum moment as it relates to the lengthwise location on the beam, and (c) determine the maximum tensile stress and whether it occurs at the top or bottom of the cross-section. Each part was worth 6-8 points for a problem total of 20-25 points. In the online version of the exam, each of these three parts was subdivided into smaller parts. Part a was divided into four parts that asked for the moment of inertia for the top and bottom webs, the moment of inertia for the vertically-oriented portion, the area times offset squared term associated with application of the parallel-axis theorem, and then the moment of inertia for the entire cross section. In part b, students were asked to determine the reaction force at the left end of the beam before finding the maximum moment. Part c required students to calculate the distance from the neutral axis to the top of the beam, the resulting flexural stress, and finally whether the stress is tensile or compressive. Each of these subdivisions in the online exam was worth 2-3 points for a similar total problem point value to that of a face-to-face exam. The answers to each part affected the final answer, so the Excel grading file used the student's answer from previous parts to determine the "correct" student answer in addition to the absolute correct answer as a comparator for awarding point scores.

By utilizing an Excel file to create the online exams, each student was assigned to a version of the exam that had different initial values, which meant that 45 different versions of an exam were generated for each class section. Students were given access to the blank template Exam file at the start of class and had 50 minutes to calculate the answers, enter them into the Excel file in specified cell locations, and then submit the file to the Blackboard course site. Students were given ten minutes following the conclusion of the exam to upload their file. If they had any difficulty with the upload process, students could email the file directly to the instructor. Once the first author had created a template answer worksheet, numerical answers for each student could be generated in a short time frame. The answer worksheet was written to automatically compare student-calculated values with answers and to award points.

One unique requirement of the first author's exams in any format is that students must provide numerical answers to five significant figures. This requirement stemmed from the fact that strains are often very small numbers. Multiple versions of an exam with slight variances in initial values are given to a single class, and because given values only vary to a small extent, answers sometimes have the same value out to the third significant figure. This requirement of five significant figures in an answer often results in some student complaints in a regular semester, but complaints were heard more frequently when the course switched to the online format.

An informal survey conducted at the end of the semester by the first author indicated that most students preferred writing their answers on a sheet of paper and submitting the exam in person as opposed to computerized answer entry in Excel. Furthermore, students felt that in-person test problems were easier than online problems by a margin of 5:3, even though they were the same problems simply divided into smaller parts. Simultaneously, students preferred having more resources in an online exam by a margin of 2:1 over in-person testing. Online exams were open-book and open-notes including practice problem solutions with access to a computer, whereas students in in-person exams were limited to a standard equation sheet and the use of a basic scientific calculator. While these informal survey results were not surprising, they could be useful for the planning of future online courses.

In order to reduce the likelihood of cheating, many universities give fixed-time online exams while utilizing proctors or lockdown browsers as their best practices.[6] Although proctors would have been preferred by the first author, the college did not have the budget to pay for online proctoring services in the middle of the semester, so this method could not be employed. With a class size of 45, a Zoom video conference was not a feasible option for the instructor to proctor his own students during an exam. Because Excel was as an integral part of the exam, a lockdown browser system could not be used. In the end, the limited time available and the unique given starting values for each student were thought to discourage cheating with classmates who also were taking the exam concurrently. Except for specific cells marked for entering answers, all other cells in the Excel file were locked and hidden. As a result, students could see the exam, but they could not cut and paste the cell contents. Whether these techniques prevented students from obtaining outside help from others could not be determined.

**Effect of Transition to Fully Online Format**

Figure 1 presents the average student performance on the pre-test and each regular exam for the two sections from spring 2020. The pre-test is administered to students at the beginning of the semester in order to gauge incoming student capability and prerequisite knowledge of Statics and Calculus. A companion paper by Smith *et al*[7] contains a more detailed description of the development of the pre-test and aggregate results from 692 students over four years. The 50-minute class had an enrollment of 45 students, of which 37 took the pre-test, all six exams, and the comprehensive final. The averages for those 37 students are shown by the pink triangle symbols. The 75-minute class also had the same enrollment, of which 42 students took the pre-test, all five exams, and the comprehensive final. The averages for those 42 students are shown by the blue circle symbols. Myose *et al.* 2020[4] reported on the average performance for 461 students from previous sections (2015-2019) of the first author's hybrid course, and those results are shown by the grey squares in the figure. The overall trend in the averages for these previous sections is depicted by the dashed line. Although Figure 1 shows when the final exam occurred, the final exam average is not provided because this information is not disclosed to the students. The red vertical line in the figure demarcates the point at which the class transitioned to a fully online format and effectively represents two weeks of time due to cancellation of classes during week 9 and the slow return to class with a week of two exam-simulating assignments.

In the spring of 2020, both sections appeared to perform relatively close to the historical average on the first two exams. However, on the third exam, the 50-minute class outperformed the 75-minute class and all prior sections taught by the first author, achieving the highest class average for this particular exam. This result may not be as surprising when the pre-test performance of the two sections from the spring 2020 are compared. The average score for the 50-minute section was 4% higher than usual, while the 75-minute section on average scored 5% lower than typically expected. The data suggests that the 50-minute class was comprised of students that were highly capable and had a solid foundation of prerequisite knowledge, and given sufficient preparation for exams, they were able to perform very well. Still, it should be noted that the performance on a single exam is not the same as an entire semester's performance.

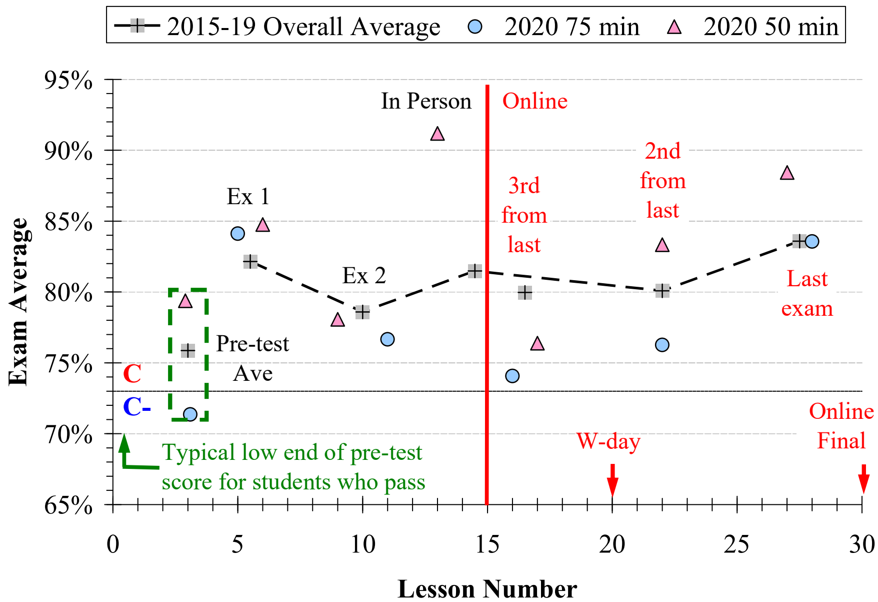


Figure 1 – Exam Averages During the Semester.

The student performance immediately after the change to a fully online format shows a relatively large reduction in the average exam score on the third from the last regular exam for both sections. This poor performance may be the result of a combination of factors such as the adjustment of students to the online exam format employed by the first author, a lack of focus by students because of the two-week hiatus and testing in a non-classroom environment, and the absence of formal class meetings. Despite an initial decrease in performance, the 50-minute section that consisted of highly capable students achieved average exam scores that are above the overall average from 2015-2019 on the last two regular exams. The 75-minute section took slightly longer to adjust, but they were able to perform at a level equal to the overall average by the last regular exam. These results suggest that the online exam format used by the first author per se does not cause students to perform poorly. Most students would require some time to adjust to a new assessment system that is significantly different from one that they have been accustomed to using.

In order to account for the poor performance from a sudden change in testing method, the first author employed a curve to the end-of-semester grade by using a section's in-person exam performance as a baseline to predict the expected semester grade. The amount of curving involved was 1-2% of the end-of-semester grade, which is equivalent to the addition of approximately half a letter grade to two or three exams, depending on the section. Individual performance above or below the expected average would adjust individual students' grades. After employing this curve, the 50-minute section's performance became the second-highest GPA achieved by Mechanics of Materials sections taught by the first author, and the 75-minute section's performance was in the middle.

In order to explore whether an online testing format can be employed effectively as a measure of student performance further, the Pearson correlation coefficients for various subsets of assessment items over the course of the semester were calculated for previous hybrid sections taught from 2015 to 2019 that had face-to-face exams and for the spring 2020 sections. The Pearson correlation coefficient ranges between +1 and –1. It is +1 when two quantities are perfectly correlated, 0 when there is no correlation at all, and –1 when an increase in one variable leads directly to a decrease in the second variable. There is less scatter in the data when the Pearson correlation coefficient approaches +/–1, while there is much more scatter when the coefficient nears zero.

Table 3 shows the Pearson correlation coefficients between the end-of-semester grade point and scores from several different assessment items. It should be noted that this is a correlation between individual students' semester grade point and scores achieved on each assessment item. The spring 2020 group contains data from 79 students, consisting of 37 students from the 50-minute section and 42 from the 75-minute section, while the 2015-19 group consists of 461 students. The results from Table 3 show that the pre-test, Exam 1, as well as pre-test combined with Exam 1 were only moderately correlated with the semester grade point. This is not surprising since students alter their level of study and exam preparation over the course of the semester, and there are a large number of assessment items still available to improve one's grades at the beginning of the semester. After all regular exams are completed, the Pearson correlation coefficient reaches a near-perfect level. This level of correlation between the cumulative average of all regular exams and the end-of-semester grade indicates that only a few students are able to change grade levels with the final exam. Similar correlation trends were found in the Statics hybrid course reported by Myose *et al.* 2019.[8]

Table 3 – Correlation Between Average of Single Exam or Several Exams Compared with Semester Grade.

| Group | Pre-test | Exam 1 | Pre-test & Exam 1 | First Half Exams | Last Half Only | All Regular Exams |
|---|---|---|---|---|---|---|
| 2015-19 | 0.528 | 0.686 | 0.643 | 0.830 | 0.898 | 0.957 |
| 2020 | 0.436 | 0.711 | 0.659 | 0.825 | 0.932 | 0.965 |

In previous hybrid sections with face-to-face exams, the Pearson correlation coefficient for the averages for exams given during the first and second halves of the semester to the end-of-semester grade were relatively high at 0.830 and 0.898, respectively. The correlation coefficient in the second half of the semester is slightly higher than that for the first half, which may be a result of the fact that only the final exam is left to affect a student's grade. By comparison, the spring 2020 sections had Pearson correlation coefficients for the first and second halves of the semester of 0.825 and 0.932, respectively. These values are similar to those from previous face-to-face hybrid sections' results and indicate that the online exams given during the second half of the semester correlated very well with the end-of-semester grades.

Figures 2, 3, and 4 present the least squares fits corresponding to the correlation coefficients in Table 3 for various subsets of exams. The cumulative exam averages at each grade point level for the dataset from the spring of 2020 are depicted as square symbols along with the number of students that received that grade. A letter grade of A with a grade point of 4.0 starts at a score of 93, an A- (3.7) from 90, a B+ (3.3) from 86, a B (3.0) from 83, and a B- (2.7) from 80, with the pattern continuing until a grade of F is reached. The standard deviation bars show the variance in the 2020 data one standard deviation above and below each average. It is important to note that the Pearson correlation coefficients in Table 3 represent the variance between the data points represented by square symbols at the different grade levels with the least squares fit line. By contrast, the standard deviation bar heights on the plots in Figures 2, 3, and 4 represent the variance in the original data used to generate the data points shown as square symbols. Additionally, for reference, the least squares fit line for the same subsets of exams in the reference dataset collected from 2015 to 2019 is plotted in each figure.

Figure 2 shows the cumulative averages for each grade level and the corresponding least squares fit line for the first half of the semester in which both the reference dataset and the students in the spring 2020 sections took in-person exams on paper. The least squares fit line for the spring 2020 students, illustrated by the blue-colored dashed line, is close to the least squares fit line of the previous hybrid sections shown in black. Both least squares fit lines correlate reasonably well to the scores associated with each grade level, except at the lower grade levels. Although it is not visible in this plot, students at the lower grade levels in previous hybrid sections exhibited a similar trend of scoring higher than expected on exams in the first half of the semester. However, the departure was roughly half the height difference shown by the spring 2020 students. In Figure 2, the standard deviation bars are relatively large in size with some bars having a range of ±8 to 9%, which is not surprising since individual student performance can vary significantly through the course of a semester. It should be noted that the number of students at each grade level for the spring 2020 data set is relatively small. Each grade level consists of less than 20 students each, thereby making the statistical confidence level marginal to an extent. One additional outlier student at a grade level has the potential to change the average value significantly, particularly in the lower grades that have a very small number of students.

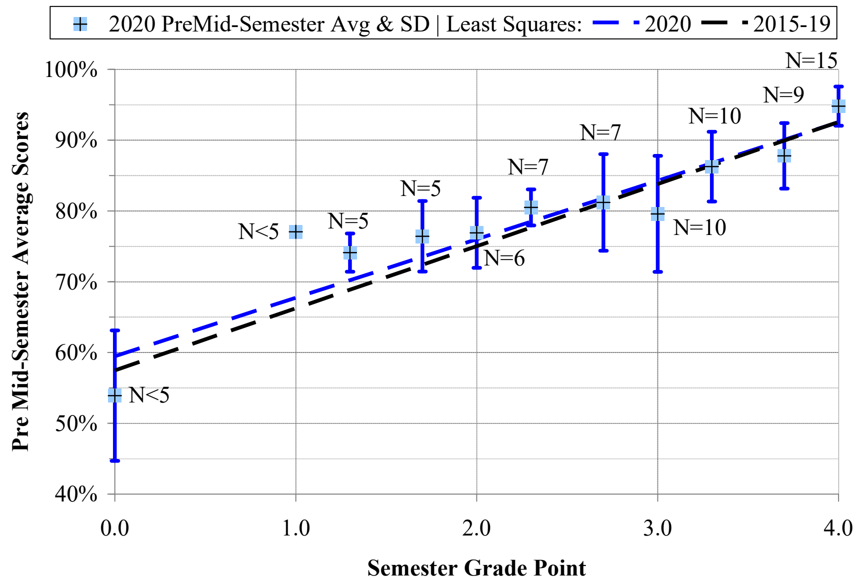


Figure 2 – Exam Averages for the First Half of the Semester as a Function of Semester Grade.

Figure 3 depicts the cumulative averages for each grade level and the corresponding least squares fit line for the second half of the semester. The solid red line represents the least squares fit for the data from spring 2020, and the solid black line represents the least squares fit for the data from the previous hybrid sections from 2015 to 2019. The dashed least squares fit lines for the first half of the semester from Figure 2 are also shown in Figure 3 for reference. From Figure 3, it is evident that the students who took the course in the spring of 2020 at grade levels below B- underperformed on the fully online exams during the second half of the semester. Contrastingly, A and B students performed at a level similar to or slightly above that of the first half of the semester. The standard deviation bar heights for the spring 2020 students remained relatively large (up to ±5 to 6%). Although not shown in Figure 3, the standard deviation bar heights were reduced by about 2-3% for previous hybrid sections from 2015 to 2019. This difference indicates that there was a large amount of variability in student performance during the second half of the semester in the spring of 2020 with the fully online exams.

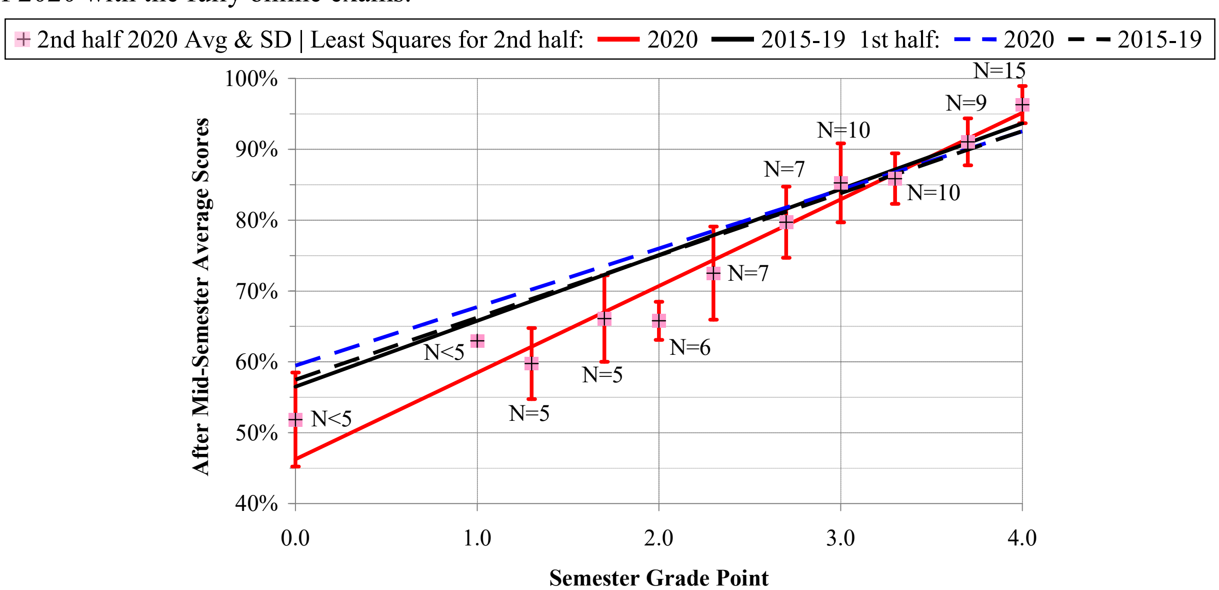


Figure 3 – Exam Averages for the Second Half of the Semester as a Function of Semester Grade.

Figure 4 shows the cumulative averages for each grade level and the corresponding least squares fit line for the cumulative average of all regular exams, excluding the pre-test and the final exam. The solid green line represents the least squares fit for the spring 2020 dataset, and the dashed black line represents the least squares fit for the previous hybrid sections from 2015 to 2019. By the last exam before the final, most standard deviations in Figure 4 are about $\pm$1-2%, which is the typical range for a grade level. This result is expected since the Pearson correlation coefficient between the cumulative average of the regular exams and the semester grade was an extremely strong correlation value of 0.965. The significant departure from the standard score-to-grade level trend seen in Figure 3 for students taking the course in spring 2020 is lessened when all of the regular exams over the entire semester are taken into consideration. Only a relatively small amount of underperformance by students at letter grades less than B- remains with the inclusion of all regular exams in the data.

As indicated in Figures 2 through 4, 15 out of the 79 students, which is 19% of the group that took Mechanics of Materials in the spring 2020 semester, earned a grade of A with a grade point of 4.0 by achieving an average score of 93 in the course. Based on the cumulative average of exams taken during the first half of the semester, 14 out of the 79 students, or 17.7%, had a cumulative average of 93 or above at the midsemester point in the spring of 2020. This result means the number of A's increased by one student or 1.3% between the middle and the end of the semester. These statistics were calculated for other grade levels in order to obtain the change in grade levels between the first half and the second half of the semester shown in Table 4. The top rows show the change in the grade levels for each individual letter grade for students taking the course in both the previous hybrid sections and the spring 2020 group. The lower rows contain different combinations of these grades.

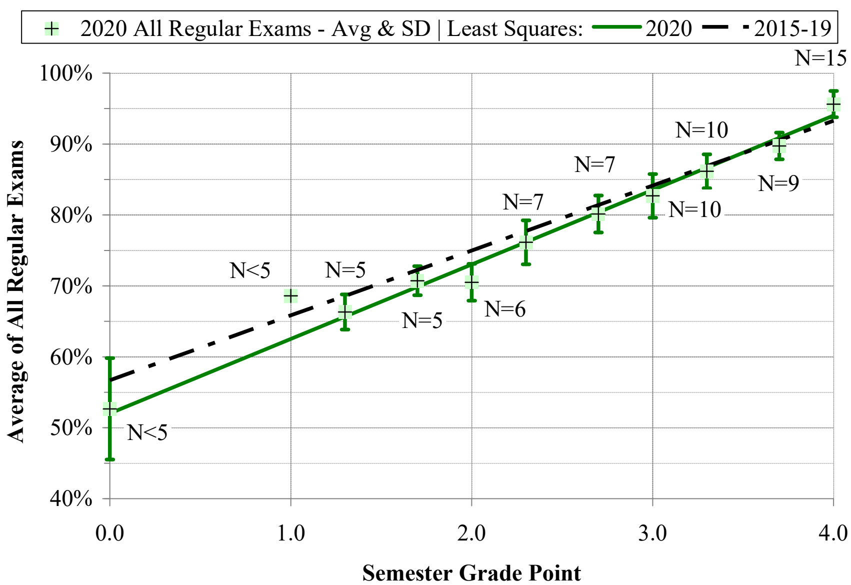


Figure 4 – Exam Averages During the Entire Semester as a Function of Semester Grade.

Table 4 shows that the number of students receiving A's increased by 5.1% between the midsemester point and the end of the second half of the semester that used fully online exams. By comparison, an increase of only 2.6% was seen for students that took only in-person exams from 2015 to 2019 and received A's. When letter grades of both A's & B's are considered, there were 2.5% more high-performing students during the fully online portion in the second half of the semester compared to the previous hybrid sections from 2015 to 2019, which saw essentially no change in grades. These percentages suggest that high-performing students improved their scores during the online exams when open resources, such as textbooks and notes, were available during the online exams. On the other hand, students who were performing marginally during the first half of the semester struggled to adapt to the online format according to the results of Figure 3 and Table 4. Here, the term marginally might be applied to C students since the number of D’s & F’s increased 3.8% during the online portion compared to the in-person portion in the first half of the semester. The reasons for the underperformance of marginal students in a fully online course need to be studied further before interventions to help these students can be developed.

Table 4 – Change in Grade Level between Midsemester and End of Semester.

| Group | A | A- | B+ | B | B- | C+ | C | C- | D+ | D | D- | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015-19 | +2.8% | -0.2% | -1.3% | -3.7% | +2.2% | +4.1% | +1.1% | 0% | -3.9% | -0.4% | +0.2% | -0.9% |
| 2020 | +1.3% | +3.8% | -1.3% | -1.3% | 0% | -7.6% | +2.5% | -1.3% | +3.8% | +1.3% | -3.8% | +2.5% |
| Group | A’s | | B’s | | | C’s | | | D’s | | | F |
| 2015-19 | +2.6% | | -2.8% | | | +5.2% | | | -4.1% | | | -0.9% |
| 2020 | +5.1% | | -2.5% | | | -6.3% | | | +1.3% | | | +2.5% |
| Group | A’s & B’s | | | | A+B+C’s | | | | D’s & F’s | | | |
| 2015-19 | -0.2% | | | | +5.0% | | | | -5.0% | | | |
| 2020 | +2.5% | | | | -3.8% | | | | +3.8% | | | |

One final item of note is that a few days before the last day to withdraw, the university announced a new Credit/No Credit policy applicable only for the spring semester of 2020. After being notified of their semester letter grade, students could choose to convert their grade to Credit in a course with grades of C- or above, while D’s and F’s would be recorded as No Credit. The choice to convert one’s grades to Credit/No Credit or to keep their original letter grade would be made during the week following the end of the semester. Both Credit and No Credit would be listed on the transcript, but these designations would not change a student’s GPA. It is likely that this option to receive Credit/No Credit instead of a low grade impacted some students’ decisions to remain in the course after the withdrawal date.

## Summary

The effect of a sudden change from a hybrid to a fully online format on student performance in a Mechanics of Materials course was investigated. In order to develop a baseline, the performance of 79 students in two sections of a hybrid Mechanics of Materials course during the face-to-face portion in the spring of 2020 was compared to the past performance of 461 students in 13 sections taught by the same instructor in a similar fashion. Using this comparison as a reference, the effect on student performance after the course transitioned to a fully online format in the second half of the semester was analyzed. In previous face-to-face hybrid sections, the Pearson correlation coefficients between the end-of-semester grade point and the averages for exams during the first and second halves of the semester were 0.831 and 0.898, respectively. By comparison, the spring 2020 sections had Pearson correlation coefficients for the first and second halves of the semester of 0.825 and 0.932, respectively. This result indicates that the online exams given during the second half of the semester correlated very well with the end-of-semester grades. Some general observations were made about students’ ability to adapt to online learning. As expected, high-performing students generally adapted more rapidly to the online environment and even improved their scores as a result of the open resources that were available in the 50-minute online exams. Conversely, students who were performing marginally struggled to adapt to the online format. The reasons for the underperformance of marginal students in a fully online course need to be studied further before interventions to these students can be developed.

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