Student Perceptions of the Complete Online Transition of Two CS Courses in Response to the COVID-19 Pandemic

Dr. Mohammed F. Farghally, Virginia Polytechnic Institute and State University

Mohammed F. Farghally received his PhD from Virginia Tech in 2016. He recently joined the computer science department at Virginia Tech as a visiting assistant professor. Starting in Fall 2021, Dr. Farghally will join the computer science department at Virginia Tech as a collegiate assistant professor. Dr. Farghally's background includes extensive teaching experience and significant contributions to the computer science education research. Dr. Farghally's work is mainly directed towards developing innovative technologies to help students better understand abstract CS concepts. Furthermore, Dr. Farghally is interested in analyzing students interactions with online eTextbook material to better understand students' learning behaviors.

Mostafa Kamel Osman Mohammed, Virginia Polytechnic Institute and State University; Assiut University

Mostafa Mohammed is a PhD candidate at Virginia Tech. He is planning to defend his dissertation on June 2021, Mostafa's background includes extensive teaching experience and significant contributions to the computer science education research. Mostafa's work is mainly directed towards developing eTextbooks with different teaching technologies to help students better understand abstract CS concepts. His PhD is about Teaching Formal Languages through Visualizations, MachineSimulations, Auto-Graded Exercises, and Programmed Instruction.

Dr. Hamdy F. F. Mahmoud, Virginia Polytechnic Institute and State University; Assiut University

Hamdy F. F. Mahmoud is a collegiate assistant professor in the Department of Statistics at Virginia Tech, and he has held an assistant professor position at Assiut University in Egypt. He earned master's and doctoral degrees in statistics from Virginia Tech. Mahmoud's research interest mainly focuses on developing statistical models, especially in semi and nonparametric statistics and regression, and applying different types of data, such as but not limited to teaching, epidemiology, spatial, spatially-temporally, and environmental data.

Ms. Margaret O'Neil Ellis, Virginia Polytechnic Institute and State University

Associate Professor of Practice, Computer Science Department, Virginia Tech

My research interests include examining ways to improve engineering educational environments to facilitate student success, especially among underrepresented groups.

Mr. Derek A. Haqq, Virginia Polytechnic Institute and State University

Derek Haqq received his MSc in Computer Science from The University of The West Indies in 2009. He is currently a PhD student at Virginia Tech. Research Interests include Technology in Teaching and Learning, Technologies to support Relational Maintenance, Technology-Mediated Recreation, and Technology on the Trail.

Ms. Molly Rebecca Domino, Virginia Polytechnic Institute and State University

Currently a second year Ph.D candidate at Virginia Tech

Dr. Brett D. Jones, Virginia Polytechnic Institute and State University

Brett D. Jones is a full Professor of Educational Psychology in the School of Education at Virginia Tech (www.theMUSICmodel.com). He has held faculty positions as an educational psychologist at Duke University, the University of South Florida St. Petersburg, and Virginia Tech. He has taught 24 different types of university courses related to motivation, cognition, and teaching strategies. Dr. Jones has also conducted workshops and invited presentations at many universities and has presented about 130 research

papers at conferences. His research, which includes examining instructional methods that support students' motivation and learning, has led to more than 100 refereed journal articles, several book chapters, and three books. He has received three grants from the National Science Foundation for a total of over $2 million to conduct his research.

Prof. Clifford A. Shaffer, Virginia Polytechnic Institute and State University

Dr. Shaffer received his PhD in Computer Science from University of Maryland, College Park in 1986. He is currently Professor of Computer Science at Virginia Tech, where he has been since 1987. He directs the OpenDSA project, whose goals include developing a complete online collection of interactive tutorials for data structures and algorithms courses. His research interests are in Digital Education, Algorithm Visualization, Algorithm Design and Analysis, and Data Structures.

Student perceptions of the complete online transition of two CS courses in response to the COVID-19 pandemic

Abstract

In this evidence-based practice paper, we present results from surveys of students in two CS courses offered in Spring 2020 at Virginia Tech, a large, public research university: a programming-intensive CS2-level course and an upper division theory course, Formal Languages and Automata. Spring 2020 was extraordinary as a result of the COVID-19 pandemic. Universities in the US and across the globe switched to a complete online delivery mode instead of the traditional face-to-face mode. This was challenging to both educators and students, as the transition took place on short notice in the middle of the Spring 2020 semester. We were interested to know those course components students perceived as most beneficial to their learning, before and then after the online transition, and their mode preferences for each regarding online vs. Face-to-Face. By comparing student reactions across courses, we gain insights on which components are easily adapted to online delivery, and which require further innovation. COVID was unfortunate, but gave a rare opportunity to compare students' reflections on F2F instruction with online instructional materials for half of a semester vs. entirely online delivery of the same course during the second half. Although the instruction provided during the second half of the semester may not be the same as what would have been provided had the course been designed as a fully online course from the beginning, it did provide the opportunity for us to acquire insights for future instruction. Results indicated that some course components were perceived to be more useful either before or after the transition, and preferences were not the same for the two courses. Furthermore, to determine what course components need further improvement before transitioning to fully online mode, we computed a logistic regression model. Results indicated that for each course, different course components both before and after the transition significantly affected students' preference of course modality.

Introduction

Face-to-Face (F2F) classes with no online components have slowly been losing their share of course delivery[1]. Recent improvements in technology and financial constraints have paved the way for higher education institutions to rely more on online learning platforms[2]. Universities in the US and worldwide are adopting technologies to deliver their courses online, allowing enrollment of more students while reducing costs. For example, most institutes now use Learning Management Systems (LMS) to deliver their course material[3]. In addition, many non-traditional students with other commitments that hinder them from registering as full time students perceive

online courses as their only option to attend college and obtain a degree[4].

Using only online material without classroom activities and instruction has its own pitfalls[5]. So, many courses at residential campuses have become a blend of some online components with the traditional classroom activities, combining the strengths of both[6].

Amongst these trends came the COVID-19 pandemic. Like most institutions at the start of the Spring 2020 semester, ours was delivering many courses using a traditional F2F mode. Lectures and labs were offered in-person, while students access the course material and submit their assignments online. However, Spring 2020 was extraordinary. As a response to the COVID-19 pandemic, our university administration declared in early March (during our Spring break) that students would not return to campus, and that all courses suddenly must be delivered fully online with no F2F activities. This was challenging to both instructors and students, as the transition was initiated in the middle of the semester, with only two weeks notice before classes resumed online. Accordingly, most instructors settled for a "quick and dirty" delivery, as they did not have the required expertise or the time to do otherwise.

Three of the authors were responsible for teaching two of our CS courses in Spring 2020: a programming intensive CS2-course (with multiple sections and instructors), and an upper-division theory course in formal languages. Course components were updated to support a fully online delivery with no F2F activities. Instructors received a training session offered by our institution on how to rapidly convert a course with some F2F components to a fully online mode. All have a CS degree and with an extensive previous teaching experience.

We were interested to see how students perceived the relative usefulness of various course components both before and after the online transition. As the two courses are of different natures, we were also interested to see if there were differences in students' perceptions between the two courses. In addition, we were also interested in determining those course components that might hinder a fully online transition and needs further consideration. Accordingly, we asked students through a survey about what course components they perceived as most beneficial to their learning, before and then after the transition. We also asked whether they have a preference of one mode over the other. Furthermore, we used the survey data as input to a logistic regression model to see what course components negatively affect students' preference of the fully online transition. We did not compare exam scores within the two courses before the transition to that after the transition as we believe that the performance in exams before the transition is not comparable to the performance after the transition. First, exams in the online version of the courses were not proctored. Second, according to[7], it is believed that to succeed in online courses, students should be more responsible of their learning, self-directed, more motivated, and more disciplined. Given the abrupt online switch, students can struggle to succeed as not all of them posses these attributes. Finally, we considered the negative impact that students might have experienced on their mental health as a result of the unexpected isolation and social distancing.

Our goal in this paper was to find an answer to the following questions:

1. Within each course, which course components were more or less useful to students before and after the online transition?

2. Is there any difference between the two courses as related to the students' overall preference of one mode over the other?

3. For both courses, what are those significant components negatively affecting the students' preference of the fully online mode?

4. What lessons learned should lead to permanent changes to our courses even after F2F courses resume? Addressed in the conclusion

The following sections describe: A summary of related work, a detailed description of the courses involved in the study, a description of the survey and statistical analysis of the results, discussion of the main results, study limitations, and conclusions.

Related Work

The literature is rich with studies comparing the effectiveness of online course delivery to traditional F2F delivery in a variety of subject areas[2,8,9]. A few studies involved CS courses[10]. Most of the CS courses studies were directed towards introductory programming courses[4,11,12,13,14,15] with a few focused on non-programming or theoretical courses[10].

Most of the available studies compared students' course performance as measured from their scores in exams and other assessments[16]. Other studies focused on the intended learning outcomes[4], or on student experiences with the material[17]. Several meta-analysis studies compared F2F versus online course delivery. However, there is no consensus about whether the online mode of delivery is better or at least as effective as F2F. Some studies concluded that on average, students taking online courses outperform students taking traditional F2F courses[16,18,19]. Other studies concluded that traditional classroom instruction outperforms online instruction[20]. Many studies achieved mixed results or did not find any superiority of one mode over the other[8,21,22,23]. A relatively recent meta study[1] concluded that the majority of the literature found that distance and online education is at least as effective as traditional education, and urged instructors and researchers to move forward to the next stage of online education.

Few studies have focused on the affective domain of learning[3] and student satisfaction with the delivery method[17]. According to[24], students in online courses may suffer from a sense of isolation, unclear direction, and lack of motivation. In addition, factors like gender, race, age, academic standing, and area of study might affect how students perform in online courses[2,7,20].

To our knowledge, our study is the first to compare students' reflections after being exposed to F2F instruction with a few online components for half of the semester, and a completely online version of the same course during the second half of the same semester. By examining student reactions to two different courses, we hoped to gain insights on what course components are easily adapted to a full online delivery using the current technology, versus those that require further innovation. An ideal outcome to this study would be to learn which changes that were forced by circumstance should be adopted permanently. We acknowledge that the instruction provided during the online components for the second half of the semester may not be the same as those that would have been selected had the course been designed intentionally as an online course from the beginning.

Course Descriptions

To see the effect of the online transition halfway into the Spring 2020 semester, we collected data from two quite different CS courses offered at the CS department at Virginia Tech. We describe the courses in more detail, including the components and mechanics of both courses before and after the transition.

Software Design and Data Structures

The first course titled Data Structures and Software Design, is a fairly standard "CS2" course that serves as an introduction to data structures and software design. This programming-intensive course is mandatory to CS majors and minors at Virginia Tech. Most students are sophomores who have completed a CS1 Introduction to Programming course or its equivalent. The course was offered in Spring 2020 in three sections, by two of the authors (one responsible for two sections, and the other for one). Before the transition, the course was offered in a F2F format with in-person activities like lectures, labs, and office hours. All course material was offered online through the Canvas LMS, and all assignments were submitted online. The material, assignments, exams, course mechanics, and deadlines were the same for all three sections. The two instructors worked together on course preparation, and the same Canvas course shell was used for all sections. The coursework included lectures, labs, office hours, homeworks, projects, two midterms, and one final. We describe how each component was delivered and administered before and after the COVID-19 outbreak.

Lectures: Before the online transition, lectures were offered two times a week for 50 minutes per session. Understanding of the core concepts presented in each lecture were tested throughout the lecture using iClicker questions that accounted for 4% of the total course grade. After the transition, lectures were prerecorded by one instructor and delivered through the course's main Canvas page. Each lecture comprises multiple videos, each corresponding to one core topic. Given the lack of F2F lectures, iClicker questions were substituted with Canvas quizzes embedded between lecture videos. The embedded quizzes accounted for the balance of the 4% originally allocated to iClicker questions.

Labs: Students were required to complete one two-hour programming lab per week to demonstrate hands-on experience with the concepts delivered in lectures. Each lab was comprised of a pre-lab activity, the programming assignment, and a post-lab activity. Students submitted their Lab activities online using the WebCAT autograder[25]. Students were expected to complete the pre-lab activity before coming to the lab session. The lab assignment was released to them once they arrived at the lab. Each lab session was administered by two TAs, so that students could ask for help while working on the assignment. After the lab session, students were given until the weekend to submit their post-lab assignment online.

After the transition, in-person lab sessions were abandoned, and students were offered optional online synchronous lab sessions instead. Furthermore, to reduce stress on the students (given the potentially stressful nature of the COVID-19 pandemic), we released the entire lab assignment before the week started on Sunday night. Students had until the following Saturday to submit their answer online to WebCAT. Lab assignments collectively before and after the transition

accounted for 15% of the total course grade.

Homework: Each week, students were assigned readings from the course textbook. To test their understanding and to make sure they had completed the reading, we offered a quiz delivered online through Canvas. The quiz was released before the week started on Sunday night, and was due the next Sunday. Homework accounted for 5% of the total course grade. Reading quizzes were treated the same before and after the transition.

Programming Projects: Before the transition, it was planned that students should complete five programming projects, four of them as individual assignments, and the last one as a comprehensive group project. Individual projects accounted for 30% of the total course grade, and the group project accounted for 10%. Like labs, projects were submitted online through WebCAT. 50% of the project grade was based on passing WebCAT testcases, and writing clean code observing styling standards. The other 50% of the grade was assigned manually by the TAs for the implementation approach including the degree the approach was flexible, maintainable, and well-documented.

After the transition, the group project was changed to be merely a design assignment with no coding. Students were required to submit a UML (Unified Modeling Language) class diagram of a COVID-19 real-time data visualization tool.

Exams: Students were required to complete two midterms and one final. All exams were available online as Canvas quizzes. The midterms each accounted for 10% of the total grade. Students were given 50 minutes to complete each midterm. The final was worth 15% of the total grade. Students were given 90 minutes to complete the final. Students took the first midterm before the transition. While the exam was available totally online, students were required to show up in lecture and answer the exam in-person, so that they were proctored. After the transition, students answered the second midterm and the final fully online without proctoring. Exams were released on Canvas, and could be taken anytime within two days of release. Students had only one attempt, with 50 minutes for the midterm and 90 minutes for the final.

Office hours: Before the transition, office hours were offered in-person. After the online transition, students were offered the same number of hours, but synchronously online via Zoom. Students were also encouraged to use the course's Piazza forum both before and after the transition.

Supplemental material: In addition to the main course textbook, students were assigned readings and assignments from the OpenDSA eTextbook[26]. OpenDSA delivers core concepts on data structures and algorithms in a visual interactive way that has been shown to engage students[27]. OpenDSA contains a wide variety of interactive exercises with automated assessment, programming assignments using the Code Workout framework[28], and algorithm simulation exercises. OpenDSA was used in the course the same way both before and after the online transition. It accounted for 2% of the total course grade. In addition, students were encouraged to perform ungraded practice quizzes online both before and after the transition.

Formal Languages and Automata

The second course we studied, Formal Languages and Automata (FLA), is a traditional course in the Computer Science theory curriculum[29,30]. It typically includes topics like finite state machines, languages, their representation by regular expressions and grammars, Turing machines, and possibly computability theory and complexity theory[31]. It is mathematical in nature. Our students must take at least one theory course for their CS degree. Most students registered in the course were seniors who have completed CS1, CS2, and data structures and algorithms courses. The FLA course was offered in Spring 2020 in two sections. One author served as the instructor to this course for both sections. Before the transition, the course was offered in a traditional F2F format. Students attended lectures in-person, and there were in-person office hours. All course materials were offered online through Canvas, and all assignments were submitted online. The coursework was divided into several components: lectures, homeworks, office hours, two midterms, and one final. We describe how each component was delivered before and after the Spring 2020 transition.

Lectures: Before the transition, lectures were offered twice a week for 75 minutes per session for the first section, and three times a week for 50 minutes for the other. After the transition, lectures were prerecorded and delivered through the course's Canvas page. Each lecture comprises multiple videos, each corresponding to one core topic. The instructor did not ask the students to answer quizzes or use iClickers during the F2F lectures.

Homework: Students had 13 homework assignments. Students worked either individually or with a partner, as they chose during the first week of the semester. Students used Overleaf to collaborate and solve the homework assignments together. In addition to the paper assignments, each student was asked to solve 40 auto-graded exercises on Canvas, created using the OpenDSA framework. The homework and the online exercises accounted for 65% of the total course grade. It is worth noting that, there were more exercises offered before the online transition. In addition, exercises were more difficult after the transition.

Exams: Students were required to complete two midterms and one final. In normal semesters, all exams were offered as traditional proctored F2F exams. In Spring 2020, the midterm exams were given in-person. Each midterm accounted for 10% of the total grade. Students were given 90 minutes to answer each midterm. However, the final exam was offered fully online as a Canvas quiz without proctoring, since it occured after the transition. The final exam counted for 15% of the total grade, and was released on Canvas and was due up to two days later. Students had one attempt, and they could take it anytime in the two-day window. Students were given 120 minutes to complete the final once they started it.

Office hours: Before the transition, office hours were offered in person. After, students were offered the same number of hours, but synchronously online via Zoom. Students were also encouraged to use the class's Piazza forum to ask for help at any time before and after the transition.

Supplemental material: There were supplemental materials (videos and research papers related to course topics) provided both before and after the transition.

Method

At the end of Spring 2020 and before releasing course grades, we gave a survey to students participating in three sections of CS2 and two sections of FLA. All students participants experienced both the F2F in-person mode and the fully online delivery mode with no choice, as the online transition was required by the university administration. This avoids any problems from selection bias as described in[1]. 389 out of 511 (76.1%) students from CS2 and 113 of 129 (87.6%) from FLA answered the survey. From those who answered the survey, 86% were males and 14% were females for the CS2 course (close to the 85%/15% split for the whole class). For the formal languages course, 80% were males, and 20% were females (compared to 79%/21% for the whole class). The survey was identical for both courses, except for two questions related to labs for CS2, and one on the partner-based homework assignments for the FLA course. The survey included 10 questions used for both courses, in which students were asked to rate the usefulness of course components before the transition and the same components after. Answers were on a scale from 1-6, where 1 means not at all useful, and 6 means very useful. In addition, students were asked about their overall preference for the course delivery mode.

Results

To compare students' perceptions about the usefulness of course components in the F2F format before and online format after the transition, we applied the Wilcoxon paired signed rank test[32] to compare students' ratings for each question. Results for CS2 are presented in Table 1, and the results for the FLA course are presented in Table 2. A "*" after any given p-value indicates significance at $\alpha = 0.05$.

As the two courses are of different types and contain students from different levels, we were interested in further exploring if there was any difference in students' preferences between the courses. Accordingly, we asked students in both sections to answer this question: *"Overall, how did you find yourself preferring one of the class formats over the other?"* Table 3 shows the percentage of students who preferred the F2F and fully online delivery in both courses, in addition to the percentages for those students who indicated no preference. Using a Chi-Square test, we found that there is a significant association between students' preferences and the course ($p < 0.001$). The majority of students from the FLA course preferred the traditional format (63%) compared to only 19% who preferred the fully online format. On the other hand, for CS2, 42% preferred F2F compared to 38% who preferred the online format.

Furthermore, we were interested to see if gender has any effect on students' preferences in both courses. We first conducted a Chi-Square test to see if there is a relationship between gender and course. We found no statistically significant relationship ($p = 0.324$). This indicates that both courses have similar gender distribution. Then, for each course, a Chi-square test was performed to test if gender has a significant effect on the students' preferences in both courses. For both courses, we found no statistically significant effect for gender on the students' preferences ($p = 0.139$ for CS2, and $p = 0.102$ for the FLA course).

To determine what course components need further consideration before transitioning to a fully online mode, we computed a logistic regression model. The response variable was the preference

Table 1: Results from the CS2 course

How helpful were the following to your learning?	Mode	Mean$\pm$ SE	p-value
Listening to in-class lecture	F2F	3.82 ± 0.06	0.018*
Watching lecture videos	Online	3.68 ± 0.06	
In-class iClicker questions	F2F	3.62 ± 0.06	0.639
Video lecture questions	Online	3.67 ± 0.06	
Time spent watching, reading, or doing supplemental work	F2F	3.84 ± 0.05	0.053
	Online	3.75 ± 0.05	
Doing lab sessions in-person	F2F	3.77 ± 0.07	$< 0.001*$
Doing labs online	Online	4.05 ± 0.04	
Reading OpenDSA	F2F	3.71 ± 0.06	$< 0.001*$
	Online	3.81 ± 0.06	
Interacting with OpenDSA visualizations	F2F	3.80 ± 0.06	0.002*
	Online	3.90 ± 0.06	
Doing OpenDSA exercises	F2F	3.86 ± 0.06	$< 0.001*$
	Online	3.96 ± 0.0	
Using online piazza forum	F2F	4.01 ± 0.05	$< 0.001*$
	Online	4.24 ± 0.05	
The in-person office hours	F2F	4.26 ± 0.04	$< 0.001*$
The online office hours	Online	1.29 ± 0.10	
How supported you felt by your instructor	F2F	3.90 ± 0.04	$< 0.001*$
	Online	3.57 ± 0.06	
How supported you felt by your peers	F2F	3.56 ± 0.06	0.010*
	Online	3.44 ± 0.06	
How stressful taking a test	F2F	3.68 ± 0.05	$< 0.001*$
	Online	3.32 ± 0.05	

for the fully online mode. The independent variables are the perceptions of course components before and after the online transition. We applied the stepwise regression method with $\alpha = 0.15$ for both variable entry and removal. Tables 4 and 5 show those significant components negatively affecting a student's preference for the fully online delivery mode at $\alpha = 0.05$ for FLA and CS2, respectively. The mode column refers to the course mode where this component was found significant.

For both courses, it is clear that F2F lectures were a significant factor in increasing the probability that a student will prefer F2F mode over the fully online mode. In addition, for the CS2 course, in-person labs and in-person office hours were significant factors pushing students' preferences towards the F2F mode. After the transition, taking a test was the only significant factor pushing preferences towards the F2F mode.

Discussion

Based on the results from the previous section, we can distinguish course components that students indicated to be less useful after the online transition from those components that were indicated as more useful. We also discuss the results from a between-course comparison

Table 2: Results from the formal languages course

How helpful were the following to your learning?	Mode	Mean± SE	p-value
Listening to in-class lecture	F2F	4.57 ± 0.07	0.007*
Watching lecture videos	Online	4.31 ± 0.09	
Time spent watching, reading, or doing supplemental work	F2F	4.54 ± 0.06	0.001*
	Online	4.35 ± 0.07	
Time spent with team members solving assignments	F2F	4.42 ± 0.08	$< 0.001*$
	Online	4.05 ± 0.11	
Reading OpenDSA	F2F	4.26 ± 0.08	0.939
	Online	4.26 ± 0.08	
Interacting with OpenDSA visualizations	F2F	4.31 ± 0.08	0.500
	Online	4.27 ± 0.08	
Doing OpenDSA exercises	F2F	4.42 ± 0.08	0.005*
	Online	4.23 ± 0.09	
Using online piazza forum	F2F	4.05 ± 0.09	0.008*
	Online	4.21 ± 0.09	
The in-person office hours	F2F	4.13 ± 0.20	0.149
The online office hours	Online	3.90 ± 0.22	
How supported you felt by your instructor	F2F	4.73 ± 0.05	0.808
	Online	4.71 ± 0.06	
How supported you felt by your peers	F2F	3.74 ± 0.11	$< 0.001*$
	Online	3.40 ± 0.12	
How stressful taking a test	F2F	3.44 ± 0.10	$< 0.001*$
	Online	3.88 ± 0.10	

Table 3: Percentage of students with online vs. F2F preferences

Course	F2F	Online	No preference
CS2	42%	38%	19%
Formal Languages	63%	19%	17%

Table 4: Significant course components negatively affecting students' preference for online mode: FLA

Component	Mode	Coefficient	p-value
F2F interaction with the instructor in lectures	F2F	-2.73	0.010

regarding students' overall preference of one mode over the other. This discussion might help CS instructors seeking to change their course to a fully online delivery mode.

Components found to be less useful

For both courses, students found the prerecorded asynchronous lectures used after the transition significantly less useful than the in-person lectures before the transition. We believe the difference here is mainly attributed to the instructor's presence and interaction with students in the F2F

Table 5: Significant course components negatively affecting students' preference of online mode: CS2

Component	Mode	Coefficient	p-value
F2F interaction with the instructor in lectures	F2F	-0.713	< 0.001
Timed in-person labs	F2F	-0.392	0.001
In-person office hours	F2F	-0.219	0.002
Taking a test	Online	-0.637	< 0.001

lecture itself. Supporting evidence for this include: For the CS2 course, there was no significant difference in the usefulness of in-lecture iClicker questions as compared to the Canvas quizzes embedded between prerecorded lecture videos. In addition, results from the logistic regression model indicate that F2F lectures in both courses were found to negatively affect students' preference of the fully online mode.

For CS2, online office hours were significantly less useful than the in-person office hours before the transition. However, no significant difference was found regarding office hours in the FLA course. Furthermore, for CS2, students found that they were less supported by their instructor after the online transition. Again, no significant difference was found for FLA course instructor support before and after the transition. In-person office hours for CS2 was also one of the significant factors negatively affecting students' preference of the fully online mode. We attribute this difference to the natures of these courses. In a programming-intensive course, it is common for students to get stuck in their programming assignments. Getting in-person support is ideal in this situation, while fully online support might not be as attractive. This is not the case for theoretical courses, as students' problems mostly are in understanding concepts. They do not need thorough technical assistance as in programming courses, just a way to discuss with someone knowledgeable.

Both courses had some group-based assignments. The last project in CS2 was in groups of 3, and all assignments for FLA were allowed to be done with a partner. For both courses, it was found that students were significantly better supported by their peers before the transition than after the transition. In addition, for FLA, students spent more time with their peers solving group assignments before the transition than after the transition. We believe this can be attributed to the better interaction experience students achieve with each other in-person as compared to collaborating online.

For FLA, supplemental material—whether graded or ungraded—was found to be significantly less useful after the transition than before the transition. We believe this is not attributed to the course mode whether online or F2F for the graded part. The reason was mentioned in the course description section, as there were more OpenDSA exercises offered before the transition than after the transition simply because we had more of these available for the earlier topics. Furthermore, the exercises offered after the transition were more difficult than those offered before the transition. For the ungraded part, we believe the reason might be due to the stress students experienced after the online transition. They focused more on the graded material with less focus on ungraded work. Perhaps this needs further investigation.

FLA students found unproctored online exams offered through Canvas after the transition more stressful than in-person proctored exams offered in lecture before the transition. The opposite was indicated by CS2 students. CS2 students reported less stress from an unproctored online test. A possible reason for this discrepancy is the nature of the exam questions in both courses. CS2 questions were mainly multiple choice, matching, and fill-in-the-blanks. FLA questions include writing longer answers of a more mathematical nature. Writing with mathematical notation on a computer might be hard for some students. Interestingly, results from the logistic regression model identified online tests as one of the significant factors negatively affecting students' preference for the online mode in CS2. This means that despite students reporting that they found it is less stressful to take an online exam, it decreased the probability that a student preferred the online mode over the F2F mode. This indicates that online tests need further consideration when transitioning programming courses to a fully online mode. We think that the synchronous presence of the instructors or the TAs in online exams might help.

Components found to be more useful

For both courses, students found the course Piazza forum more helpful after the transition. This was expected, as online forums like Piazza are known to be the students' resort when it comes to seeking quick help from instructors, TAs, or classmates. This might relate to the finding that F2F lectures for both courses and in-person office hours for the CS2 course were reported more useful than the online office hours. After the online transition and the cancellation of F2F lectures and office hours, it was expected that students will rely more on the online (written) forum to ask questions.

Students from CS2 indicated that all materials (textual discussions, visualizations, and exercises) from the graded supplemental online OpenDSA eTextbook were more useful to them after going online than before. This aligns with results from[4] which found a significant difference in the frequency of utilizing online resources for a fully online group as compared to a F2F group. However, this was not the case for FLA, in which no significant difference was found in the usefulness of OpenDSA textual discussions or visualizations after the transition. We believe that the course type might have an impact on what type of online resources are more useful for a fully online course as compared to a F2F course. For a programming-intensive course, visualizations are important in providing a concrete depiction of the dynamics of a specific algorithm or program, while for a theoretical course, visualizations might not be as helpful in depicting mathematical arguments and proofs unless it is designed in a specific way for some topics[27].

CS2 students found labs more useful after the transition, which might be unexpected. We believe this is mainly attributed to the additional time given to solve the assignment post-transition, rather than preference for online labs, per se. Before the transition, students solved the lab assignment in a two-hour, in-person session. After the transition, they had an entire week to submit their assignment online. However, an interesting result was found from the logistic regression model. In-person F2F labs was a significant factor that negatively affected students' preference of the fully online mode. This might indicate that students still feel that the in-person contact with a TA is important.

Between-course comparison

An important difference between the two courses comes in overall preferences between online vs. F2F course delivery. Students in FLA significantly prefer the traditional F2F version of the course, while no significant difference was detected for CS2 students. Students in FLA are generally older than CS2 students. In[7], it was mentioned that younger students suffer significant declines in course performance in a fully online course as compared to older students. However, we found that older students in the formal language course preferred the F2F version to the fully online version. It may be that students' preferences do not necessarily reflect their learning. Future research could investigate this. Furthermore, we did not find significant effects from gender on the preference of one mode over the other. It seems that course type is more significant than gender in determining delivery mode preference.

Limitations

A limitation to this study is that some differences might be due to the different instructors. Two instructors taught three sections of CS2, and one instructor taught FLA. While this is a reasonable concern, we don't believe it is a major issue as all instructors have taught their courses multiple times previously. We conducted a Chi-Square test to see if the instructor has any effect on the students' overall preference of F2F versus online mode for the CS2 course. No significant difference was detected with $p = 0.353$.

Another concern is that the study might be prone to recall bias, because it asks students about their online and F2F experiences at the same time, while the online experience is recent and the F2F experience is far. We don't think this is a major concern, as the period between the courses' last in-person activity and answering the survey was about two months which is not that long to make the students forget about how the courses were managed in the F2F mode.

One more concern is that the results and conclusions out of this study should not be used to compare the effectiveness of F2F mode of instruction to its corresponding online mode. The online versions of the courses involved in this study were not developed under ideal circumstances, and classes deliberately designed for an online environment may have different opportunities. The purpose of this study was to invest this rare opportunity of offering a course in both F2F and online modes in the same semester with the same student sample to gain insights about students' preferences as related to both modes of delivery. However, we believe that the online transition was successful from the students' perspective. Most differences were at the tenths level for a 6 point Likert scale. Given the short time frame to create the online material, we think if we had more time, maybe we would have done even better.

Conclusions

We conducted a study to compare students' perceptions of the usefulness of course components in a F2F format versus a fully online format after the online transition amid the COVID-19 outbreak. Our results indicate that the usefulness of some course components as perceived by students vary according to the course type. For a CS2 programming-intensive course, students found all the online eTextbook components more useful, exams less stressful, and office hours less useful after

the online transition. For an upper-division FLA course, students found exams more stressful and supplemental material less useful. Overall, FLA students strongly preferred the F2F format over the fully online format. For CS2, no significant difference was detected regarding students' overall preferences. For both courses, F2F lectures were indicated as more useful than prerecorded lectures, and students indicated they felt more supported by their peers in group-based assignments when F2F. Our conclusion is that for fully online courses, having synchronous sessions offered in addition to asynchronous recorded lectures are beneficial. More live tutorial sessions could also be offered. Another possibility is to give incentives for attending synchronously or watching recorded versions. Improvements to how students interact with each other in group assignments should be considered for online courses. For CS2, online office hours and instructor support were less useful after the transition. Again, we recommend that instructors try to find ways to better support their students online.

The greatest benefit to this experience might be to identify changes to course components caused by transition that appear to be actual improvements to the course. Giving more time for lab sessions and offering online exams where the questions are primarily multiple choice that are high-level cognitive challenges are examples[33]. However, we find that students need to feel the presence of their instructor to feel properly supported. For example, online exams could still be synchronous with the instructor available to clarify exam questions.

References

[1] Tuan Nguyen. The effectiveness of online learning: Beyond no significant difference and future horizons. *MERLOT Journal of Online Learning and Teaching*, 11(2):309–319, 2015.

[2] David Figlio, Mark Rush, and Lu Yin. Is it live or is it internet? experimental estimates of the effects of online instruction on student learning. *Journal of Labor Economics*, 31(4):763–784, 2013.

[3] Udeni Jayasinghe, Anuja Dharmaratne, and Ajantha Atukorale. Students' performance evaluation in online education system vs traditional education system. In *Proceedings of 2015 12th International Conference on Remote Engineering and Virtual Instrumentation (REV)*, pages 131–135. IEEE, 2015.

[4] Waleed Farag. Comparing achievement of intended learning outcomes in online programming classes with blended offerings. In *Proceedings of the 13th annual conference on Information technology education*, pages 25–30, 2012.

[5] Jill E Courte. Comparing student acceptance and performance of online activities to classroom activities. In *Proceedings of the 8th ACM SIGITE conference on Information technology education*, pages 185–190, 2007.

[6] Yong Zhao, Jing Lei, Bo Yan, Chun Lai, and Hueyshan Sophia Tan. What makes the difference? a practical analysis of research on the effectiveness of distance education. *Teachers College Record*, 107(8):1836, 2005.

[7] Di Xu and Shanna S Jaggars. Performance gaps between online and face-to-face courses: Differences across types of students and academic subject areas. *The Journal of Higher Education*, 85(5):633–659, 2014.

[8] William G Bowen, Matthew M Chingos, Kelly A Lack, and Thomas I Nygren. Interactive learning online at public universities: Evidence from a six-campus randomized trial. *Journal of Policy Analysis and Management*, 33(1):94–111, 2014.

[9] Gale Mentzer, JohnRobert Cryan, and Berhane Teclehaimanot. Two peas in a pod? a comparison of face-to-face and web based classrooms. *Journal of Technology and Teacher Education*, 15(2):233–246, 2007.

[10] Joe Dumas. Online vs. face-to-face student performance in an introduction to operating systems course. *Journal of Computing Sciences in Colleges*, 32(2):185–191, 2016.

[11] William D Armitage, Naomi Boyer, Sarah Langevin, and Alessio Gaspar. Rapid conversion of an it degree program to online delivery: impact, problems, solutions and challenges. In *Proceedings of the 10th ACM conference on SIG-information technology education*, pages 100–107, 2009.

[12] Christopher D Hundhausen, Pawan Agarwal, and Michael Trevisan. Online vs. face-to-face pedagogical code reviews: an empirical comparison. In *Proceedings of the 42nd ACM technical symposium on Computer science education*, pages 117–122, 2011.

[13] Rex Karsten, Shashidhar Kaparthi, and Roberta M Roth. Teaching programming via the web: A time-tested methodology. *College Teaching Methods & Styles Journal (CTMS)*, 1(3):73–82, 2005.

[14] Carol J Romanowski, Rajendra K Raj, and S Manian Ramkumar. Successful practices for online computing, engineering, and technology courses. In *2011 Frontiers in Education Conference (FIE)*, pages T1C–1. IEEE, 2011.

[15] Rebecca Thomas. Experiences teaching c++ programming online. *Journal of Computing Sciences in Colleges*, 15(5):211–219, 2000.

[16] Barbara Means, Yukie Toyama, Robert Murphy, Marianne Baki, et al. The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record*, 115(3):1–47, 2013.

[17] Gail Miles. Comparison of satisfaction and success of traditional and online students in an introductory computer literacy course in a small liberal arts university. *Journal of Computing Sciences in Colleges*, 27(2): 206–212, 2011.

[18] William G Bowen, Matthew M Chingos, Kelly A Lack, and Thomas I Nygren. Interactive learning online at public universities: Evidence from randomized trials. *Ithaka S+ R*, 10, 2012.

[19] Barbara Means, Yuki Toyama, Robert Murphy, Marianne Bakia, and Karla Jones. Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. 2009.

[20] Shanna Jaggars and Di Xu. Examining the effectiveness of online learning within a community college system: An instrumental variable approach. 2013.

[21] Robert M Bernard, Philip C Abrami, Yiping Lou, Evgueni Borokhovski, Anne Wade, Lori Wozney, Peter Andrew Wallet, Manon Fiset, and Binru Huang. How does distance education compare with classroom instruction? a meta-analysis of the empirical literature. *Review of educational research*, 74(3):379–439, 2004.

[22] Shanna Jaggars and Thomas R Bailey. Effectiveness of fully online courses for college students: Response to a department of education meta-analysis. 2010.

[23] Kelly A Lack. Current status of research on online learning in postsecondary education. *Ithaka S+ R*, page 3, 2013.

[24] Shanna Smith Jaggars. Choosing between online and face-to-face courses: Community college student voices. *American Journal of Distance Education*, 28(1):27–38, 2014.

[25] Stephen H Edwards and Manuel A Perez-Quinones. Web-cat: automatically grading programming assignments. In *Proceedings of the 13th annual conference on Innovation and technology in computer science education*, pages 328–328, 2008.

[26] Eric Fouh, Ville Karavirta, Daniel A Breakiron, Sally Hamouda, Simin Hall, Thomas L Naps, and Clifford A Shaffer. Design and architecture of an interactive etextbook–The OpenDSA system. *Science of Computer Programming*, 88:22–40, 2014.

[27] Mohammed F Farghally, Kyu Han Koh, Hossameldin Shahin, and Clifford A Shaffer. Evaluating the effectiveness of algorithm analysis visualizations. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, pages 201–206, 2017.

[28] Stephen H Edwards and Krishnan Panamalai Murali. Codeworkout: short programming exercises with built-in data collection. In *Proceedings of the 2017 ACM Conference on Innovation and Technology in Computer Science Education*, pages 188–193, 2017.

[29] Michael Sipser. Introduction to the theory of computation. *ACM Sigact News*, 27(1):27–29, 1996.

[30] Michael Sipser. *Introduction to the Theory of Computation*. Cengage learning, 2012.

[31] Peter J Denning, Jack B Dennis, and Joseph E Qualitz. Machines, languages, and computation. 1980.

[32] Frank Wilcoxon. Individual comparisons by ranking methods. biometrics bulletin, 1 (6), 80-83, 1945.

[33] W James Popham. *Test better, teach better: The instructional role of assessment*. Ascd, 2003.