

A Look at the Performance in Vibration Course during COVID-19 Pandemic

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Abstract

This paper compares the performance in Vibration course taught during and prior to COVID-19 pandemic. Normally, this class is taught in-person. During the pandemic lockdown, this class was taught virtually. Two in-class tests for summer and spring 2021 classes during COVID, and for three summer and three spring classes prior to COVID were investigated. Test 1 results showed that during COVID, the percentage of failure was significantly high while the percentage of excellence was almost non-existent. Some improvement was made on test 2, however, only between failure and mediocrity. Excellent performance was still rare. Conversely, test 1 results in the pre-COVID classes showed that the percentage of failure was much lower, a typical 20% while the percentage of excellence was at the expected level near 22%. The improvement on test 2 in pre-COVID classes was between mediocrity and excellence.

Keywords

Vibration, student performance, grading protocol, virtual, in-person, COVID-19, pandemic.

Introduction

Vibration is the core course in mechanical engineering, and universities across the world have continuously searched for ways to teach the course more effectively. Real-world vibration problems were introduced to the course to provide hands-on experience¹. Vibration concept demonstrations via software tools such as Math CAD[®] and Working Model[®] were used to enhance student understanding². Computation laboratory using MATLAB/Simulink was added to existing Vibration course³. Instructor even modified the course lay-out away from the norm. Na Zhu's Vibration class contained two tests and four open-ended projects⁴. The purpose here was to emphasize on the problem-solving ability in real-world applications rather than to spend time on rigorous mathematics. Vibration has been extended beyond mechanical engineering as well. Luciana Barroso inserted Vibration into civil engineering curriculum at Texas A&M University⁵.

The impact of COVID-19 on university students was well-documented⁶. Kristi Boardman surveyed 109 students at a liberal arts college and found that the lack of students' connection to their peers and professors strongly affected personal motivation and academic success⁷. Universities were encouraged to engage students in various activities to combat anxiety, depression, infection fear, ambiguity due to the pandemic, etc.⁸

Vibration at NC State University is a one-semester course credited three hours. Typically, five classes are offered in an academic year. Since 2016 these classes average approximately 60

students. The class meets twice a week for one hour and 15 minutes each meeting. Summer classes are smaller at an average of about 24 students. They meet every day of the week for one hour and 30 minutes each meeting. Topics covered are discrete and one-dimensional continuous systems. Discrete systems, single-degree-of-freedom (SDOF) and N-degree-of-freedom (NDOF), are analyzed in free and forced vibration while continuous system is limited to only free vibration. Common assignments are homework, small projects, two in-class tests and a final examination. Under normal circumstances, all classes must be taken for a letter grade, resulting in a contribution to the grade point average (GPA). Although Vibration is not a C-wall class, students must earn a D- or higher to move forward in the curriculum.

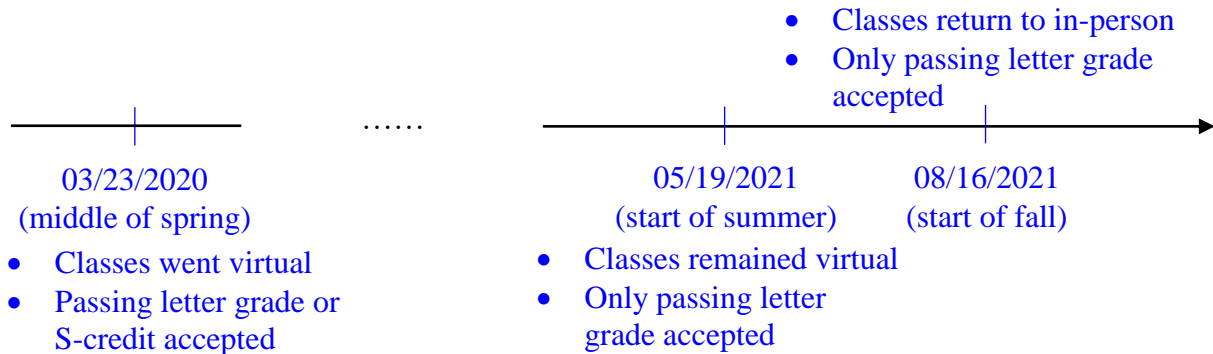


Figure 1. Continuity plan and grade policy during COVID-19 pandemic

Some issues for the students during the pandemic were being isolated at home versus getting together with study groups, lacking concentration virtually versus retaining attention in class, etc. To assist students cope with such hardship, NC State University implemented a continuity plan where faculty changed the framework of the class and were encouraged to be more lenient. In addition, the grade policy was changed to allowing classes in spring, summer and fall 2020, and spring 2021 to be taken for credit-only. The students could convert a letter grade to credit-only after the academic term with C- or higher resulting in satisfactory (S) and D+ or lower resulting in unsatisfactory (U) credit. With S credit in these classes, the students can move forward in the curriculum. Neither S nor U counts toward the GPA. Figure 1 shows the time line of the adaptation of classes to COVID-19 pandemic. Note that summer 2021 classes remained virtually but the grade policy returned to normalcy.

In Vibration, the only change was the replacement of the three-hour in-class final examination with a group project. This project was assigned in the last two weeks of the semester. Homework, small projects remained the same with the exception of electronic copy. Two in-class tests also remained the same with the exception of performing virtually.

Method

Tests are scored in the 100-scale with 0 being the lowest and 100 being the highest. For analysis purpose, the scores are grouped into five letter grades. Table 1 shows how letter grades are categorized according to the scores. A letter grade is in the interval of 10 points. Vibration is not a C-wall class, that is, a D will allow the students to move forward. To that end, the passing range is from D to A with D-C referred to as the low passing range and B-A the high passing

range. A higher percentage in the passing range is considered better. Conversely, a higher percentage in the failing range is considered worse.

Table 1. Standard letter grading for an assignment

$90 \leq A \leq 100$	High passing range
$80 \leq B < 90$	
$70 \leq C < 80$	Low passing range
$60 \leq D < 70$	
$0 \leq F < 60$	Failing range

Consider a class j of N_j students. Let $x_{j,k}$ be the test grade for student k in class j . The test average for class j is

$$\bar{x}_j = \frac{1}{N_j} \sum_{k=1}^{N_j} x_{j,k} \quad (1)$$

In class j , $N_{A,j}$, $N_{B,j}$, $N_{C,j}$, $N_{D,j}$ and $N_{F,j}$ are the numbers of students with test grades A, B, C, D and F respectively. The percentages of class j earning grades A, B, C, D and F are

$$\begin{aligned} \% A_j &= \frac{N_{A,j}}{N_j} \times 100, & \% B_j &= \frac{N_{B,j}}{N_j} \times 100, & \% C_j &= \frac{N_{C,j}}{N_j} \times 100, \\ \% D_j &= \frac{N_{D,j}}{N_j} \times 100, & \% F_j &= \frac{N_{F,j}}{N_j} \times 100. \end{aligned} \quad (2)$$

Suppose there are M classes, the test average for the accumulation of M classes is

$$\mu = \frac{1}{\sum_{j=1}^M N_j} \left(\sum_{j=1}^M \sum_{k=1}^{N_j} x_{j,k} \right), \quad (3)$$

and the percentages of the accumulation of M classes earning grades A, B, C, D and F are

$$\begin{aligned} \% A &= \frac{1}{\sum_{j=1}^M N_j} \left(\sum_{j=1}^M N_{A,j} \right) \times 100, & \% B &= \frac{1}{\sum_{j=1}^M N_j} \left(\sum_{j=1}^M N_{B,j} \right) \times 100, \\ \% C &= \frac{1}{\sum_{j=1}^M N_j} \left(\sum_{j=1}^M N_{C,j} \right) \times 100, & \% D &= \frac{1}{\sum_{j=1}^M N_j} \left(\sum_{j=1}^M N_{D,j} \right) \times 100, \\ \% F &= \frac{1}{\sum_{j=1}^M N_j} \left(\sum_{j=1}^M N_{F,j} \right) \times 100. \end{aligned} \quad (4)$$

Results

Because only spring and summer 2021 classes were investigated, the study was limited to the latest three spring and three summer terms prior to the pandemic. In so doing, a large gap in sample size can be avoided. Table 2 shows test 1 averages for springs 2021, 2019, 2018 (001) and 2018 (002) classes. Recall that a grade of 70 is “desirable” because it satisfies the requirement for C-wall classes under normal circumstances and for S-credit classes under COVID-19 period. Spring 2021 class failed test 1. Its average was 47.22, far below the desirable level. The three pre-COVID spring classes met the desirable level. Test 1 average for the accumulation of these classes was 71.55.

To improve test 1 average for spring 2021 class, an in-class, extra credit test was given one week after the original test was graded and returned. It had a maximum of 23 points and contained two topics where the majority underperformed in the original test. Even so, spring 2021 class could not reach the desirable level ($\bar{x} = 63.46$).

Table 2. Test 1 average for spring terms

	Class Size	Test 1 (original)	Test 1 (with extra credit)
Spr. 21 (during COVID)	54	$\bar{x} = 47.22$	$\bar{x} = 63.46$
Spr. 19 (pre-COVID)	66	$\bar{x}_1 = 74.39$	
Spr. 18 (001) (pre-COVID)	57	$\bar{x}_2 = 70.49$	
Spr. 18 (002) (pre-COVID)	63	$\bar{x}_3 = 69.52$	
Spr. 19 + 18 (001) + 18 (002)	186	$\mu = 71.55$	

Figure 2 shows the performance on test 1. The distributions for springs 2021, 2019, 2018 (001) and 2018 (002) classes are shown in blue, purple, pink and green respectively while the distribution of the accumulation of pre-COVID classes, used as standard, is shown in red. Shockingly, 72.22% of spring 2021 class failed test 1. In the low passing range D-C, the percentages of spring 2021 class with passing grade D and desirable grade C were both 9.26%. In the high passing range B-A, the percentages with grades B and A were 7.41% and 1.85% respectively.

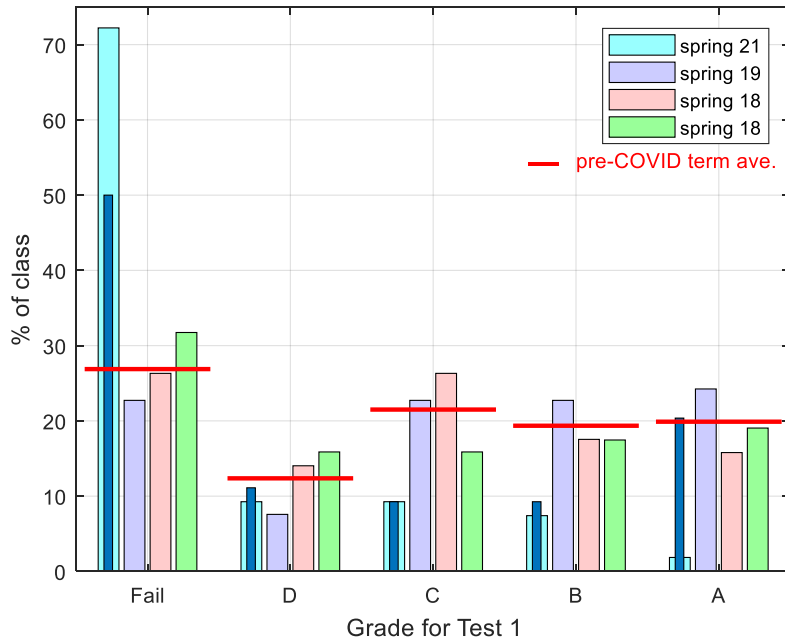


Figure 2. Grade distribution of test 1 in spring terms

The distribution for spring 2021 when 23-point extra credit was added to test 1 is shown in darker blue. Still, 50% failed test 1, 23.12% worse than standard. In the low passing range D-C, it remained worse than standard. In the high passing range B-A, even though worse in B, it caught up in A at 20.37%. Note that the performance on the extra credit test itself improved to a distribution usually seen (30.2% F, 17% D, 11.3% C, 3.8% B and 37.7% A).

Spring 2021 class passed test 2 with a D average (Table 3). Its average was 67.76, below the desirable level just as on test 1. The pre-COVID classes exceeded the desirable level. In fact, test 2 average for the accumulation of these classes approached the high passing range at 77.84. 5% of the students in pre-COVID classes dropped the course after the first test.

Table 3. Test 2 average for spring terms

	Number of students dropped after test 1	Class Size	Test 2
Spr. 21 (during COVID)	0	54	$\bar{x} = 67.76$
Spr. 19 (pre-COVID)	3	63	$\bar{x}_1 = 74.97$
Spr. 18 (001) (pre-COVID)	3	54	$\bar{x}_2 = 82.93$
Spr. 18 (002) (pre-COVID)	3	60	$\bar{x}_3 = 76.28$
Spr. 19 + 18 (001) + 18 (002)	9	177	$\mu = 77.84$

Figure 3 shows the performance on test 2. 27.78% of spring 2021 class failed test 2. In the low passing range D-C, the percentages with passing grade D and desirable grade C were 20.37% and 24.07% respectively. In the high passing range B-A, the percentages with grades B and A were 24.07% and 3.70% respectively.

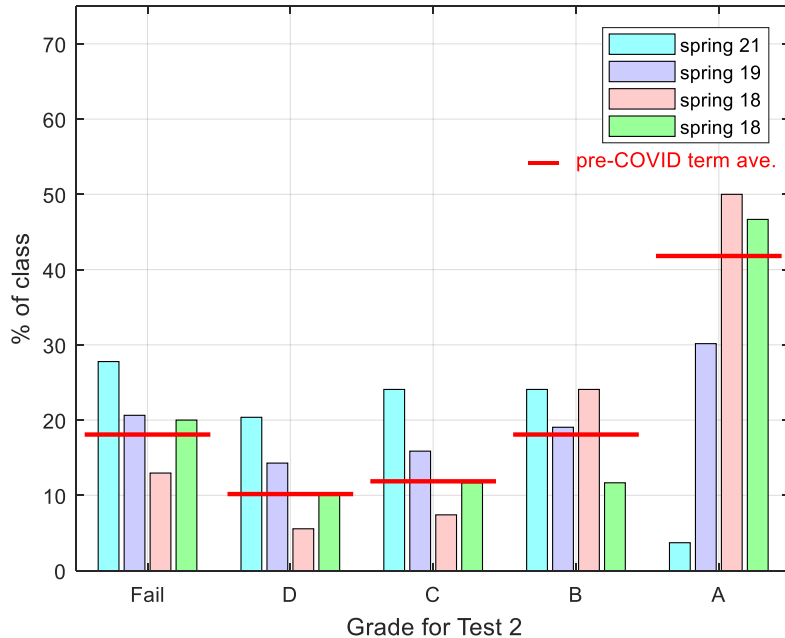


Figure 3. Grade distribution of test 2 in spring terms

Let observe the performance of spring 2021 class on both tests (Table 4). Recall that the distribution of the accumulation of pre-COVID classes was used as standard. The performance on test 1 was worse than standard across all letter grades. The percentage of failed students was compellingly worse than standard, and the number of students earning highest passing grade A was almost non-existent. On test 2, the percentage of failed students was worse than standard just as on test 1, but not as severely. It seems that a number of them had transitioned to the passing range. From D to B, spring 2021 class performed better than the standard on test 2. Interestingly, the number of students earning highest passing grade A was still almost non-existent.

Table 4. Comparison of grade distributions for tests 1 and 2 for spring 2021 class

	F	D	C	B	A
Test 1	Worse (45.34%)	Worse (3.11%)	Worse (12.25%)	Worse (11.95%)	Worse (18.04%)
Test 2	Worse (9.70%)	Better (10.17%)	Better (12.21%)	Better (6.00%)	Worse (38.10%)

Summer classes are compacted into five weeks and meet every day. Table 5 shows test 1 averages for summers 2021, 2019, 2018 and 2016 classes. Summer 2021 class failed test 1. Its average was 57.29, far below the desirable level of 70. All three pre-COVID summer classes

exceeded the desirable level. The average of their accumulation actually approached the high passing range ($\mu = 78.14$).

An extra credit test was also given to summer 2021 class one week after the original test was graded and returned. It had a maximum of 14 points and contained one topic where the majority underperformed in the original test. The desirable level was not reached ($\bar{x} = 65.11$).

Table 5. Test 1 average for summer terms

	Class Size	Test 1 (original)	Test 1 (with extra credit)
Sum. 21 (during COVID)	35	$\bar{x} = 57.29$	$\bar{x} = 65.11$
Sum. 19 (pre-COVID)	32	$\bar{x}_1 = 78.16$	
Sum. 18 (pre-COVID)	20	$\bar{x}_2 = 75.20$	
Sum. 16 (pre-COVID)	21	$\bar{x}_3 = 80.90$	
Sum. 19 + 18 + 16	73	$\mu = 78.14$	

The performance on test 1 for summer classes is shown on Fig. 4. 54.29% of summer 2021 class failed test 1. In the low passing range D-C, the percentages of summer 2021 class with passing grade D and desirable grade C were 14.29% and 25.71% respectively. In the high passing range B-A, the percentages with grades B and A were 5.71% and 0% respectively.

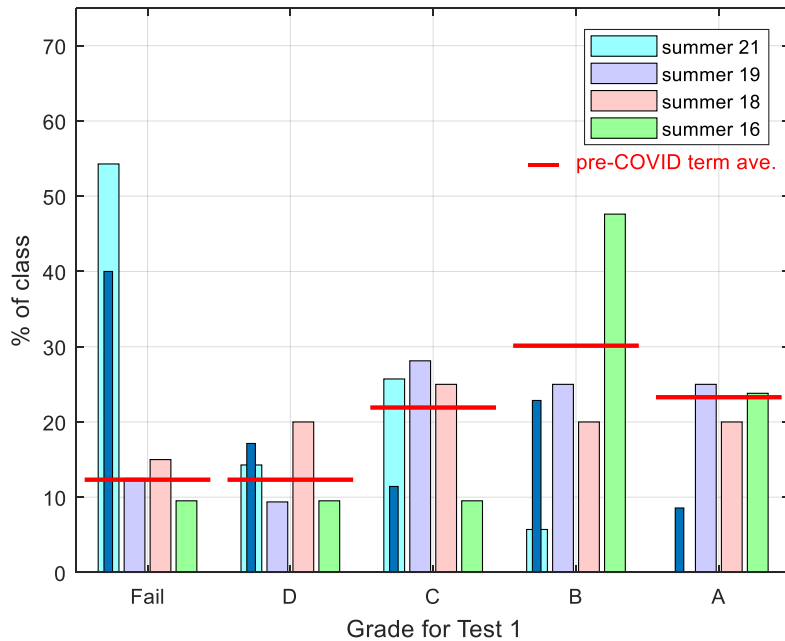


Figure 4. Grade distribution of test 1 in summer terms

With 14-point extra credit added to test 1, as shown in darker blue (Fig. 4), 40% still failed, 27.67% worse than standard. It caught up in D at 17.14%, but worse than standard from C to A. An observation on the extra credit test itself revealed an unusual distribution, no improvement in the failing range (55.9% F) and an extreme improvement in the passing range (0% D, 0% C, 0% B and 44.1% A).

Summer 2021 class passed test 2 with a C average (Table 6). Its average was 71.11, meeting the desirable. The pre-COVID classes exceeded the desirable level. Test 2 average for the accumulation of these classes were at the border of the high passing range at 79.16. Only 4% of the students in pre-COVID classes dropped the course after the first test.

Table 6. Test 2 average for summer terms

	Number of students dropped after test 1	Class Size	Test 2
Sum. 21 (during COVID)	0	35	$\bar{x} = 71.11$
Sum. 19 (pre-COVID)	2	30	$\bar{x}_1 = 80.50$
Sum. 18 (pre-COVID)	1	19	$\bar{x}_2 = 77.42$
Sum. 16 (pre-COVID)	0	21	$\bar{x}_3 = 78.81$
Sum. 19 + 18 + 16	3	70	$\mu = 79.16$

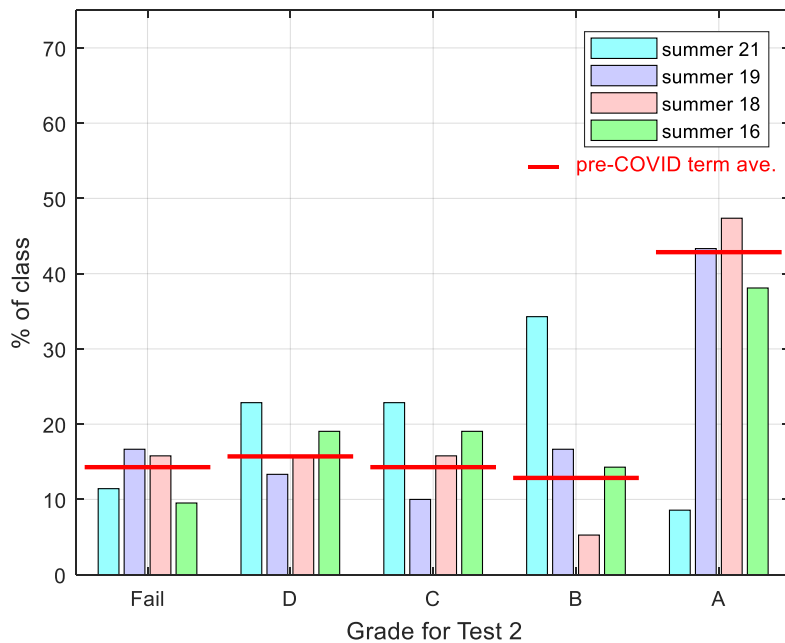


Figure 5. Grade distribution of test 2 in summer terms

Figure 5 shows the performance on test 2. 11.43% of summer 2021 class failed test 2. In the low passing range D-C, the percentages with passing grade D and desirable grade C were both 22.86%. In the high passing range B-A, the percentages with grades B and A were 34.29% and 8.57% respectively.

Table 7 compares the performance of summer 2021 class on both tests. The percentage of students who failed test 1 was again considerably worse than standard. In the low passing range D-C, it performed better than standard. In the high passing range B-A, it performed worse than standard with no student earning highest passing grade A. On test 2, the percentage of failed students was slightly better than standard unlike test 1. A number of failed students had transitioned to the passing range. From D to B, summer 2021 class performed better than the standard on test 2. However, the number of students earning highest passing grade A was still significantly low.

Table 7. Comparison of grade distributions for tests 1 and 2 for summer 2021 class

	F	D	C	B	A
Test 1	Worse (41.96%)	Better (1.96%)	Better (3.80%)	Worse (24.42%)	Worse (23.29%)
Test 2	Better (2.86%)	Better (7.14%)	Better (8.57%)	Better (21.43%)	Worse (34.29%)

Conclusions

Vibration has always been a core class in mechanical engineering. Whether it is taught in regular academic year or compact summer, the structure remains the same. From mid-spring 2020 to beginning fall 2021, Vibration class was converted to virtual due to COVID-19 pandemic. Therefore, the curiosity has been the change in performance. This paper answered the question by looking at the performance on two in-class tests for spring and summer 2021 classes during the pandemic, and for three spring and three summer classes prior to the pandemic.

The grade distribution of the accumulation of pre-COVID classes was used as standard for comparison. For both spring and summer classes during COVID, the number of students failed test 1 was significantly higher than standard. The percentage earning grade B was also noticeably worse than standard. What so astounding is the number of students earning the highest passing grade A was almost non-existent. The overall performance, from A to F, was still below standard even when extra credit was added to test 1. A transformation took place for both spring and summer classes during COVID on test 2. A number of failed students transitioned to the passing range, but only up to grade B. The percentage of students with the highest passing grade A was still insignificant.

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