

The Impact of Teaching Operating Systems using Two Different Teaching Modalities

Synchronous Online versus Traditional Face-to-Face Course Delivery

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Abstract—This paper presents a preliminary look at the performance of two cohorts enrolled in an Operating System course which was taught using two different teaching delivery methods. Operating systems is a technical, senior-level, undergraduate course that includes abstract concepts, mechanisms, and their implementations. This course exposes students to a UNIX-based operating system and includes concurrent programming (threads and synchronization), inter-process communication, CPU scheduling main memory, and virtual memory management. Technical courses present an additional dimension of difficulty when compared to non-technical courses which are more focused on soft skills because they require strong technical skills such as programming and problem-solving. This paper discusses other research studies and statistical data which underscore some of the challenges and differences encountered when teaching a traditional face-to-face versus an online course and the impact on student success. In this work, the 2019 cohort was taught operating systems in the traditional face-to-face modality, while the 2020 cohort was taught the course using the synchronous online modality. The synchronous online modality is very similar to the face-to-face traditional class, in that, lectures are delivered in real-time; this allows students to ask the instructor questions in real-time. Each cohort was tested on the same course objectives (topics) over one semester in 2019 and 2020. The instructor presents the students' performance on three(3) course exams and discusses the differences and similarities in their overall performance between the two groups.

Keywords—Operating systems; synchronous online course; traditional course; face-to-face course; online course

I. INTRODUCTION

Online education (ELearning) is not a new practice, millions of students have been taking online courses at various universities around the world for over 21 years [15]. It is unlikely for online or ELearning to decrease in the future [3], as the research [20] predicts that the global ELearning market is expected to reach \$336.98 billion by 2026. Many studies and research have been completed to understand the difference in student's perception, challenges, and performance in online courses versus a traditional face-to-face course. There are some benefits to offering online courses. They allow a diverse population of students, who are unable to enroll in traditional classes the opportunity to take courses online at their convenience. In recent years, more universities that exclusively offered traditional courses, are now offering

online courses to meet the demands and needs of their student body. However, with the advent of the COVID-19 pandemic, many universities were forced to offer traditional courses online for the first time with limited resources and preparation time [6, 17]. Naturally, instructors from a large cross-section of disciplines have different experiences and views about teaching a course online versus face-to-face in a classroom.

Some researchers pose that the swift switch to online, from face-to-face classes with inadequate preparation time, is not technically an online class, instead, they referred to this circumstance as emergency remote teaching (ERT) [12]. Typically, online classes are planned, designed, and constructed specifically for online delivery, and are tailored to suit the nature of the course, whether technical or nontechnical. However, they assert that ERT is different from online learning because it is a temporary shift of instructional delivery to an alternative delivery mode due to crisis circumstances, brought about by war, natural disasters, or a pandemic. In general, some hold a negative view of online classes or online degree programs, assuming that they may not provide the same quality of instruction when compared to traditional face-to-face courses or degree programs. While others believe there is no difference in quality between the two types of instruction delivery methods or student satisfaction [12]. Despite the challenges, discipline, students enrolled in traditional degree programs have a higher chance of completing required courses, whether they are offered online or face-to-face. Students know that completing a required course is a requirement for graduation.

Some studies have been conducted that compare and analyze student retention and performance in online versus traditional face-to-face courses, some of them are discussed in this paper, along with the challenges faced by quickly transitioning from a face-to-face class to an online class. This paper presents a preliminary comparison of student's performance in a traditional operating system course versus the synchronous online version of the course. The students' performance on course exams are examined to determine whether there is a significant difference in teaching a technical computer science course using the synchronous online versus the traditional face-to-face modality.

The outline of the paper is as follows. Section 2 presents a literature review of some studies and statistical data for students enrolled in online and face-to-face courses. Section 3

presents an overview of the traditional and synchronous teaching modalities, learning management systems, and resources used to teach the operating systems course. Section 4 describes the operating systems course structure. Section 5 discusses the approach used to teach the operating system course and highlights the differences and similarities between the face-to-face and the synchronous online class. Section 6 presents the results of the students' performance on three exams and section 7 provide some conclusions.

II. LITERATURE REVIEW

This section provides an overview of some data, and research studies that have been conducted to better understand the various challenges, and factors that may impact student's success in online versus traditional face-to-face courses.

Atchley, Wingenbach, and Aker [5] conducted a study to compare course completion and student performance in online and traditional courses. They found that students performed better in online courses, while students who took classes in traditional courses had higher completion rates. Similarly, Paul and Jefferson [16] completed a similar study, they found that there was no statistical difference in the performance of students in online courses versus face-to-face courses. Cavanaugh and Jacquemin [7] ran a study to determine if there is a difference in grades when students completed courses online versus face-to-face. They found that grades were nearly similar regardless of the method of instruction used. While other studies [19] have found that students taking an online introductory course were more likely to fail compared to students in the face-to-face counterpart of the same course. Christian et. al. [10] did a large-scale study involving 72,000 students enrolled in 433 summer courses. Their result showed that students in the online summer courses performed slightly worse than students in the face-to-face summer courses, and interestingly, the results showed that at-risk students were not at a greater disadvantage in online courses.

Arias, Swinton, and Anderson's [4] study results showed that the face-to-face class performed statistically better than the online class in terms of the exam average and improvement between a pre-test and post-test in a Principles of Macroeconomics course. Aguilera-Hermida [1] surveyed 270 students and found that students preferred face-to-face traditional classes more than online classes. Additionally, Duffin [9] completed an extensive survey involving 1500 colleges to obtain students' perception of the quality of online education in comparison to a face-to-face classroom education in the United States in 2020. This survey showed that 41% of graduate students reported that online college-level education was better than their experiences in college-level face-to-face classroom learning. Gonzalez et. al. [11] completed a study with 458 students and found there was no significant change in student grades on tests, when they learned three subjects in the face-to-face modality, and completed activities in a laboratory, compared to students who learned the same subjects online.

Bozkurt [6] and Salto [17] examined the impact of the COVID-19 pandemic in different countries around the world. More specifically [17] discusses the effect of the pandemic on higher education institutions in Latin America who had to rush

to move their teaching online. This study found that these institutions faced two primary limitations: a) the unequal access to technology and the internet; b) their capacity to provide online classes in a short time with limited capacity. Li and Lalani [13] showed that technology and internet access challenges were more common in low-income countries but not only in access but also in the reliability, quality, and speed of the service. Another challenge faced during the COVID-19 pandemic by many academic institutions is the number of students who had access to a working computer [13]. In developed nations, such as Norway, Switzerland, and Austria 95% of students have a computer to use for their schoolwork.

Similarly, in the United States, there is a substantial gap between students from privileged and disadvantaged backgrounds. All most all students from a privileged background reported they had a computer to work on, while nearly 25% of those from disadvantaged backgrounds did not [13]. According to Tam and El-Azar [21], even the software tools used to provide online instruction in developed versus developing nations [8, 14] were also different. They stated that most developed nations utilized a learning management system (LMS) and other technological tools and platforms such as Zoom¹ and Google Drive². While instructors in less developed economies used WhatsApp³ and e-mail to share lessons and assignments with their students [21].

In traditional face-to-face courses, students are influenced by their peers and they tend to build relationships when they meet regularly each week over one semester or a 4-year degree program. While students taking online courses, may not put effort into interacting with their peers and build a rapport or support system. A good example of these types of online courses is the massive open online course (MOOC)⁴. These are online courses, that allow an unlimited number of students to enroll in a course via the web for free. With MOOCs and other free online courses, students do not have the same financial burden, as they would, if they were enrolled in a traditional or online degree program. Additionally, there is no pressure to complete these types of courses on any schedule, therefore, only highly motivated students generally complete them. Irrespective of the teaching modality, challenges, and limitations, the goals of most universities are to provide quality instruction to their students and achieve high graduation rates.

III. TRADITIONAL AND SYNCHRONOUS ONLINE MODALITIES AT FLORIDA GULF COAST UNIVERSITY (FGCU)

Most of the courses are taught face-to-face in the Software Engineering Department at Florida Gulf Coast University (FGCU). The Canvas⁵ learning management system (LMS) is used at FGCU to manage courses undergraduate and graduate courses.

¹ <https://zoom.us/> (Zoom footnote)

² https://www.google.com/intl/en_in/drive/ (Google Drive footnote)

³ <https://www.whatsapp.com/> (WhatsApp footnote)

⁴ https://en.wikipedia.org/wiki/Massive_open_online_course (MOOC footnote)

⁵ <https://www.instructure.com/canvas/higher-education> (Canvas LMS footnote)

A. Canvas Learning Management System (LMS)

Canvas LMS is used to manage course activities (assignments, exercises, quizzes, labs, etc.) and student grades. It allows instructors to assign assignments to students with set due dates. It allows students to submit assignments, project work, exercises and it can be used to administer quizzes and exams. The Canvas LMS is integrated with Canvas Conference which can be used to deliver virtual lectures and virtual office hours. It allows the instructor to upload PowerPoint presentations, work out problems on electronic whiteboards, communicate with students, and answer their questions in real-time. Canvas Conference allows the instructor to record all lectures, which provides students with an opportunity to review lectures as many times as they want.

Additionally, the Canvas LMS is integrated with the LockDown Browser-Respondus⁶ and Respondus Monitoring⁷ to facilitate exams and quizzes. The LockDown Browser locks down the testing environment within a learning management system. While Respondus Monitoring extends the capabilities of the LockDown Browser, by using a student's webcam and video analytics to prevent cheating during non-proctored online exams.

B. Florida CyberHub

The Florida CyberHub⁸ is a virtual learning laboratory that facilitates and enhances cybersecurity educational programs throughout the state of Florida. It provides cloud-based tools, for education and research to faculty members at universities in the State University System of Florida Institutions. The Florida CyberHub installed and set-up virtual machines with a Unix-based operating system and tools to allow students in the operating systems course to learn and investigate operating systems concepts in a remote Sandbox.

C. Traditional Modality

Courses offered in the traditional modality are taught face-to-face in a computer lab where each student has access to a computer. The lab has two projectors on either side of the room. The walls of the lab have many whiteboards for students to practice questions, work individually, or in teams. The front of the lab, has a podium, a whiteboard, a computer, and other teaching tools for the instructor to utilize while teaching the class. Students are required to attend traditional classes in person and these lectures are not recorded. Students use the Canvas LMS to submit assigned classwork and take quizzes during class time. Office hours are given in person at set hours each week.

D. Synchronous Online Modality

Courses taught in the synchronous online modality allows students to attend lectures online, in real-time, at set times each week. With this modality, lectures are taught using Canvas Conference which is integrated with the Canvas LMS. However, students are expected to meet the following

⁶ <https://web.respondus.com/he/lockdownbrowser/> (LockDown Browser-Respondus footnote)

⁷ <https://web.respondus.com/he/monitor/> (Respondus Monitoring footnote)

⁸ <https://floridacyberhub.org/> (Florida CyberHub footnote)

minimum equipment and technology requirements to enroll in online (synchronous or asynchronous) courses:

- Processor: Current generation Intel Core Series (i3, i5, i7, i9) or AMD Ryzen equivalent.
- Memory: 8GB RAM.
- Storage: 250GB hard drive/SSD.
- Webcam, microphone, and speakers.
- Wireless internet (WiFi).
- Windows 10 or Mac OS X (High Sierra or newer recommended).
- High speed Internet access at home (10mbps per device is a good rule of thumb).

Operating systems is a technical course that is taught at the undergraduate level, in the traditional face-to-face modality within the Software Engineering Department at Florida Gulf Coast University. However, in 2020, due to the COVID-19 pandemic, this course was offered for the first time, in fall 2020 in the synchronous online modality.

At FGCU, the operating systems course has been taught by the same instructor since 2015 in the traditional face-to-face modality. Operating System is a required course that students in the Software Engineering degree program must complete to graduate and obtain a degree in Software Engineering. This course is offered once, each academic year, in the fall. Seniors typically take the operating system course and are generally more committed and motivated to complete and pass the course irrespective of the modality of the course.

In fall 2019, the operating system course size was capped at 32 students for the traditional face-to-face modality. While in fall 2020, the class size was capped at 42 students for the synchronous online modality. The next section describes the structure of the operating system.

IV. THE OPERATING SYSTEMS COURSE STRUCTURE

The operating systems course introduces components of operating systems including process management, memory management, CPU scheduling, threads, synchronization, and protection/security are explored. Contemporary design issues and current directions in the development of operating systems are discussed and case studies of several prominent operating system implementations are studied. The course objectives are:

- 1) Be able to use some basic Unix commands.
- 2) Understand the concepts of process and threads and be able to create them in C/C++.
- 3) Understand and be able to compare different CPU scheduling methods.
- 4) Understand and explain semaphores and monitors to avoid race conditions in programming.
- 5) Be able to explain deadlocks and their prevention.
- 6) Be able to explain the features of segmentation and paging memory management and storage management.

The prerequisites for the operating systems course are Data Structures and Computer Organization and Assembly Language Programming. Seniors take the operating systems course in the final year of the 4-year Software Engineering degree program.

Seniors are expected to have a good understanding of programming principles and data structures, in addition to an understanding of the organization and low-level computing hardware components, because these principles are fundamental to understanding operating systems principles.

Students are given a variety of activities, exercises, labs, quizzes, and exams in one semester. Exams and quizzes account for the majority of the overall course grade. In 2019 and 2020 the exams and quizzes accounted for 85% and 81% of the overall course grade respectively. The grading scale and is used for both years is shown in Table I.

TABLE I. THE COURSE GRADING SCALE

GRADE	PERCENTAGE
A	93 – 100
A-	91 – 92.9
B+	87 – 90.9
B	82 – 86.9
B-	80 – 81.9
C+	77 – 79.9
C	72 – 76.9
C-	69 – 71.9
D	60 – 68.9
F	0 – 59.9

The textbook used in this course is *Operating Systems Concepts*, the 9th Edition by Silberschatz, Galvin, and Gagne [18]. This textbook covers each topic in-depth and provides many conceptual and technical practice questions for students.

V. THE APPROACH USED TO TEACH OPERATING SYSTEMS COURSE IN 2019 AND 2020

Generally, seniors in their final year of the Software Engineering degree enroll to the take Operating Systems course each academic year. In fall 2019, the operating systems course was taught face-to-face in the traditional face-to-face modality. The lectures are 75 minutes and are given twice each week. Traditional class lectures are not recorded. All exams and quizzes are given during class time and are invigilated by the instructor. Each academic year, there are two sections of the course. In 2019, both course sections combined had 62 students in total. However, throughout the semester one student dropped out of the course, leaving 61 students. Office hours are given in person, allowing students to drop in at will to get assistance from the instructor.

While, in fall 2020, the operating systems course was taught in the synchronous online modality. Students met with the instructor online twice each week, in real-time, for 75 minutes' lectures using the Canvas Conference tool. All exams are given online, in real-time in Canvas, using

Respondus LockDown Browser and Respondus Monitor. Two sections of the course were available, which had had 81 students in total. In the fall 2020 semester, four(4) students dropped the course, leaving 77 students. Office hours were given online using Zoom [24]. However, students had to schedule a time to meet with the instructor for office hours to obtain tutoring instead of dropping in at will, which is more common with the face-to-face office hours.

A. Operating Systems Exam Format

The exam formats used in 2019 and 2020 are different. In the traditional class, students took two paper-based exams worth 70% of their overall grade. Additionally, students completed six quizzes worth another 15% of their overall course grade. More specifically, the six quizzes served as the third exam, which means that all exams and quizzes combined are worth 85% of the overall course grade in 2019. The two exams were hand-written. While the six quizzes were completed in the classroom using the Canvas learning management system (LMS) software. In 2019, all exams and quizzes were completed inside the classroom and invigilated by the instructor.

Students in the synchronous online class completed three exams which are worth 81% of their overall course grade. Students completed the three exams synchronously online, using the Canvas LMS, Lockdown Browser Respondus, and Respondus Monitor. These exams had a combination of multiple-choice questions, true/false, fill in the blanks, and questions where students had to show the details of working out a problem. The instructor moderated all online exams, using the moderating feature in the Canvas LMS, to ensure that any issues being experienced by students can be resolved promptly.

In 2019, students would receive their graded exams in hardcopy format, while in 2020 all graded exam comments were accessible online in the Canvas LMS. Irrespective of the teaching modality, all students in each course section are required to take exams and quizzes at the same time to reduce the likelihood of cheating.

B. Assignments, Activities, Exercises and the Unix Operating System

In 2019 and 2020, students accessed and submitted assigned work (assignment, exercises and, activities) via the same means. The instructor provided all feedback on assigned work using the Canvas LMS. Most of the students enrolled in the operating system course have Windows operating systems installed on their personal computers. As a result, the instructor collaborated with the Florida CyberHub to provide virtual machines with the Ubuntu operating system, and all the necessary tools required for students to complete their assigned work.

Students are given a unique account and access the Florida CyberHub system remotely from anywhere via the Internet. This allowed students to access a virtual machine with the Ubuntu operating system and to complete assigned labs related to threads, processes, and process synchronization. This worked out well in both the traditional face-to-face and synchronous online classes. In 2019, even though the class

was offered in the traditional modality, the CyberHub was used, because it provided convenience and the flexibility for students to continue their work from home without having to go to a lab at the university or to install a virtual machine. In previous years, students installed the virtual machine on their personal computers. However, some students have older computers with a variety of specifications, and some students experienced a lot of technical issues with the installation process. To avoid this problem one system was made available for all students. Additionally, the Florida CyberHub provides technical support to students and instructors, Mondays – Fridays from 8:00 AM to 5:00 PM.

VI. THE TRADITIONAL (2019) AND SYNCHRONOUS ONLINE (2020) EXAM RESULTS

Students enrolled in the operating system course completed three exams over one semester. The results of all exams were taken from the Canvas LMS which stores the grades for all students in fall 2019 and 2020. The students in 2019, took two exams, and six quizzes. Note that, the six quizzes were combined to form (create) the third exam. While students in fall 2020 took three exams. The results of the exams are given in Table II, which provides the averages of each exam and the corresponding standard deviations.

Fig. 1, 2, and 3 provide a comparison of the grade distribution for exams#1, exam#2, and exam#3 in 2019 and 2020 using the grading scale presented in section 4.

The results show that students in the traditional class performed better on exam#1 which covered course objectives 1-3. The students in both cohorts performed relatively the same on exam#2. Exam#2 covered course objectives 3-6. Students in the traditional class did not perform as well on exam#3 as the 2020 cohort. In the traditional class, exam#3 covered all the course objectives (1-6).

The 2020 cohort, performed poorly on exam#1 with an average of 63%, while the average on exam#1 was 82% in the traditional face-to-face class. The results show that the performance on subsequent exams and quizzes did not increase in the traditional class. It is noteworthy to mention that, all the exams in the synchronous online course covered fewer course objectives than the exams in the face-to-face class. This means that the exams in the traditional face-to-face class were more rigorous when compared to the synchronous online class.

TABLE II. RESULTS OF THE THREE EXAMS

	Exam#1	Exam#2	Exam#3
Year: 2019 Traditional Modality			
Number of Students	61	61	61
Average	82.04	75	72.01
Standard Deviation (SD)	9.66	10	7.50
Year: 2020 Synchronous Online Modality			
Number of Students	77	77	77
Average	63.12	72.07	88.60
Standard Deviation (SD)	14.64	15.55	9.99

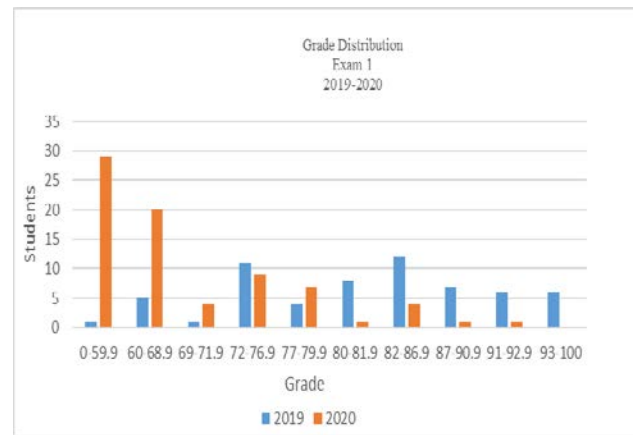


Fig. 1. Exam#1 Grade Distributing.

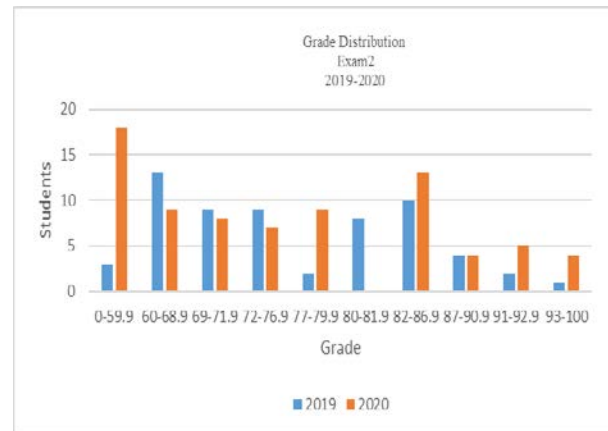


Fig. 2. Exam#2 Grade Distribution.



Fig. 3. Exam#3 Grade Distribution.

The student’s in the synchronous online class grades improved steadily after exam#1, obtaining average grades of 72% and 88% on exam#2 and exam#3 respectively. Exam#2 covered course objectives (2 and 3), and exam#3 covered course objectives (5 and 6). Since these exams covered fewer course objectives on each exam, this naturally reduces the complexity of these exams when compared to the exams taken by students in the traditional face-to-face class.

A. Primilinary Two-tailed Exam Results

A two-tailed t-test was performed to determine if there was a significant difference between the students' performance on

exam#1, exam#2, and exam#3 in the traditional face-to-face versus the synchronous online class. In this test, a p-value less than 0.05 is statistically significant ($p < 0.05$). The preliminary results are given in Table III. The two-tailed t-test p-values show a statistical significance in the students' performance on exam#1 and exam#3. While the p-value for exam#2, shows no statistical significance in the student's performance on exam#2.

The results for the synchronous online modality show an improvement in student's grades from exam#1 to exam#3 over one semester. Students became more motivated after performing poorly on exam#1 because they did not want to risk failing the course. Overall the synchronous online modality yielded better student performance on exams when compared to the traditional face-to-face modality. However, additional studies must be completed using both modalities, to better determine if the synchronous online modality will yield improved student performance when compared to the face-to-face modality when teaching operating systems. Further studies will help determine what other factors could have caused one group to do better on exam#2 and exam#3.

Perhaps student preparedness [2, 22], the number of course objectives covered on each exam, the complexity of the exam questions, when exams are given have a greater influence on students' performance on exams, than the course modality. In general, students do not perform well on quizzes when compared to exams. Students in 2019 completed six quizzes without the assistance of cheat-sheets, and this formed exam#3 for that cohort. While students in 2020 utilized cheat-sheets during exam#3. Furthermore, the weight of exams in 2020 was less, each accounting for 27% of the overall course grade. While in 2019, exam#1 and exam#2 each accounted for 35%, and exam#3 (comprised of 6 quizzes) accounted for 15% of the overall grade.

Additionally, student retention is another primary goal of most universities. However, this presents more of a challenge for students taking asynchronous online courses. Typically, when students get to the senior year in the Software Engineering degree program, they generally graduate and are less likely to abandon or stop their degree program at this late stage. Even if a senior fails a required course, they can take the course at another institution in the following spring or summer, which is in the same academic year, and transfer those credits to FGCU. As a result, failing a required course does not necessarily delay graduation significantly. Furthermore, the majority of the students who took operating systems in fall 2019 completed their required courses and graduated. While students in the 2020 cohort are on schedule to graduate in 2021. Note that the COVID-19 pandemic may impact the 2021 graduation for a variety of personal reasons. However, it is unlikely that the teaching modality will be the primary cause.

TABLE III. PRELIMINARY RESULTS OF THE TWO-TAILED T-TEST

$p < 0.05$	Exam#1	Exam#2	Exam#3
T-test (p-value)	9.70128E-15	0.204479332	7.96E-20

VII. CONCLUSION

Students who are enrolled in a degree program are more motivated to complete their course because it is a requirement for graduation. It is common, for most universities to offer a mix of traditional and online courses. However, courses taught using the synchronous online approach is quite similar to a traditional face-to-face course. In the former, students meet the instructor online, in real-time at a set time, while students in traditional courses meet their instructors in person in a classroom at a set time for lectures. The main difference between these two modalities is how examinations are administered to students in the synchronous online approach when compared to the traditional course approach. Students take their exams in the classroom with the instructor present, and the instructor serves as the invigilator, which has its limitations. While students in the synchronous online course, take their exam online using monitoring tools that proctor them during the entire examination. Based on the results of the students' performance on three exams, and the other factors that could have contributed to their performance on these exams, the t-test results show a notable steady improvement in students' performance on each successive exam in the synchronous online course, while the face-to-face does not. Additional studies must be undertaken to include additional cohorts, to gather more data which will provide better insights on the impact of teaching operating systems in the synchronous online versus the traditional approach.

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