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Switching to Virtual Classes Due to Covid-19: Correlation and Panel Data Analyses for Modeling Students' Academic Performance

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ABSTRACT

Due to the Covid-19 pandemic, the education institutions were required to transform their traditional teaching methods (face-to-face classes) to online courses. In Puerto Rico, news outlets expressed a national concern regarding this teaching style as there was an increase in the percentage of students who failed their academic semester. Based on a previous research, this study aimed to identify if students' attitudes towards a course was correlated to their grades, rather than the fact that the class was taught in a virtual setting. Information about number of times the students viewed the material as well as the day they decided to work on the course were retrieved from students enrolled in a Statistics course during the Spring 2021 semester at the University of Puerto Rico at Mayagüez. Correlation analyses, as well as panel data models, suggested that the only variable that influences students' performance is the amount of time that has elapsed for them to work on the course. The results were then validated with a Transportation Engineering related course. Although it may be the case that students were not ready for the transition from the traditional classroom to virtual classes, there is no evidence that online education is linked to poor student performance.

Keywords: virtual classes, online teaching, panel data, academic performance

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1. Introduction

On March 12th, 2020, the governor of Puerto Rico declared the island a state of emergency due to the Covid-19 pandemic. Three days later, the governor signed Executive Order OE-2020-23 implementing a curfew and a total lockdown of operations, except those considered essential services. The education system was transformed to online teaching, and although some time was given for the adaptation process, it seemed to be an overnight change.

As a result of the new measures, a national concern was raised due to students falling behind in their classes. The news outlet reported that 10% of students in Puerto Rico's public system failed their grade whereas years before this number was between 4 and 6%, as indicated by official of the Department of Education (Gutiérrez, 2021). Among the reasons cited for this increase in percentage of failing students were: health emergencies due to the coronavirus, online teaching, poverty levels, and lack of parental support. In an article title "Thousands of Students in Puerto Rico will not Pass their Semester" named one specific given reason, that seemed to conglomerate all the previous ones: the students "were not prepared for the culture of online courses". It is suspected that students from the higher education system also experienced lower grades, but these were never mentioned in the news. However, some students were indeed able to pass their grades. So the question arises: why some students perform better than others when it comes to online education?

2. Background and Formation of Hypotheses

To some, online degrees are viewed as inferior with respect to traditional programs. However, the majority of employers are embracing this teaching method. In a survey performed by Excelsior College and Zogby International, it was found that 83% of CEOs and small business owners indicated that online degrees were as credible as any other degree obtained from a traditional educational institution (Zupek, 2010).

Maybe at the top of those who are resistant to online courses are faculty members. A study found that professors are more pessimistic than optimistic when considering online learning; they question their legitimacy and perceive the outcomes from online education as having less value somehow. What is interesting is that, even if they are skeptical about this learning method, 60% of the faculty members indicated that they have recommended at least one online course to their students (Allen et al., 2012). Despite this lack of support from the faculty, distance education continues to grow. Between the years 2012 and 2015, the number of enrollments in distance education increased, even if the overall number of enrollments in higher education institutions decreased. By 2015, almost 30% of students enrolled in higher education institutes were taking at least one distance course (Allen & Seaman, 2017).

The disruption of the traditional classroom in the Spring 2020 semester due to the Covid-19 pandemic took an emotional toll on students. The transition from face-to-face classes to distance education raised concerns about students' performance. Some concerns were related to the familiarity of professors with online teaching methods as well as students' access to internet and computers. However, a study on the perception of students regarding this transition was positive in terms of faculty adaptability. The survey from 148 students indicated that 82% of them believed their professors were effective in transitioning to online courses. The survey also examined the students' emotional reactions during the transition. Although students agreed that their professors were helpful during this period, the majority of them expressed feelings of uncertainty, anxiety, and nervousness, with less than 5% of students indicating happiness and excitement (Murphy et al., 2020).

Even if students' performance, as measured by their final grades, is a main concern, there is no indication that online courses contribute to lower grades. A study performed on students enrolled in an Environmental Science class between the years 2009 and 2016 found that there were no differences in performance between online and face-to-face courses. A total of 548 students from Fort Valley State University in Georgia were included in the study; 147 students were enrolled in the distance course while the remaining 401 students took the class in the traditional setting. Besides teaching method, the results of the study also showed that there were no differences in performance across gender or class rank (*Paul & Jefferson, 2019*).

A study developed by Cruzado & Román (2011) determined that the academic performance of student was correlated to their level of responsibility, regardless of teaching method. In this study, the grades of students in an Engineering course were analyzed during two semesters: the first semester was taught in the traditional environment whereas in the second semester the class was taught using the Inverted Classroom method. In this method, students study the material beforehand then, during the class period, they ask questions and resolve practice problems. The results of the study determined that level of responsibility, as indicated by the students' number of absences to class and their willingness to do practice problems, were the only variables found to be statistically significant on students' grades. Based on this study, as well as the educational environment during the pandemic, it was theorized that the student's level of responsibility could be the determinant factor on their academic performance in virtual classes as well. As such, the following hypotheses were formed:

- Hypothesis I: Students' grades are influenced by the number of times they review the material for the class.
- Hypothesis II: Students' grades are influenced by the time that has elapsed, from the date the assignment or quiz was available, until they decided to work on it.
- Hypothesis III: Students' grades are influenced by the variability in the time that has elapsed, from the date the assignment or quiz was available, until they decided to work on it (i.e. if they chose a specific day of the week to work on the course).

The rest of this paper is organized as following: description of the course considered in the study as well as the students enrolled in it; discussion of the results of the statistical analyses; validation of the results with a second course; and finally the conclusions of the investigation as well as recommendations for future research studies.

3. Information and Characteristics of the Online Course and the Students Enrolled

The Applied Statistics to Civil Engineering course (INCI 4136) is a two-credit course that encompasses general topics of probability and statistics. According to the curriculum, students enrolled in the Civil Engineering program at the University of Puerto Rico at Mayagüez (UPRM) take this course in their second semester of their third year. It is important to mention that the Civil Engineering program is a five-year curriculum with a total of 180 credits.

The structure of the virtual classroom for the Spring 2021 semester was the following: the class was taught asynchronously, meaning that the students were not required to attend class at a specified time period. Each week the material for the class (i.e. approximately three videos lasting ten minutes each) was posted in the Moodle platform. At the end of the videos were included practice problems; the answers to these were also posted in a PDF document and uploaded to the Moodle platform as well. The students were then required to do either a short quiz (less than 10 questions) or a homework assignment each week. Some key characteristics regarding the required work were:

- Every Monday at 8:00 am, all the material for the week, including the quiz and/or homework, was available. The students then had between seven and 14 days (the deadline varied) to complete the required work starting that respective Monday.
- Students could use all the course materials (class notes, books, etc.) as well as the internet to answer the quiz, but they were warned they had to do it by themselves.
- Usually quizzes had a time limit from the moment they started (between 30 and 90 minutes); homework assignments did not.
- Most of the times the students had two attempts to do the quiz. If they were not successful in their first attempt, they could meet with the professor during the period assigned to the class or during office hours to verify their work and ask questions before doing the second attempt. The highest grade of the two attempts was the one considered for the course grade.

Table 1 shows the topic for each week as well as the type of required work the student had to complete, the number of attempts allowed, the number of questions for each quiz, the maximum grade that students could obtain, the number of days the student had to complete the work, and the time limit, if any, to finish the quiz.

A total of 31 students were enrolled in the course; five students did not finish the semester (i.e. they either dropped the course or stopped attending); therefore, these students were not included in the study. A sixth student was also not included in the analyses as this student had a personal situation and more time was allowed for this student to finish all coursework (additional discussion in section 4). As such, the final number of students considered in this study was 25. All but two students were enrolled in Civil Engineering; the other two were enrolled in the Surveying program (in which the Statistics course is not a requirement).

Table 1.
Characteristics of Required Work by Week

Week #	Topic	Type of Work	Attempts Allowed	Number of Questions	Maximum Grade	Permitted Days	Time limit (hours)
1-2	Introduction; Samples	quiz	2	5	10	10	0.5
3	Descriptive Statistics	homework	1	n/a	20	12	none
4	Graphic Methods	homework	1	n/a	15	8	none
5	Space and Events	quiz	2	9	25	8	1
6	Tree Diagram	homework	1	n/a	10	9	none
6	Counting Techniques	quiz	2	2	10	9	0.5
7	Probability	quiz	2	4	15	8	2
8	Discrete Variables	quiz	1*	7	25	8	none
9	Continuous Variables	quiz	2	8	20	5	1
10	Normal Distribution	quiz	2	6	20	7	1
11	Central Limit Theorem	quiz	2	5	20	10	1
13	Confidence Intervals	quiz	2	5	20	8	1.5
14	Two-Sample t-test	quiz	2	5	15	7	none
15	Hypothesis Tests	quiz	1	4	10	7	1
16	Linear Regression	quiz	2	7	10	7	1.5
17	Linear Regression	quiz	2	3	5	7	none

*The students could ask for a second attempt during office hours and during the course assigned period.

Based on the students' identification number (i.e. school ID), it was possible to determine the year the student was in and if the student was transferred from another campus of the UPR system. All but four students did not initiate their studies at the UPRM campus; they were either transferred from the campuses of Cayey, Rio Piedras, Bayamón or Ponce. Seven students (28%) were in their third year, five students (20%) were in their fourth year, another 20% in their fifth year, and the remaining eight students (32%) have been enrolled in the university for over six years.

4. Preparation of Database and Statistical Analyses

As mentioned before, three hypotheses were formulated for this research. The goal was to determine if students' aptitudes towards the class (i.e. how many times they reviewed the material, how long it took them to do the required work, or if they chose a specific day of the week to work in the class) were influential on their grades. These three measurements were considered to be representations of the students' level of responsibility.

The first step was to prepare a database with the students' information; a lot of this data had to be obtained from "log" reports exported from Moodle which instructors have access to. A file in Excel was then prepared with the following information taken from Moodle:

- Grade report exported in CVS format and transferred to the Excel File.
- The outline report that indicated the number of times the student viewed the material for the class (both videos and supplemental material such as documents with practice problems and their answers). It also indicates the date and time the student last viewed

the material as well as when they took the quiz. If the student took two attempts to do the quiz, only the latter date was input in the Excel file.

- The topic and the number of video classes per week during the semester. Also, per quiz/assignment, the date it started to be available, the date it closed, the number of attempts the student had, the time limit, and the number of questions it included.

Only the grade report was automatically exported from Moodle; all the other information was manually input into one of three Excel sheets to later prepare the sheet that will include all the data to be analyzed using a statistical software; in this study Minitab and Stata software programs were used.

The statistical analyses were then divided into two categories corresponding to the type of data: aggregated (average final grade) and disaggregated (individual grades for each quiz/homework assignment).

4.1. Aggregated Data: Correlation Analyses

To perform the analyses, it is important to mention that only those students who completed the course were included in the database; those who withdrew or did not finish the course (some students never withdrew) were not considered in the study. As such, out of 31 students, five of these were not included in the database.

As shown in Table 1, students were required to do three homework assignments and 16 quizzes; they also had a final exam at the end of the semester. According to the course syllabus, homework assignments and quizzes were 75% of their final grade while the remaining 25% was the final exam. Since the final grade (the dependent variable in this part of the study) is calculated from all these individual grades, the data is of aggregated nature. Similarly, the explanatory (independent) variables, in the order of the three hypotheses formulated, were: 1) total number of views, 2) average number of days to do the work (from the day that it was available), and 3) standard deviation of number of days to do the work (as an indication of consistency in selecting a particular day to dedicate to the class).

Visual correlation analyses were initially performed using scatterplots between the response variable (final grade) and each of the three explanatory variables. One obvious outlier (an observation with a high deviation from the rest) was present, so it was closely examined in order to determine if it should be included in the analyses or not. It was determined that this observation belonged to a student who had a personal situation during the semester and they were allowed additional time to do the quizzes. Hence it was determined to not include this student in the database, lowering the number of students to 25. The correlation analyses were then performed again without this student. Table 2 shows the descriptive statistics for the variables considered and Table 3 shows the correlation analyses for this part of the study.

Table 2.
Descriptive Statistics for the Variables Considered

Variable	Average	St. Deviation	Maximum	Minimum
Final Grade (Percentage)	79.82	15.627	99.7	44.4
Total Number of Views	114.20	38.218	218	70
Number of Days to Work (Average)	5.39	1.794	7.57	1.13
Number of Days to Work (St. Deviation)	1.91	0.644	3.266	0.911

Table 3.
Pearson Correlations for the Statistics Course (p-value)

Variable	Final Grade	Total No. Views	Average No. of Days
Total number of views	-0.086 (0.684)	-	-
Average Number of Days	-0.409 (0.042)	-0.270 (0.192)	-
St. Deviation Number of Days	-0.078 (0.712)	0.304 (0.140)	-0.498 (0.011)

Based on the results of the correlation analyses, the average number of days for a student to work on the quiz/assignment was the only variable influential on their final grades (Hypothesis II) at the 95% confidence level (p-value of 0.042). This correlation is negative indicating that the longer the student takes to do the assignment (i.e., the more they leave it "for the last minute"), the more probable they are to obtain a lower grade in the class. On the other hand, students who did the classwork early were more probable to get better grades. This is expected as students could improve their grades by asking questions before trying a second attempt for the quiz; those students who decided to work on the assignment days before the deadline (usually on the weekends), had no time to meet with the professor and ask if they have doubts on the material. A scatterplot presenting this relationship is shown in Figure 1.

The other two variables (total number of views and standard deviation of number of days) had no correlation with the final grade, as their p-values were greater than 0.05 (0.684 and 0.712, respectively). This suggests that the number of times a student clicks on the course material, as well if they chose a specific day of the week to dedicate to the course (Hypotheses I and III), were not influential or their grades.

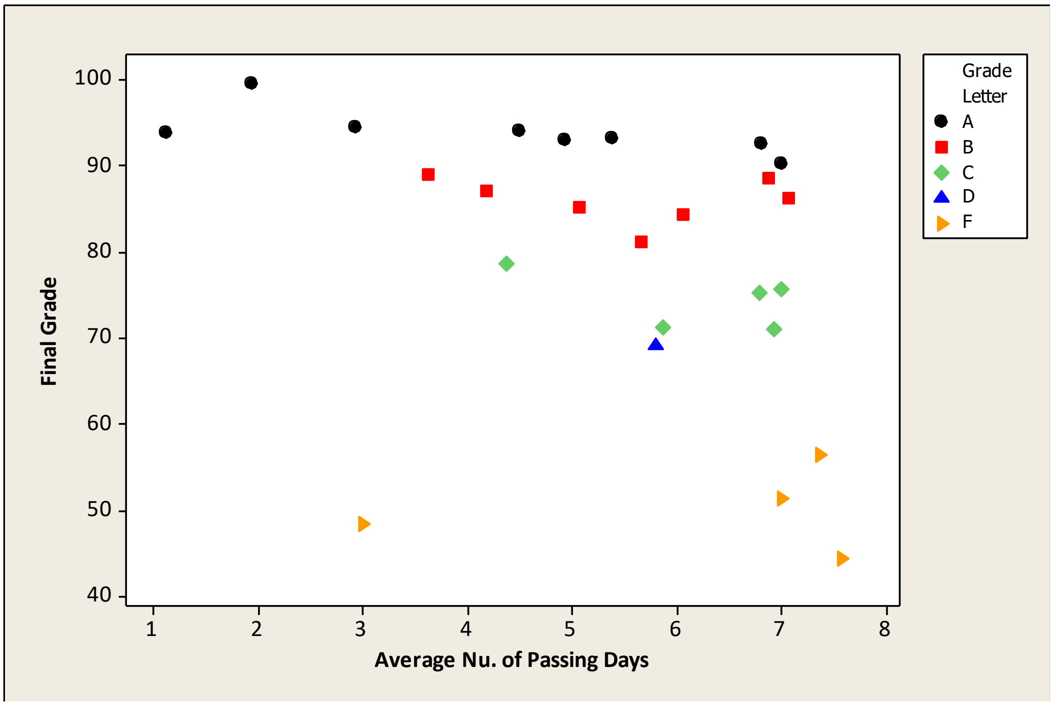

Figure 1. Scatterplot of Grade versus Average Number of Elapsed Days (by Letter Grade)

4.2. Disaggregated Data: Panel Analyses

Using the final grade of the course as well as other aggregated data (i.e. average number of days to work on the assignment) raises concerns regarding ecological fallacy: our inferences are made according to a group instead of focusing on individual details. In other words, even if conclusions are made for a group, they might not apply to an individual. When developing prediction models, using aggregated data might result in better goodness-of-fit parameters (less error, better coefficient of determination), but there is uncertainty about the estimated parameters (Garrett, 2003).

Panel data analysis are useful when observations on an individual are collected over time, thus taking into account the correlation between observations. In other words, and for the situation in this study, they can take into account the students' individual characteristics. The data can be viewed as a cross-section of students where their grades are repeated measurements over the weeks of the semester. It can also be viewed as modeling different clusters, one for each student, with all the observations for that student within (inside) the cluster. Among the advantages of panel data (Brüderl, 2005) are:

- More variability, less collinearity, and more degrees of freedom resulting in a more informative model.
- Estimates are more efficient than those developed by Ordinary Least Squares.
- The characteristics of each unit (students) are considered.

Although there were 26 students who completed the coursework, for each individual there should be 17 grade observations: three homework assignments, thirteen quizzes, and one final exam. For each of these grades, it is possible to determine the number of times the students viewed the material for each topic and the number of days it took them to work on a homework assignment or quiz; but since the final exam had a specific date, it was decided not to be included in this part of the analyses. Therefore, a second database was created with disaggregated data. The database should have had a total of 26 students * 16 grades = 416 observations; however, some observations were deleted since some students did not do the required work. As such, the final number of observations for this part of the study was 391 observations.

Since no aggregated data could be used (i.e. no average or standard deviation of a variable), only Hypotheses I and II (number of views and number of days to work on an assignment) were investigated. The panel data analyses were performed using Stata software. Two models were developed: the fixed effects (FE) model and the random effects (RE) model. The FE model allows for the unobserved variables to have any association with the observed variables whereas in the RE model these is no such association (Allison, 2006). In this study, the FE model indicates that the students behave the same across time while the RE model would state that students behave different across time. To determine which model, FE or RE, is more appropriate, the Hausman test is performed. Under its hull hypothesis, the estimators of the RE model are preferred over the FE estimators; if the null hypothesis is rejected, then the FE model is favored over the RE model. The Hausman test in this study resulted in a p-value of 0.0566, thus not rejecting the null hypothesis and selecting the RE model as more appropriate. Table 4 summarizes the results of the RE model with the two variables considered (for both Hypotheses I and II).

Table 4.
Random-Effects Panel Data Model for the Statistics Course

Parameter	**Estimate**	**St. Error**	**t-statistic**	**p-value**
Number of Views	-0.128	0.262	-0.49	0.624
Number of Days to Work	-1.929	0.477	-4.04	<0.001
Constant	93.000	4.257	21.85	<0.001
Sigma_u	12.471			
Sigma_e	21.559			
Rho	0.251			

The results of the RE model further strengthen the initial results that indicated that the number of days that a student let pass until they decide to work on the required assignment is statistically significant at the 95% confidence level (p-value was less than 0.05). The value of the coefficient (-1.929) establishes that a decrease in approximately 2% of the grade is associated with the passing of each day that a student decides to not work on the required quiz or assignment. The number of views was not found to be influential on grade (p-value of 0.624).

The output from Stata also provides with the values of *sigma_u* and *sigma_e*, which correspond to the between-subject and within-subject standard deviations, respectively. These are interpreted as follow:

- A standard deviation of 12.5% of the grade is associated with different students (between-subjects) and
- A standard deviation of 21.6% of the grade is associated with the presence of the student cluster (within-students).

Stata also provides with the value of the within-subject correlation, *rho*, also called the intraclass correlation, which varies between zero and one. If this value is close to one, it indicates that there are no differences between observations for each subject (i.e. grades are the same across the weeks of the semester). The value of 0.251 is closer to zero, thus suggesting that students' grades did vary across the weeks of the semester. This makes sense as each week the material for the class was different. The intraclass correlation for this model can be interpreted as 20% of the variance in grade that is not explained by the model is due to time-invariant student-specific characteristics.

Finally, Stata also provides with values for three type of coefficients of determination (R-square): within, between, and overall (not shown in Table 4); these values were 0.0289, 0.2606, and 0.0898, respectively. These values are interpreted as follow:

- Overall the model explains approximately 9% of the variance in grades.
- The model explains approximately 3% of the variance associated within each student (i.e. with the student cluster) while explaining 26% of the variance associated from student to student (i.e. different students).

5. Validation of the Model

In order to validate the results, the same analyses were performed to a second course: Introduction to Transportation Engineering. The three-credit course is also a requirement for the bachelor's degree in Civil Engineering at UPRM and students are expected to take it during their fourth year. As a pre-requisite, students should have passed the Statistics course, therefore no student during the Spring 2021 semester was enrolled at the same time in the two courses mentioned in this study.

A total of 35 students were enrolled in the course; two of those did not finish the required work (i.e. dropped out), thus the final number of students for these analyses was 33. Differently from the Statistics course, students in the Transportation course had two partial exams during the semester. The distribution of the grade (i.e. weights) was also different: homework assignments were 30% of the grade, quizzes and partial exams were 50%, and the remaining 20% was the final exam. Therefore, it was decided to take into account only the information from quizzes and assignments during the semester, just as it was done with the Statistics course, for consistency reasons.

The results from the initial correlation analysis (using aggregated data) were similar to the ones obtained for the Statistics course. The only variable to have a correlation with students' grades with a p-value less than 0.05 was the average number of days that a student takes to work on the required tasks for the class (p-value of 0.028). This correlation was negative, once again indicating the more days a student lets pass to work on an assignment or quiz, the lower their grade will be. The total number of views and the standard deviation for number of days to work on an assignment were found not to have a strong correlation (p-values of 0.377 and 0.381, respectively). Figure 2 shows the distribution of grades by the average number of days for students to work on the assignment.

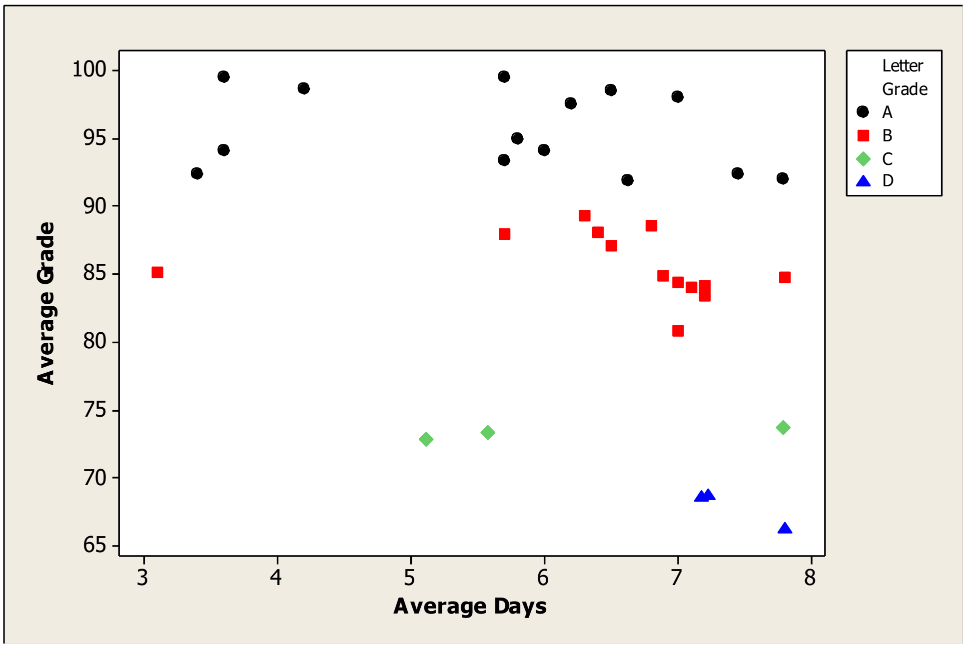

Figure 2. Scatterplot of Average Grade versus Number of Elapsed Days (by Grade Letter)

The next step was to develop the panel data models for this course. Both the FE and RE models were applied to the disaggregated data and once again the Hausman test favored the RE model (p-value of 0.0877, thus not rejecting the null hypothesis). Table 5 shows the results of the RE-model for the Transportation course. The results were almost the same as those obtained with the Statistics course: the number of days was found to be statistically significant (p-value of 0.049); its coefficient indicates that every day that a student let pass to do the required work is associated with a 1% decrease in the grade. The number of views of the material was not statistically significant at the 95% confidence level (p-value greater than 0.05).

Table 5.
Random-Effects Panel Data Model for the Transportation Course

Parameter	Estimate	St. Error	t-statistic	p-value
Number of Views	-0.332	0.213	-1.56	0.118
Number of Days to Work	-1.163	0.589	-1.97	0.049
Constant	98.181	4.554	21.56	<0.001
Sigma_u	5.326			
Sigma_e	22.192			
Rho	0.054			

The values for the between- and within-subject standard deviations were 5.326 and 22.192, respectively. These indicate that a standard deviation of 5.3% points is associated with different students (lower than the 12.5% for the Statistics course) and a standard deviation of 22.2% of the grade is associated with the presence of the student cluster (as compared to 21.6% for the Statistics course). The value for the intraclass correlation, *rho*, was again closer to zero (0.054) indicating that, for each student, the grades varied over the time period (weeks). Finally, the values for the within-, between-, and overall coefficients of determinations were 0.016, 0.0511, and 0.023, respectively. This suggests that, overall, the model explains less than 3% of the variance in grades, less than 2% of the variance in grade within students, and approximately 5% of the variance in grades from student to student.

6. Conclusions and Recommendations

The Covid-19 pandemic resulted in the immediate change of the traditional face-to-face education system to online teaching. The increase in the number of students who failed their grades raised concerns about the effectiveness (and appropriateness) of virtual classes. However, studies have shown that students' performance in online courses are no different from the traditional teaching style.

Since a previous study determined that a student's level of responsibility was the determinant factor for their grades, the same was theorized for online courses. This study investigated if the variables of number of times a student views the material, the number of days it took them to work on the class, and if they separated a day in particular to work on the class, significantly influenced their grades, as these were the variables available from Moodle's platform.

Correlation analyses on the aggregated data determined that, for a Statistics course in which students had over a week to do the required work, the average number of days it took a student to work on an assignment or quiz was negatively associated with their grades. This could be interpreted as those students who leave the work for the last minute obtained lower grades than those who decided to work on them at an earlier date. When considering disaggregated data, the results of the panel data models indicated the same. In addition, panel data analysis concluded that over 20% of the standard deviation in grades was associated with the student cluster. The results of these analyses were then validated with a Transportation course.

This study was not able to consider a wide variety of variables that could have been helpful in developing better fit models. The main reason for these omitted variables was the limited information obtained from the Moodle platform. Surveys to the students could provide additional information, such as if they did (additional) practice problems to study for the class. Other factors that could be explored are: access to a computer, access to reliable internet services, level of responsibility in the household, and number and level of difficulty of other classes in that semester for a particular student. It is recommended that future studies incorporate these variables and apply statistical analyses that allow for correlated observations in order to account for individual characteristics.

Finally, this study had some limitations. For example, a student could "click" on an online material without actually studying it, thus the variable "number of views" may not be an indication of a student actually studying the material. Also, it is important to indicate that, for each course material, Moodle indicated the total number of times the students viewed it, even if they later reviewed the material again to study for the final exam. Although it is possible to identify the exact moment a student viewed a particular material, this was not done as it would have been extremely time consuming. This should be considered in future studies what would like to explore this aspect using disaggregated data.

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