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Student performance impacted from modifying a first-year/semester engineering core course during a global pandemic

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Work-in-Progress of an initial phase of a research study of data on student performance impacted from modifying a first-year/semester engineering core course during a global pandemic

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Abstract

We consider the impact of precipitous decisions to abruptly migrate a first-year and first-semester engineering core course to partially online as a response to a pandemic. This quantitative and retrospective study seeks to identify any effects of a global pandemic on student performance in a course at a large research university in the southwestern continental United States. The study focuses on student performance as an important factor that directly impacts and concerns many students. The study compares 340 Fall 2019 students' performance to 293 Fall 2020 students' performance on similar coursework. The Fall 2020 course implemented a transition to a hybrid format (combined online and in-room class meetings) as part of precautions over the pandemic. We employed statistical analyses methods (paired t-tests, etc.) on the student data. The Fall 2019 exam average decreased from the first to the second by 13.37 whereas Fall 2020 hardly had a change in the two exam averages (difference in mean of 0.3208). The paired t-tests showed the significance of the variations: 5.974 for the first test for fall 2019 compared to Fall 2020 with a significance of 3.868×10^{-9} and -4.406 for the second test for fall 2019 compared to Fall 2020 with a significance of 1.238×10^{-5}. The result of this study can help determine the impact of precipitous decisions to abruptly migrate a course to partially online as a response to a pandemic and thereby help inform future preparations for similar events.

Introduction

This paper presents what may be considered a Work-in-Progress of an initial phase of a research study of data representative of Fall 2019 and 2020 student performance to help understand the

effects of a pandemic. Given the unexpected nature of the pandemic certain detailed characteristic demographic data on the students were not already planned for collection. However, both groups of students entering this first-year engineering (FYE) course are accepted into the university within a year time frame, with similar pre-requisites, and with similar distribution of demographic characteristics. The study focuses first and foremost on the similar implementations of the course and on the available student performance data, leaving demographics for later correlation.

The beginning of the Spring 2020 semester coincided with the emergence of a deadly disease due to a novel severe acute respiratory syndrome corona-virus (SARS-CoV-2). The illnesses began as 2019 ended (hence the disease caused by the coronavirus is termed COVID-19). Doctors started noticing a group of increasing pneumonia cases by December 2019 due to a new virus in the city of Wuhan, in the province of Hubei, in China[1] , considerably far removed from the continental United States (US). Very little was then known about SARS-Cov-2 or COVID-19, especially to many at the large U. S. research university in this study. The semester had reached its mid-point, Spring Break, when the World Health Organization (WHO) officially began using the global pandemic terminology[2]. The virus had high transmission, hospitalization[3], and mortality rates[1,4]. The carriers of the virus could be pre-symptomatic[2] or asymptomatic[4] among the many then-unknowns of COVID-19 leading to many concerns about community transmission[5]. To minimize transmission and overwhelming hospital resources many governments decided to encourage or order their population to quarantine, self-isolation and social distancing (people keeping 1.5 to two meters or about six feet away from one another[6]). Many institutions went on a lockdown (shuttering many "non-essential" companies, businesses, universities, etc.). Many university administrators then decided to expeditiously move courses already in-progress in classrooms situated in a geographically allocated, physical building, to online only.

Purpose of the Study

The research presented in this paper has a main purpose of quantifying the effects of suddenly moving a course from a physical classroom in a building to a partially online virtual classroom environment. The study focuses on student performance to help gauge how the transition impacts and concerns students, and subsequently, their parents, faculty and administrators alike. It would be of interest to know what contributes to any observed changes in student performance. It is then of interest to analyze existing course data to quantify any possible observable effects on student performance. The grades are a very important indicator of performance to many students, their parents, university faculty, staff, and administrators alike, as they are some of the stakeholders in what happens in the engineering education process. The grades are a factor that represent one specific exhibit of the effects of the global pandemic locally materializing in student class and college life. This paper presents retrospective analyses of students' grades data from the Fall 2019 semester preceding the pandemic compared to the Fall 2020 semester during the pandemic.

Research questions

The purpose of the study leads to the following research questions:

1. How does a major change in delivery format due to modifications for a pandemic affect students' performance in their grades?

2. How does students performance in the course material change during each semester for students who have been affected by the pandemic compared to students before it?

Potential benefits of the study

The sudden change in course delivery format has the potential to impact these quintessential education stakeholders: the students, their parents, university faculty, staff, administrators, and law-makers. The sudden closure of university physical environments indirectly influences a lot of staff, maintenance, housing, miscellaneous personnel, as well as the neighborhoods surrounding such universities, travel to, from, and through the universities. Thus, there exist possibly hundreds of thousands of indirect stakeholders, albeit not as direct as any student. The impact on these less direct stakeholders can in-turn influence the more direct stakeholders on later occasions. While acknowledging those less direct stakeholders, the study focuses on the most direct stakeholders, the students, and through their work. The lessons learned from the observations of data before, during, and after the event could, through evidence, provide some guidance to streamlining and disciplining the stakeholders' decision-making, preparation, planning, responses, implementation, and processes for handling future similar major events or recurrences.

Background

A pandemic and 21^{st} century technology

Global pandemics have occurred throughout human history[7,8,9,10]. One extremely significant and current distinction is the existence and generally widespread availability of the internet. This, along with other supporting technologies, helped make it possible for a course to transition to online at the time of COVID-19's official acknowledgement as a global pandemic. An important factor on student performance is how the use of the internet and associated technologies that facilitate such a major transition play a role. The works on courses that used internet technologies can have results of relevance to the study due to the use of online technologies and are part of the literature survey for the framing of the course in the study but the focus of the study is on student performance. Researchers studied the effects of technology for distance learning[11], flipped or inverted classroom[12], mixed face-to-face with online or partially flipped courses[13]. Research findings indicate preferences for in-person or face-to-face (F2F) education[14,15,16]. Downs[14] quotes students who preferred face-to-face interactions and getting feedback on course grading. Interestingly, Wladis et al.[16] found no significant differences in preferences by gender.

The course

First-year and first-semester courses are the general introduction to the major disciplines that students get when they first enter college. First-year engineering (FYE) courses in particular have been focusing on getting engineering students a closer experience to the engineering profession[17,18]. The FYE courses engage students in engineering activities to get them to better learn the engineering disciplines as intended by experiential learning theory (ELT)[19,20,21]. The university in this study made major changes in the design of their FYE courses from project-based[22,17,18] to a more subject-specific format[23,24] in 2018 to improve retention.

The subject of the new FYE course was to be engineering and introduction to associated programming using python. The first-course in engineering for entering students became an introduction to programming where each week consists of one hour of lecture and three hours of in-class programming laboratory activities. The Computer Science faculty developed the content for this course. The course would provide sufficient understanding of computer logic and good, structured, modular programming habits to be a foundation and base level of preparation for any other supplemental languages that students may end up mostly using when problem-solving in consequent courses of their major disciplines.

Methods

Setting

The on-campus physical classroom environment is the typical format for Fall 2019. A version combining the onsite physical classroom concurrently with a virtual classroom environment became the format for fall 2020. The Fall 2019 and 2020 implementations of the courses are described each in this section with respect to the original intent of the class.

The typical class

The class was designed to be an engineering computation laboratory via an introduction to programming in python[23,24]. The typical class laboratory activities are worked in teams of four where students apply the basic programming concepts to solving common engineering problems (e.g., interpolation; analyzing, arranging, controlling repetitive processes; pattern identification and matching). Many studies[25,22,19,26,27] emphasize the importance of such team problem-solving in building hard and soft skills (communication, networking, etc.) in engineering education. The team laboratory activities would continue outside of class to be submitted online within approximately one week.

The physical classroom

The physical classroom contains the most up-to-date technology to create a modern active learning environment. The physical classroom is state-of-the-art with tables for four students with connections for their laptops, including the ability to connect to a large screen monitor at one end of each table. The classroom has several larger monitors mounted high on each of its four wall, even though some walls are transparent glass or have large windows. The instructor had a podium in front of a “smart” writable touch screen monitor (largest in the classroom). Either the podium or the large monitor behind it control all other monitors.

A typical classroom would consist of 96 students with four per table. Another table would be for four peer-teachers who are undergraduate students who would assist the instructor in walking around the classroom helping students. There would also be quizzes administered during a small portion of the laboratory hours, in the physical classroom but using the online learning management systems (LMS).

The partially virtual classroom

The university was transitioning the learning management systems (LMS) from 2019 to 2020 (from BlackBoard™ to Canvas™). The university had switched the university-wide licensing of the remote virtual conferencing systems by 2019 (from Cisco WebEx™ to Zoom™). The university had switched to completely virtual classrooms (with options for synchronous and asynchronous content delivery) after Spring Break 2020 with the worldwide acknowledgement of a global COVID-19 pandemic. The university faculty and student groups' surveys found that most did not like the completely virtual classroom of the second half of the spring 2020 semester. According to some surveys, many students did not feel connected to their peers and the college classroom experience, reflecting a broader body of related research on COVID effects[28,29], importance of peer interactions in FYE education[17,18], and teaming[25,22,19,26,27]. Therefore, the university decided to have onsite classes for Fall 2020 with a virtual option for students who were not comfortable attending class in-person or face-to-face, in other words, a hybrid format: combined virtual and onsite class meetings (again with synchronous and asynchronous content delivery options). Any student may choose to attend online or in-person as they wish, felt safe, or following university protocol to self-isolate if positive for SARS-CoV-2 or awaiting test results.

To facilitate the hybrid classroom and maintain social distancing, the typical classroom population was reduced by a factor of three. This would enable only one student per table, where there were four before the pandemic. Each table had a one-inch circular adhesive tab of a particular color at each of the four places to sit at the table as a color code to dictate when students would sit at that location. For example, the first class to use that classroom would only have masked students sit according to the color on a chart at the entrance to the building. the next class to use that classroom would sit students according to the next color on the chart, and so forth. The classrooms were to be cleaned in-between classes as needed. Students were to wait outside the classroom (socially distanced) and enter the classroom after the instructor came in to start class. Everyone was to enter a classroom through doors designated only for entry and leave through doors designated only for exit.

The contact hours were changed to the instructor in the physical classroom holding the one-hour in-person lecture for the one-third of the class expected to attend in-person while other students attended virtually for synchronous content delivery. The remaining contact hours were completely virtual and dedicated to the lab as per the design of the course. The instructor came in and set up the classroom technology and the virtual connection to enable students that chose not to attend in-person to join the in-person group to have as close to the same experience as possible. However, due to occasional technical issues, the instructor elected to modify some "rules of online etiquette" allowing some students to not turn on video, if internet-challenged, but still be prepared to participate in classroom discussions or when asked a question. This was intended to engage the remote students the same as the in-person ones but then became an unintended check on students who were not necessarily paying attention or as present as the zoom window would suggest. The peer teachers did not need to attend class in-person but attended virtually. The instructor preferred this arrangement to minimize the number of persons in the classroom and so that the peer teachers could answer questions in the chat box of the virtual meeting software.

The laboratory activities were primarily handled by the peer teachers completely virtually. Since there was less control over who could attend virtually depending on how healthy a student felt, the arrangements of teams of students to work on laboratory activities needed a lot of flexibility due to the course taking place in the midst of a pandemic. Students were able to join virtual breakout rooms to continue their teamwork on team laboratory activities. The team laboratory activities were to continue outside of class and students could then choose to work virtually or in-person if possible. Other coursework were to be conducted individually. Quizzes would be administered entirely virtually but still use the LMS.

The classwork

The lecture part of class introduces a programming concept then quickly goes into uses of that concept in engineering problem-solving examples that would show up in later classes. For example, upon introducing the order of operations on variables in the programming language, students would then have laboratory activities where they write interpolation codes to see how it applies to say, the physics of constant velocity motion. Subsequent classes would show why you need loops to use interpolation on large data sets after introducing conditional logic and loops, and why the interpolation needs to be coded as a function for re-use after introducing functions. The instructor and peer teachers would walk around to help students as needed or upon requests but this was highly discouraged during a pandemic.

The instructor (the first author) has a teaching style that is interactive lecturing for an hour on the first of two days of each week of class meeting. The second hour and the second day were for team activities. The instructor's Socratic approach centers the student-teacher relationships around discussions of the course subject matter: engineering (e.g., Parker Palmer's[30] "subject-centered" teaching, 2021 Wakonse conference). The interaction enables quick small checks to see if students are engaged and getting the material. Hence, the instructor asks many questions and encourages many questions (Freire's[31] "dialogic teaching"), and furthermore, question every design and more. The instructor in fact, would frequently leave the slide presentation to work examples with students on the integrated development environment (IDE) to return often to a form of the intended engagement of ELT[19,20,21]. However, walking around the classroom when students were working on team activities to see how students were implementing their own examples or to help them was discouraged during the pandemic. The coursework of students of other instructors (e.g., the second author) are excluded due mainly to variations in key assignments (e.g., different quizzes).

Fall 2019. The syllabus topics for Fall 2019 did not change significantly from the original design of the course[23,24]. A minor rearrangement of topics introduced simple functions earlier for more utility throughout the semester. The Fall 2019 course topics are in table 1.

Fall 2020. The syllabus topics for Fall 2020 did not change significantly from 2020 to try to give students as much of an equivalent experience to their pre-pandemic peers as possible. The two exams were administered online though on an LMS. The schedule was moved up, however, because the university started the semester earlier in order to end at the Thanksgiving break, without requiring students to return to campus for final exams, to not exacerbate the spread of COVID-19. Table 2 lists the course topics for the Fall 2020 semester. Courses that had final

Table 1: Fall 2019 Course Topics, Calendar of Activities, Major Assignment Dates (dates may be changed due to exigent circumstances)

Week	**Class Topics**	**Assignments**
1 (8/26-8/30)	Introduction to Course, Engineering, and Programming	Lab 1, 1b
2 (9/2-9/6)	Sequential Steps, Variables, Assignment, Data Types	Lab 2, 2b
3 (9/9-9/13)	Input/Output and Modules and Calling Functions	Lab 3, 3b
4 (9/16-9/20)	Conditionals and Boolean Expressions	Lab 4, 4b
5 (9/23-9/27)	Loops and Iteration	Lab 5, 5b
6 (9/30-10/4)	Creating and Testing Programs and Basic Debugging	Lab 6, 6b
7 (10/7-10/11)	Arrays and Lists of Data (last topic on Midterm)	Lab 7, 7b
8 (10/14-10/18)	Top-Down Design of Programs	Lab 8, Exam 1 during second class of week
9 (10/21-10/25)	File Input and Output	Lab 9, 9b
10 (10/28-11/1)	Using Engineering Modules in Python	Lab 10, 10b
11 (11/4-11/8)	Writing Functions, Scope	Lab 11, 11b
12 (11/11-11/15)	Functions and use in top-down/bottom-up design	Lab 12, 12b
13 (11/18-11/22)	Systematic Debugging	Lab 13
14 (11/25-11/26)	Exam 2	Exam 2
15 (12/2-12/4)	Topic TBD	*possible project*
14 Finals Week	NO FINAL	

Table 2: Fall 2020 Course Topics, Calendar of Activities, Major Assignment Dates (dates may be changed due to exigent circumstances)

Week	**Class Topics**	**Assignments**
1 (8/19-8/25)	Introduction to Course, Engineering, and Programming	Lab 1, 1b
2 (8/26-9/1)	Sequential Steps, Variables, Assignment, Data Types	Lab 2, 2b
3 (9/2-9/8)	Input/Output and Modules and Calling Functions	Lab 3, 3b
4 (9/9-9/15)	Conditionals and Boolean Expressions	Lab 4, 4b
5 (9/16-9/22)	Loops and Iteration	Lab 5, 5b
6 (9/23-9/29)	Creating and Testing Programs and Basic Debugging	Lab 6, 6b
7 (9/30-10/6)	Arrays and Lists of Data (last topic on Midterm)	Lab 7, 7b
8 (10/7-10/13)	Top-Down Design of Programs	Lab 8, Exam 1 during an online period
9 (10/14-10/20)	File Input and Output	Lab 9, 9b
10 (10/21-10/27)	Using Engineering Modules in Python	Lab 10, 10b
11 (10/28-11/3)	Writing Functions, Scope	Lab 11, 11b
12 (11/4-11/10)	Functions and use in top-down/bottom-up design	Lab 12, 12b
13 (11/11-11/17)	Systematic Debugging	Lab 13, Exam 2 during an online period
14 (11/18-11/24)	Topic "Instructor's Choice"	*Optional* Project due
14 Finals Week	NO FINAL	

exams would take them completely online but the course in this study did not have exams during finals week and essentially ended by Thanksgiving.

The one-hour-lecture and three-hours-laboratory structure of the course was maintained for Fall 2020. However, the students were to watch video lectures for asynchronous content delivery recorded by two other instructors prior to the start of the Fall 2020 semester. The in-class lecture was more of a complement to the video lectures for synchronous content delivery to the in-room and remote students. The one-hour in-person time was used to, say, quickly summarize lecture videos as needed and answer any questions on them, but mostly to work on examples and applications of the concepts with the limited in-person interaction contact time available.

Students

There are normally up to 384 students in the four sections of this first-year engineering class taught by the instructor (the first author). However, for this study, by the end of the Fall 2019

semester there were 340 students total. The Fall 2020 decomposition of the usual four sections into 10-12 smaller sections led to 293 students by the end of the semester. Other further details on the demographic data are not considered in the retrospective analyses of strictly performance via grades data. Consideration of demographic data is left for other research that go deeper into the students and course topic [32,33].

Measures

Grades are considered in the analyses because they are of the most important to the students and likely to be most directly and indirectly impacted by the pandemic. The final letter grade may be of greatest importance to many students as it will impact their entry to a major (ETAM) but this study focuses on the two major exams that contribute more than half the points for the final letter grades. It is likely that the pandemic would affect the team laboratory activities, the homework, the quizzes, and exams, and therefore, the pandemic could directly or indirectly affect much coursework, exams and final grades. Consequently, the exams are not the only items analyzed but other coursework (laboratory activities, assignments, homework, quizzes, etc.) that relate to them are also analyzed within the context of their later bearing on the exams. We can analyze the exams by questions but such data was only collected for 2019 due to disruptions in the instructor's normal interactions and communications with the less easily accessible Fall 2020 graders. Exams are valued as partly indicative of course performance [14]. The exam topics are the same and arranged in similar order for Fall 2019 and Fall 2020 though the problem statements or questions varied. The most difficult topics in the first exam, according to tables 1 and 2, are "Conditionals and Boolean Expressions," "Loops and Iteration," and "Arrays and Lists of Data." Therefore, coursework related to these topics are more closely scrutinized. For brevity, these difficult topics are cited as conditionals (abbreviated as cond.), loops, and lists.

Data analyses

The first analysis was of a graphical representation of the performance of the classes on similar coursework. The coursework performance were plotted collaterally to elucidate any obvious visual distinctions. Then came using paired t-tests of the unequal samples of 340 of Fall 2019 coursework to 293 of Fall 2020 coursework.

Results

The observations of performance are shown via the graphical representation of the exam grades. The comparison of Fall 2019 to Fall 2020 is numerically detailed in the paired t-test results. Similarly results on other relevant coursework are considered.

Performance on Exams

Figure 1 shows the changes from exam 1 to exam 2 for Fall 2019 and Fall 2020, respectively. Exam 2 is not necessarily nor intentionally cumulative but uses topics tested in exam 1. For example, using functions to manipulate and visualize large data sets and using loops and lists to access and manage files of large data sets. Exam 2 typically has a lower average than exam 1

because of having more difficult concepts and their combinations with difficult earlier concepts. However, Fall 2020 shows the opposite trend but not significantly. Unfortunately, Fall 2020 students' performance on exams started off poorer with the mean of Fall 2019's first exam being 7.262 points higher than that of Fall 2020's. Unusually, Fall 2020 students did perform atypically better on the second exam than Fall 2019 students, with the mean of Fall 2019's first exam being 5.791 points lower than that of Fall 2020. For Fall 2019 there was a decrease in exam average from the first to the second by 13.37 whereas Fall 2020 hardly had a change in the two exam averages (difference in mean of 0.3208).

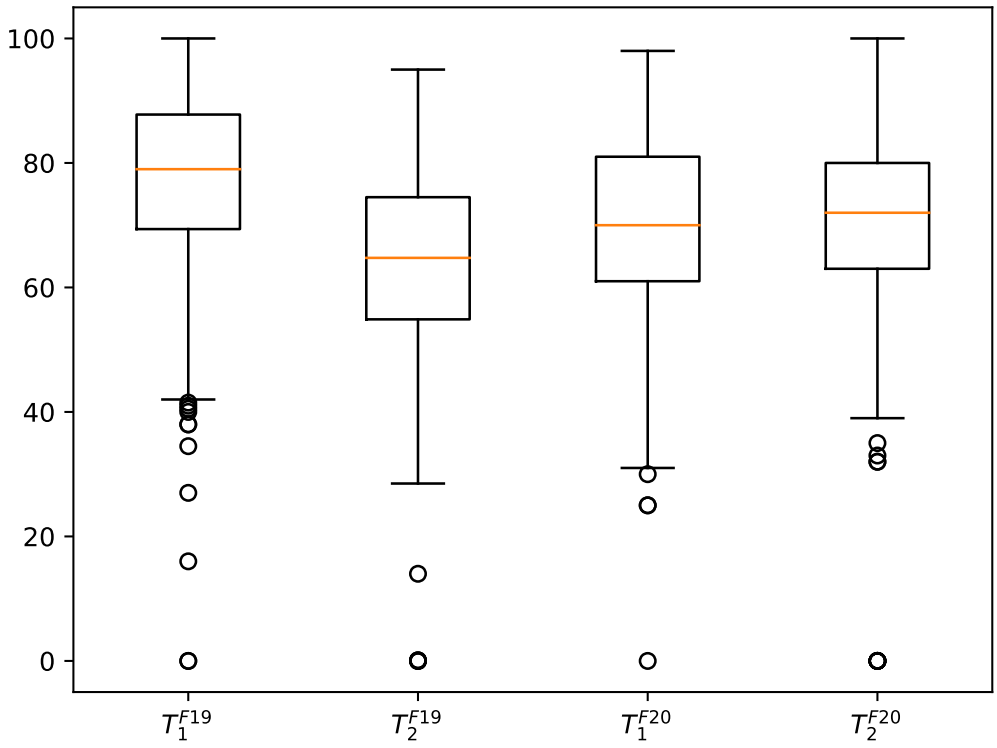

Figure 1: Changes from exam 1 to exam 2 for Fall 2019 and Fall 2020.

Table 3 enumerates the distinctions illustrated in Fig. 1 using paired t-tests of the unequal samples of 340 of exam 1 from Fall 2019 to the 293 of Exam 1 for Fall 2020 in the first row. The second row of table 3 shows paired t-tests of the unequal samples of 340 of exam 2 from Fall 2019 to the 293 of Exam 2 for Fall 2020. The high t-test statistic of 5.974 with a significance of 3.868×10^{-9} is a strong indicator that Fall 2020 students showed lower than the typically low performance in Exam 1 supported by the approximately 0 p-value. However, there is the opposite performance of Fall 2020 students in exam 2 indicated by the negative t-test statistic of -4.406 with a significance of 1.238×10^{-5}, also at an approximately 0 p-value. Unfortunately, Fall 2020 students' performance on exams started off poorer and did not significantly improve though they did atypically perform slightly better on the second exam than Fall 2019 students.

Table 3: Paired t-test of exam 1: Fall 2019 to Fall 2020; then Exam 2

t-tests	statistic	p-value
$t - test_{ind}(T_1^{F19}, T_1^{F20})$	5.974	3.868×10^{-9}
$t - test_{ind}(T_2^{F19}, T_2^{F20})$	-4.406	1.238×10^{-5}

Table 4: Paired t-test of quizzes on major course material, Fall 2019 to Fall 2020

t-tests	statistic	p-value
Cond.: $t - test_{ind}(Q_{Cond}^{F19}, Q_{Cond}^{F20})$	5.172	3.1174×10^{-7}
Loops: $t - test_{ind}(Q_{Loops}^{F19}, Q_{Loops}^{F20})$	2.0324	0.04253
Lists: $t - test_{ind}(Q_{Lists}^{F19}, Q_{Lists}^{F20})$	-0.9619	0.3365

Performance on Assignments That Contribute the Most to Exams

The team laboratory activities and homework typically had high averages with students having more time to work on them, procrastination until last minute submission common to both groups not withstanding. The timed in-class quizzes are more closely examined for indicators of any bearing on exams (see Fig. 2). The average on the conditionals quizzes for the Fall 2019 students was 11.7 points higher than for the Fall 2020 students. The average on the loops quizzes for the Fall 2019 students was 4.778 points higher than for the Fall 2020 students. The average on the lists quizzes for the Fall 2019 students was 1.987 points lower than for the Fall 2020 students. This indicates that conditionals and loops were the major factors for the lower performance of Fall 2020 students on exam 1 than for the Fall 2019 students.

The paired t-test results shown in table 4 indicate that Fall 2020 students initially performing worse than fall 2019 students on conditionals quizzes. Fall 2020 students' average on the conditionals quizzes was 11.7 lower and the t-test statistic was 5.172 with a p-value of 3.117×10^{-7}. Fall 2020 students' average on the loops quizzes was 4.778 lower with a t-test statistic of 2.032 at a significance level of 0.04. No significant effects on the performance on lists emerged per the paired t-test results on that topic given that the average for Fall 2019 and Fall 2020 lists quizzes are so much closer.

Discussion

Despite the best attempts to maintain consistency in student experience during the Fall 2020 semester congruent to the Fall 2019 typical experience, there inevitably emerged variations. The biggest variation was the poorer start to the course by Fall 2020 students compared to Fall 2019 students. Fall 2019 students showed a decrease in exam average from the first to the second by 13.37 whereas Fall 2020 students hardly changed in the two exam averages (difference in mean of 0.3208). Perhaps some adjustments and further considerations of flexibility on assignments for the number of students requesting accommodations and re-structuring teams due to COVID, that kept increasing as the semester evolved, may have helped performance on later coursework.

Adjustments had to be made during Fall 2020 when at one point there was only one student present in the physical classroom with the instructor. In other words, the course at times became

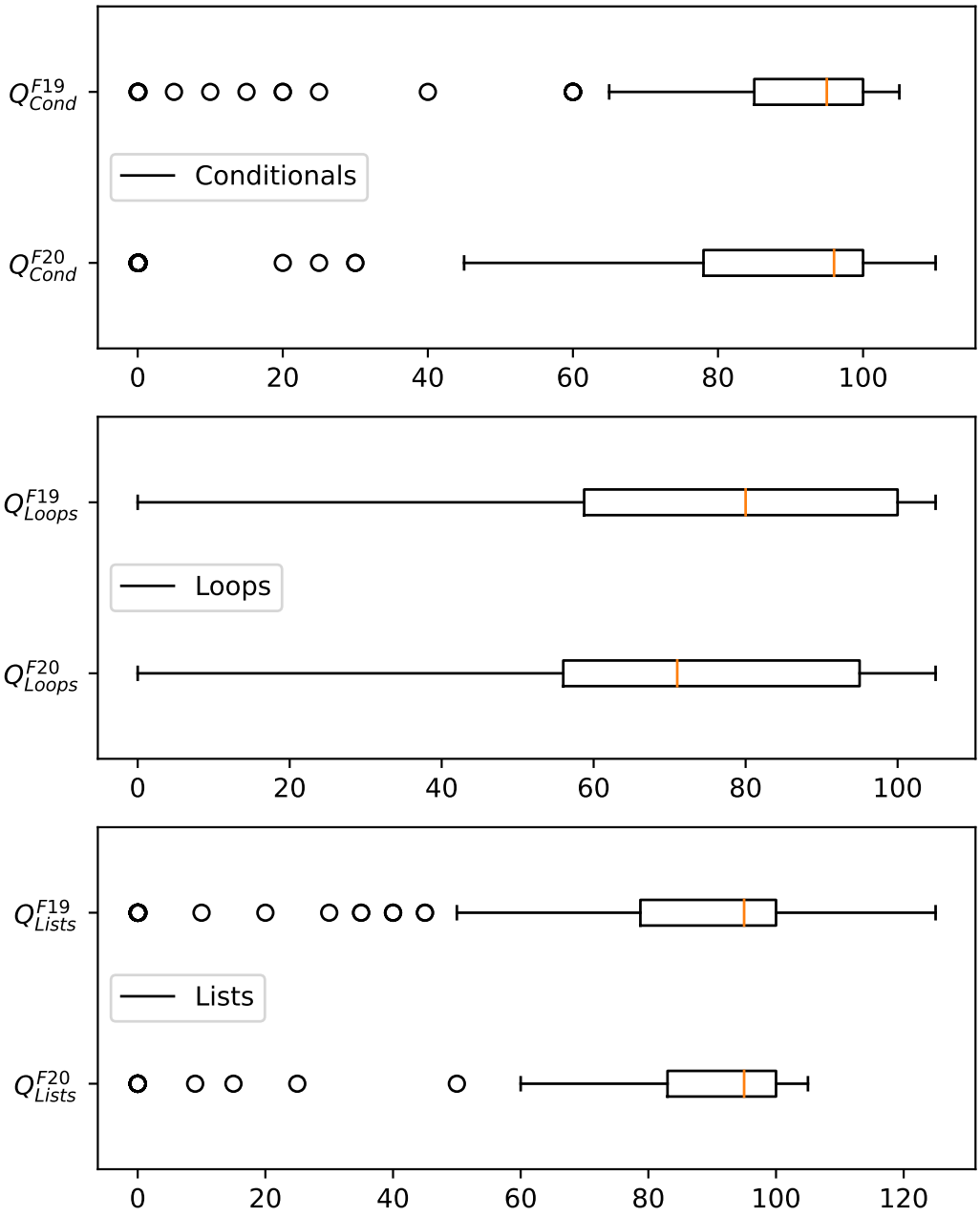

Figure 2: Quizzes on some of the more difficult course material for Fall 2019 and Fall 2020.

more inverted than the intended partially-flipped format. Given such occurrences, the instructor would occasionally email a random student among those who would suddenly stop attending face-to-face, to check on them. The instructor found students who had the usual issues (transitioning to college, family matters, other illnesses, etc.) and some were concerned about increasing COVID case numbers among reasons to temporarily stop attending class in-person. The technology helped students continue to attend class virtually if attending in-person was not possible. The technology also helped class participation by showing student names by the small window for the student in the virtual meeting software, alleviating the difficulty in remembering names in large classes. However, some students took advantage of the instructor relaxing the rules of "online etiquette" to accommodate students with internet issues and mostly kept video off. A few students did find the virtual option helpful for the typical pre-pandemic reasons, when running late for example, but in one case, a student admitted to being in bed when asked a question during class participation, and then later said that he moved to a table, presumably to be more involved. There were a few occasions when some of the technology failed adding to frustrations. However, office hours were aided by sharing screen to help a student instead of looking over a shoulder, except on the other hand that the instructor could not type on the students laptop if needed. A lesson learned from this study on modifying this course for a pandemic is that some virtual meeting technology may improve office hours while also providing alternate ways to help students.

The paired t-test results did not indicate any similarity or correlation in performance on quizzes on harder course material and by the second exam. The improved performance observed in previous research on flipped or partially-flipped classrooms[13] were not evident in this study.

Conditionals and loops are the most difficult course subject for Fall 2019 and 2020 students to grasp and strongly affect the performance on the first exam. However, the performance on conditionals and loops was worse for Fall 2020 students. The hybrid format evidently may not have been as conducive to mastering certain topics. The results suggest allocating more class time and resources to conditionals and loops, virtual or not.

Teamwork in laboratory activities are a large part of the course and intended to help students get immediate support from teammates, thereby helping them do well in a large class[25,27]. Difficulty forming teams may be why performance in exam 1 was worse for Fall 2020 students than Fall 2019 students, undoubtedly due to the pandemic. Typically students stay on the same team and rarely change teams during the semester. However, for Fall 2020, students had difficulty forming or finding teams in the hybrid class structure. It was difficult to follow a more formal process[22,26] of team formation with trying to plan so many modifications for Fall 2020. Some in the physical classroom would gravitate to the usual teaming with people they already know but Fall 2020 meant not already knowing anyone led to teaming with the students who are usually present and co-located in the physical room. In other words, teaming was just not necessarily with a lesser-known person in a virtual room especially if remote students preferred video off when virtually attending class[29]. Nonetheless, a few virtually-attending students expressed that they found it advantageous to have a teammate who could attend in-person who then could supplement anything that might be missed. Team dysfunctional complaints arose more frequently. Switching teams occurred more frequently. The more favorable team interactions in some inverted or flipped classrooms noted in previous research on such classrooms[12] was not observed in this study.

However, it should be noted that any class taking place during a pandemic is likely subject to more tensions than without the looming subconscious presence of a pandemic.

Students made fruitful use of the technology available to them, despite occasional technical issues (a few students suggested that they might design new technologies or redesign some of them in a job one day). Even some students who attended class in-person would watch both the pre-recorded lectures and the recording of the in-class lectures, after attending class face-to-face, bestowing upon themselves both the synchronous and asynchronous content. Many teams used the same virtual meeting software used in class and other internet collaboration software (e.g., Google Groups, Slack, Microsoft Teams). Another lesson of this study on modifying this course for a pandemic would be to plan for how to team with optimal beneficial use of technology under difficult circumstances.

Students' statements in the course evaluations indicated that they preferred the time spent with peer teachers or teaching assistants during virtual office hours even more for Fall 2020 than Fall 2019. Students appeared to relish the one-on-one time spent with the instructor or PT's more than usual, even though it was virtual. However, any anecdotal increase in the request for office hours was not observed. Stopping by the podium to discuss anything with the instructor after class rarely occurred, which is to be expected given the social distancing requirements.

Limitations of the Study and Suggestions for Future Research

The opportunity for a comparative study emerged from the unexpected pandemic that caused a difference between the implementation of the same course over two subsequent semesters, one before and one during the pandemic. As the study was not planned, it had to be conducted quantitatively and retrospectively on existing comparable data. An obvious limitation then is that there were no other corresponding data characteristic of the students in the courses to enable a broader perspective correlated with qualitative research. For example, student observations were not readily available for the pre-pandemic semester that would correspond that well to impressions of students during the pandemic. Focus group interviews could be conducted with the caveat that pre-pandemic students would be trying to retrospectively reflect with a known context: the pandemic, thus potentially presenting an un-intended bias. Demographic data was difficult to gather but could be considered to bring a broader context of the results. Specific roles of specific technologies should be studied for not just the impact on students but if even suitable or viable for the human students. Studying other sections by other faculty would be helpful but the coursework need to be analyzed and deemed sufficiently similar across sections. A study of faculty teaching the courses could also help incorporate their perspectives. Assembling this study with those of other institutions FYE experience would also help broaden and deepen the understanding, and also the scope of the study, of the effects of the pandemic.

Significance of the Study

The findings of this study have several implications for the design of university courses to be prepared in case of not just a pandemic but natural disasters or other unexpected major societal disruptions. It does not suffice to just have the technology available (the internet already existed, LMS and virtual meeting software were already licensed, etc.) but now the specific role of the

technology must already be planned just in case. Specific to the FYE core course is the need to consider the technology that has to be amalgamated appropriately with the human needs (e.g., student health (not just physical but mental, etc.), teaming, staying connected). Also, with respect to the course subject matter, conditionals and loops emerged as topics that need more resources and support for ensuring student understanding and performance.

Conclusion

We conducted a quantitative and retrospective study to quantify how student performance is influenced by changing a first-year engineering programming course from completely face-to-face for Fall 2019 to partially online for Fall 2020 as a response to a global pandemic. The study did not find improved performance observed in previous research on partially-flipped classrooms, possibly due to Fall 2020 occurring during a pandemic. The pandemic adversely affected the usual teaming in a course that is intended to be one-hour lecture and three-hours in-class laboratory team activities: difficulties arose in team formation, communication; more teams than usual needed re-structuring throughout the semester. However, the teams and student work eventually stabilized such that the Fall 2020 students level of performance in the second exam more closely matched the Fall 2019 students. The Fall 2019 average decreased from the first exam to the second one by 13.37 whereas Fall 2020 hardly had a change in the two exam averages (difference in mean of 0.3208). Further analyses of the course topics of the first exam showed that both groups of students had difficulties with the concepts of conditionals and loops. However, the Fall 2020 students performed the poorest on the topics of conditionals and loops by an amount that explains the first exam's difference in average. The results indicate a need to allocate more resources to difficult topics like conditionals and loops in the course, especially if taught with any part inverted, or under pandemic-type conditions.

The availability of internet technologies enabled quickly adapting the course and even showed that it could benefit assisting students virtually due to direct though remote access to the student work, even if the instructor or teaching assistant could only watch with current technology. The evolution of virtual meeting and collaboration software would benefit from incorporating more teaming and interaction capabilities (face-to-face or not) to use what worked well for human connections and what did not. Whether the evolution of education and technology can favorably impact the interactions and connections also depends on other factors. This Work-in-Progress of an initial phase of a research study of available FYE course students' data looked at attempts to continue classes as usual, with minimal disruption courtesy of modern technology, is a start and further studies on the COVID-19 global pandemic effects can help better prepare for similar events.

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