2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #36748

Did the COVID-19 Pandemic Affect Student Performance on Exams in a Dynamics Course?

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Abstract

During the COVID19 pandemic many faculty switched to a form of online teaching and assessment for the 2020-2021 academic year. To prepare for this new mode of assessment, old exams from previous years of teaching became a collection from which to pull problems to create the *online* exams for the new academic year.

In this analysis we compare the results of the online exams (administered during the 2020-2021 academic year) with the same problems collected from Pre-pandemic exams. The online Dynamics exams:

- Covered three to four topics per exam (Same as previous semesters)
- Each topic had an option of 2-3 different problems that were randomly assigned to each student
- Each problem had randomized numbers for certain variables within the problem

This made every exam unique from one-another either in terms of problem and/or numbers, while covering all the same topics. Previous years' exams had 4-6 problems per exam per year; each student had the same problems and same numbers on each problem, however, the problems changed from semester to semester.

This is the beginning of a more detailed comparison of student performance on Pre-pandemic and Intra-pandemic exam problems. Our prediction is that students will perform worse in the online exams when compared to those same sets of problems that have been worked out on previous exams due to the extra stresses associated with pandemic issues and online courses.

Contrary to our expectations, students showed a marginal improvement in exam performance during the 2020-2021academic year when compared to exam problem performance from pre-pandemic exam problems. However, it may be difficult to identify single variables that could have affected performance of students taking exams during the COVID-19 pandemic versus those before the 2020-2021 academic year.

INTRODUCTION

The shift to online education during the COVID19 pandemic provided an opportunity for students to 1) learn at their own pace and 2) in the safety of their own/home environments (unknown as to if this is good or bad) and potentially 3) using a non-traditional mode of learning [1]. It also challenged faculty to find new ways to teach the same material using new modes of delivery; at times blending their modes of teaching (Synchronous, A-synchronous, Hybrid) [2]–[4]. As it turns out … from experience … it can be a significant challenge.

This quick shift required a way to quickly build quiz/test banks to perform assessments. The most accessible source to build these banks was previous exams. This provided multiple problems and solutions covering the multiple topics. This allowed for evaluation of student performance on the same topic with similar problems – to prevent cheating. In addition, building the test banks and randomization of input numbers allowed for each problem to have a unique final answer [5]. Overall, with at least two problems per topic and randomized numbers in each problem, every student could have a "totally different" exam. It also provided for an opportunity to investigate student performance in these two realms of teaching: In-Person vs. Online.

Course Flows

Below is a description of the Pre-pandemic and Intra-pandemic course designs described in terms of the Class, Exam and Homework breakdowns. This is here to provide an idea of differences in execution of each course.

PRE-PANDEMIC

Before the pandemic, Dynamics was usually divided into 3 sections with exams at 5 and 11 weeks in a 16-week cycle covering 7-9 topics per exam. In addition, there is one final exam. The course consisted of 3 exams with online and handwritten homework. The grading breakdown is shown in Table 1.

Table 1: Course Breakdown for Pre-pandemic Dynamics Course

Homework	18%
Exam I:	25%
Exam II:	25%
Final Exam:	32%

Class

Pre-pandemic classes were given in a typical lecture style organized into 3 sections. Students were provided handouts with problem statements, figures, and answers. The first section contained a discussion of theory with a problem outlined and solved until we had a complete set of equations (no algebraic solution) with little input from students; it was an ***instructor led solution***. Answers to each problem was provided on the lecture handout and students were encouraged (and taught) how to use their calculators to solve 3x3 sets of equations.

The second section contained a slightly more challenging problem in which lecturer and students worked collectively to solve a new problem on the same topic. After the first problem is completed, students are asked to work together at their tables to select coordinate systems, set up Free Body and Acceleration diagrams. After circling the classroom and reviewing some students work, the class reconvenes. The lecturer and students work collectively to set up the problem up until a complete set of equations are achieved. Usually there is a lot of interaction between students and lecturer to set up and solve the problem; this is the ***collective solution***.

The third and final section of the class is directed as a student led effort. With a new problem, set up by the instructor, students are asked to first work alone to set up their coordinate systems and diagrams, and then check their solution against other students work. As the class reconvenes, the instructor leans on the students to select coordinate systems, drawing of free body and acceleration diagrams, and deriving equations from those diagrams; this is the ***student led solution***.

Exams

Typically, there are 3 exams per semester that students work out by hand, during the class/exam period. The exams are graded by hand according to the rubric below. Two exams during the semester contain four problems and focus on the most recent material. The final exam usually consists of six problems and is comprehensive. These are closed book, closed note exams. Students are provided equation sheets from the NCEES booklet (Units, Math & Dynamics sections).

Grading Rubric:

1) Problem Set up (Correct coordinate systems, free body and acceleration diagrams) @ 42 %,
2) Equations (Correct and Complete Set of Equations): @ 32 %
3) Solution (Calculations are done properly): @ 18 %
4) Presentation (Is the solution easy to follow and set up correctly): @ 8%

Homework

Homework was assigned in two formats: online and handwritten. Online homework was assigned through Pearson's Mastering Engineering program and stressed to be used for students to evaluate their own understanding of the material from class. Handwritten homework was stressed as a method for the faculty to 1) provide input into student's problem-solving process and 2) provide students familiarity with the grading rubric used for evaluating their exams.

INTRA-PANDEMIC

During the 2020-2021 academic year, Dynamics was run as a flipped synchronous online course – for the first time. The course was divided into four modules covering 6-7 topics per module. The course breakdown is shown in Table 2.

Table 2: Course Breakdown for Intra-pandemic Dynamics Course

Practice Problems:	5%
Lessons:	15%
Exam I:	17%
Exam II:	17%
Exam III:	17%
Final Exam:	24%
Participation & Professionalism:	5%

Here, "Practice Problems" refer to the online problems assigned through Mastering Engineering; usually 1-2 per lesson. These would typically be homework problems in a Pre-pandemic class. "Lessons" here refers to the handwritten notes that students take while watching video lectures. These are essentially the notes that students would take during an in-person lecture. There were 4 exams. And finally, 5 percent of the final student grade is reserved for student participation and professionalism during the course.

Class

Video lecture sets were recorded during the summer 2020 and grouped into four modules by topic. Each video set consisted of at least three problems worked up to a final set of equations – no final algebraic solution process was provided (similar to an in-person class period). All lecture handouts did have final answers on each problem. Usually, the first problem during a lecture contained a theory development while working through an example problem. Remaining videos consisted of working problems on lecture hand out with narration consistent with theory and hints into problem solving process. Students could work at their own pace through each video and module. The problems are the same problems used in lectures for the pre-pandemic courses. I could not follow a 1) Instructor Lead 2) Collaborative and 3) Student lead format, that I might use in-person.

To motivate student preparation for each class period, students were assigned to watch lecture videos for the following class period as their "homework assignment." Students were asked to turn in their handwritten notes from video lectures before class starts. Successful completion and submission of their notes counted towards their Lessons grade (15% of total grade). Class time consisted of answering questions regarding the lecture topic and specific lesson problems. This time was intended to be a chance for students to clarify any issues that may have been unclear in the lesson videos. However, in the case that there were no questions – extra problems from the book were prepared to be worked out during the class period. Sometimes students would be placed in "Zoom - Breakout Rooms" to start each extra problem in smaller groups before coming back together as a whole class period and working the problem together. There were ***a lot*** of quiet moments when asked "Does anyone have any questions from yesterday's lessons?"

Exams

Exams were administered at the end of every Module (6-7 topics/class periods). Four questions were randomly selected from each category for each exam at the end of each Module. For example, Module 1 cover topics a) Cartesian Motion b) Normal and Tangential Kinematics, c) Radial Kinematics, d) Constrained Kinematics e) Relative Motion and f) Linear Kinetics.

Two questions on each topic (e.g Linear Kinetics) were programmed into Blackboard. A student would be randomly assigned one of those two problems with randomized numbers for certain variables. Another student would be randomly assigned the other problem also with randomized numbers. Each student would solve their individual problem and enter their answer into the Blackboard window for automatic grading for correctness.

In this case, if there are 7 topics, only 4 of the same topics would be selected for each exam. For example, Exam 1 would consist of problems from the topics: Cartesian Motion, Normal and Tangential Kinematics, Radial Kinematics, and Linear Kinetics.

At the end of the exam period, students were provided an extra 15-30 minutes upon completion of their exam to scan their handwritten work and upload it to Blackboard for partial credit grading. Only the handwritten work was graded for their exam grade. The Blackboard grade was simply a check to see if the student came to the correct answer. Partial credit grading rubric was divided into 4 sections

This is the same rubric used in the in-person class; however, the rubric was programmed into Blackboard for ease of use.

1) Problem Set up (Correct CS-FDB-ADs) @ 42 %
    a. Units & Notation (3%)
    b. Problem Geometry & Vectors (7%)
    c. FBDs (32%)
2) Equations (Correct and Complete Set of Equations): @ 32 %
3) Solution (Were calculations done properly): @ 18 %
    a. Solution Process (13%)
    b. Answer (5%)
4) Presentation (Is the solution easy to follow and set up correctly): @ 8%

Homework

Homework was assigned in two formats: "Practice Problems" and completion of video lecture and uploading of "Lesson Notes." Recall the Practice Problems are Mastering Engineering online problems. Students are informed that these problems are for students to evaluate their own understanding of the material. Lesson Notes are the replacement for In-Person lectures and, in this format of the course, are considered homework.

METHODS

Exam Problem Collection & Organization

Individual ***problem scores*** from pre-pandemic exams were collected and grouped into sets that *represent* the same set of problems used on intra-pandemic exams. They were summed to represent a total score for a "fictitious" pre-pandemic exam that directly matched the problems used on the intra-pandemic exam. This allowed for direct comparison of intra-pandemic exams with scores consistent with problems used on pre-pandemic exams.

Statistical Methods

Each group of exam score data (pre- and intra-pandemic) was evaluated graphically for normality using a probability plot. All data sets were highly skewed and non-normal, necessitating the use of non-parametric statistical methods. This is partially attributed to multiple scores of 0% and 100% in each data set. Each exam score data set is a collection of exam problem scores, not aggregate exam scores for individual students. Each set of exam score data was transformed to *categorical data* using three categories of student performance (A, B, or C) corresponding to high (score $\geq$ 80), moderate (60 $\leq$ score $\geq$ 79.5), or low (score $\leq$ 60) exam scores. The categorical data was summarized in a contingency table that conveniently compares mode of teaching to student performance. An example is shown in Table 3 for exam 1. This table provides six cell totals that provide the basis for a hypothesis test.

Table 3. Contingency table for Exam 1 data summarizing 396 exam scores regarding mode of teaching and student performance

	Mode of Teaching		
Student Performance	Pre-pandemic (In-Person)	Intra-pandemic (Online)	Total
Category A (>=80)	53	36	89
Category B (60-79.5)	81	29	110
Category C (<60)	138	59	197
Total	272	124	396

A standard hypothesis test for independence was conducted for each contingency table (4 total). This test assumes independence for the null hypothesis (i.e., student performance is independent of mode of teaching). Under the assumption of a true null hypothesis, frequencies for each of the six cells are computed and a χ^2 test statistic is computed for the table using

$$?^2 = \sum \frac{(O-E)^2}{E} \tag{1}$$

where O is the observed cell frequency in Table 3 and E is the expected cell frequency based on a true null hypothesis. High values of χ^2 lead to rejection of the null hypothesis in favor of the alternate hypothesis (i.e., student performance affected by mode of teaching). Additional details on this statistical technique can be found in [6]. This technique was implemented for all four exam data sets using the software package MiniTab. P-values were used to evaluate the plausibility of the null hypothesis with a level of significant equal to 0.05.

RESULTS

A boxplot of the data for all four exam problem collections are shown in Figure 1. In addition, a table of the Chi-Square independence test are included in Table 4.

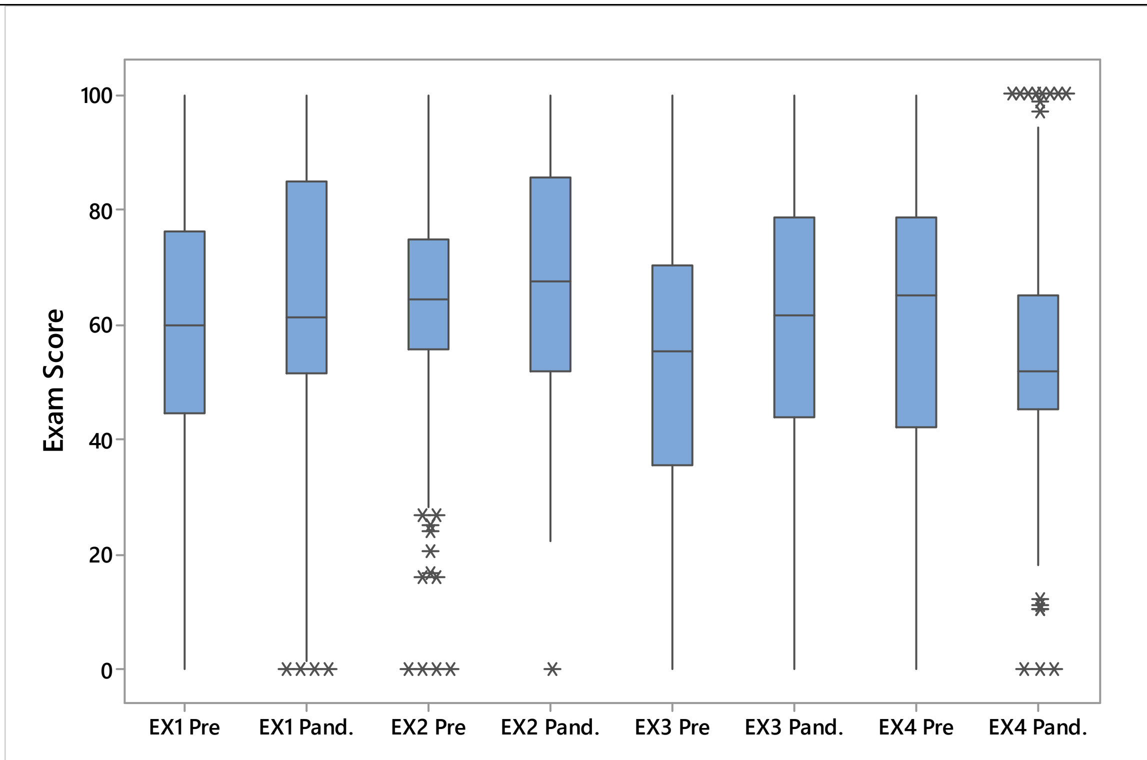

Figure 1. Boxplot of four exam problem collections for pre-pandemic and Intra-pandemic conditions.

Table 4. Summary table of results for a χ^2 test of independence for four exam problem collections

	Sample Sizes				
	Pre-pandemic	Intra-pandemic	χ^2	P-Value	Conclusion
Exam 1	272	124	4.88	0.087	Not Significant
Exam 2	227	85	7.101	0.029	Significant
Exam 3	345	142	14.18	0.001	Significant
Exam 4	208	174	29.29	0.000	Significant

The first two results to point out in Figure 1 are 1) there is similar variability across all exam collections and 2) there is no significant difference between the results of problems assigned for Exam 1 Pre-pandemic or Intra-pandemic. This is predictable since the material covered here is usually a review of material from Physics: particle kinematics and linear particle kinetics.

Median scores of Pre- and Intra-pandemic Exams are included in Table 5 below. Notice that there are very close medians for Exam 1 through Exam 3, even though the differences are significant between Exams 2 and 3. Exam 2, the Intra-pandemic group marginally (3-point difference), but significantly, outperformed students who had the same problems compared to the Pre-pandemic group. The difference increases even more (6.5 point difference) for Exam 3.

Table 5: Medians of Exams Pre- and Intra-pandemic

	Medians			
	Exam 1	Exam 2	Exam 3	Exam 4
Pre-pandemic	59.77	64.6	55.25	65.0
Intra-pandemic	61.34	67.5	61.79	51.98
Difference	1.57	2.9	6.54	-13.02

Finally, poorest performance in the Intra-pandemic group came on their final exam – Exam 4: a 13 point drop relative to students who had the same problems pre-pandemic. It is difficult to know exactly what the cause for this might have been – Pandemic/Zoom fatigue or students back calculating the effort necessary to get the desired grade. We may never know; but it is clear - this was the worst performance overall. However, it did have the most outliers from any of the exams: both high and low.

DISCUSSION

Based on the categorical data, there is no significant difference in the performance of students early in Dynamics, whether they were taking exams pre-pandemic or intra-pandemic. This may be due to overlapping coverage of material in Physics.

Potential reasons for significant changes

One speculation for these changes in overall student performance is that they reflect going from three exams per semester to four. This leads to less content per mid-course exam. But when it comes to a final exam when students are required to illustrate overall knowledge of the course material, they were not able to retain and show comprehensive knowledge, resulting in a dip on their final exam.

In addition, logistics of having students take online exams while still allowing for grading of handwritten work, required allowing students an extra 15-30 minutes upon completion of their exam to scan their handwritten work and upload it to Blackboard for partial credit grading. Extra time allotted to submit exam could have been used to finish work on exam. This may have influenced overall scores.

On the instructor end of things, grading using an online rubric seems vastly different than grading by hand. It is easier to "click" in a grade without a lot of reflection of how the rest of the class is doing. This could lead to inconsistency because one loses the ability to lay out exams and refer back to previously graded exams to enforce consistency. Grading with an online rubric may have influenced overall scoring.

Finally, the change in how the course was delivered may have had the largest effect on student performance. Breaking down a class period into three sections (Instructor led, Collective and then Student led problem solving) is one of the structuring tools that may have affected student learning. Active learning has been shown to positively affect student performance. This was hard to do and enforce in an Online & Flipped style of class. Although the differences between Pre- and Intra-pandemic exam performances were only marginal, the huge drop in the final exam performance in concerning and will be addressed by investing in more active learning activities in future offerings of an online-flipped class.

CONCLUSIONS

A Dynamics course was redesigned with the intent to relieve some stress associated with learning in the midst of a pandemic. The course was flipped and delivered as an online synchronous course. Lecture videos were uploaded to the learning management system. Student homework was to watch videos and take notes while watching those videos – similar to an in-person lecture.

Online exams were created from old exam problems. After taking online exams, students were able to get partial credit by uploading their handwritten work although their exam was online and graded for one final answer. To evaluate student performance, we used exam scores from student's intra-pandemic and compared their results to pre-pandemic scores on the same groups problems collected into fictitious pre-pandemic exams.

Was it all successful? We don't know. The course redesign illustrated that students' exams on mid-course content showed significant differences but only marginal (3-7 points median difference). We also showed that final exams (a proxy for knowledge retention), were much poorer (13-point median difference) for students taking the course in the middle of the pandemic.

By spreading material over four exams, instead of three, and flipping a class – thereby allowing students access the lecture material at their convenience, we hoped for overall student improvement. This was not the case.

REFERENCES

[1] S. Asgari, J. Trajkovic, M. Rahmani, W. Zhang, R. C. Lo, and A. Sciortino, "An observational study of engineering online education during the COVID-19 pandemic," *PLoS One*, vol. 16, no. 4 April, Apr. 2021, doi: 10.1371/journal.pone.0250041.

[2] N. L. Ramo, M. Lin, E. S. Hald, and A. Huang-Saad, "Synchronous vs. Asynchronous vs. Blended Remote Delivery of Introduction to Biomechanics Course," *Biomed Eng Educ*, vol. 1, no. 1, pp. 61–66, 2021, doi: 10.1007/s43683-020-00009-w.

[3] L. D. S. Lapitan, C. E. Tiangco, D. A. G. Sumalinog, N. S. Sabarillo, and J. M. Diaz, "An effective blended online teaching and learning strategy during the COVID-19 pandemic," *Education for Chemical Engineers*, vol. 35, pp. 116–131, 2021, doi: https://doi.org/10.1016/j.ece.2021.01.012.

[4] K. McMullen, D. Carlson, B. Davis, B. Barry, and J. Bruhl, "Comparison of Four Flipped Classroom Implementations in a Civil Engineering Curriculum during the COVID-19 Pandemic," in *2022 ASEE Annual Conference & Exposition*, 2022.

[5] J. L. Davis, T. McDonald, and B. L. Kicklighter, "Online Testing with Blackboard: Lessons Learned (Perspectives from Three Engineering Faculty)," in *2021 ASEE Virtual Annual Conference Content Access*, 2021.

[6] D. C. Montgomery and Runger George C., *Applied Statistics and Probability for Engineers*, 6th ed. John Wiley & Sons, 2014.