Comparison of Engineering and Computer Science Student Performance and Opinions of Instruction of a Microcomputers Course Across Delivery Formats

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Introduction

The delivery format of college and university courses lies on a spectrum with live face-to-face at one end, asynchronous virtual delivery at the other, and all other hybrid formats between them. Each delivery format has different affordances, with asynchronous online lectures providing an opportunity for increased flexibility in accommodating students schedules and the ability to pause and rewatch lectures at their own pace. However, this format does not afford interactions between instructor and students in comparison to live, face-to-face lectures. This prevents adapting an asynchronous lesson to individual questions and student feedback in real-time. With a broad array of delivery formats available it is important to evaluate how student performance is impacted by the choice of format. This is especially important given the rapid shift in delivery format (typically from face-to-face to asynchronous) that universities and colleges around the world faced in response to the COVID-19 pandemic. Recent studies have reported the impacts of this transition at a Hispanic-serving institution [1], detailing lessons learned from teaching cybersecurity courses [2], detailing student experiences [3,4] and student adaptation [5] during this time, and comparing synchronous and asynchronous delivery of physics courses [6]. While this is not a comprehensive review of recent research on this topic, it does highlight the range of questions and topics being investigated.

Since 2017 an undergraduate course on microcomputers at the University of Alabama has been delivered in a traditional face-to-face format (3 sections), online asynchronous format (1 sections), and hybrid flipped-class format (3 sections) by the same instructor. For the asynchronous iterations the content was delivered using pre-recorded virtual lectures, online homework / projects / exams, and students were provided support through weekly virtual office hours. Participation with lectures was a mandatory course element with weekly deadlines for each set of lectures. For the flipped-style iteration, the course content was again delivered using the same pre-recorded virtual lectures (also as a mandatory course element with weekly deadlines), online homework / projects / exams, but students were able to attend optional face-to-face work periods with the course instructor during the regularly scheduled lecture times.

This work will provide a quantitative analysis and comparison of student course performance (e.g. final grade and final cumulative examination grade) across modalities. The aim is to evaluate the research question: **Was there a difference in undergraduate student performance in a junior-level microcomputers course based on the delivery format?**

Further, student opinions of course instruction, which captured student feedback using both Likert-scale questions and open-ended equations, will be analyzed to evaluate qualitative differences based on delivery format. These details are expected to help other engineering educators in evaluating how delivery format may impact their own courses as they are designing new courses or revising existing courses.

Summary of ECE 383

The electrical engineering course analyzed for this work was a 15-week course delivered at the University of Alabama; a large, southeastern public university in the United States. Undergraduate students in the department of electrical and computer engineering and the department of computer science at this institution are expected to complete these courses in their 3rd year of study. In terms of structure, the course had 12 weekly online assignments and 3 examinations. The course also had a laboratory component with students completing 8 laboratories during the semester.

This course was designed by the instructor for a face-to-face delivery with initial syllabi and student learning objectives provided by the department (the course was not a new course to the institution prior to delivery by this instructor). Details regarding the design and differences between styles of delivery as the courses evolved from face-to-face to asynchronous to flipped style are detailed below:

> *Face-to-Face Format:* For each course, 150 minutes of lectures were delivered each week. To support students during lectures, a digital course notes package was provided that included the majority of course theory and notes but had the detailed solutions to examples removed. The contents of these notes were presented by the instructor to the class during each lecture period. Students were encouraged to print and bring copies to class to collect the missing details and assist in completing examples during small-group work. The detailed notes and examples were developed to support students completing the weekly online assignments and preparation for examinations. Attendance was not required and not tracked by the instructor. Beyond lectures, students had access to instructor support with the course materials at 2 weekly, 1-hour, in-person office hours sessions. Students were also required to attend weekly 2-hour lab sessions coordinated by the course lab instructor (under the guidance of the overall course instructor). During this time, students had access to the lab instructor for support on completing the lab deliverables and were required to complete a demonstration of the lab prior to leaving.

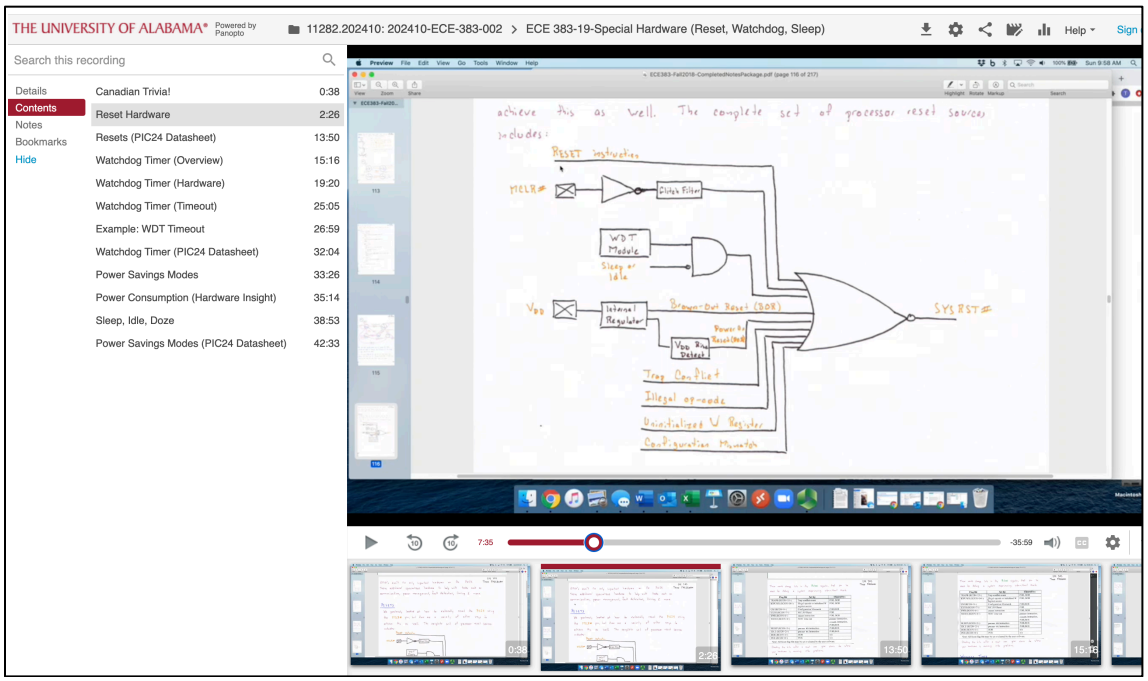

Figure 1: Sample virtual lecture in Panopto system for ECE 383.

Asynchronous Format: Approximately 150 minutes of weekly virtual lectures were recorded and delivered using the Panopto platform (https://www.panopto.com) that is integrated into the Blackboard Learning Management System (LMS) at the institution. Panopto is a video platform that supports recording, editing, and managing video content. Additionally, it provides tools for measuring student engagement (such as the number of times a video has been viewed, the minutes delivered during each viewing, and the date/time of the viewing). These recordings covered the exact material as the face-to-face iterations, with the course notes contents presented by the instructor. A sample of a course video is given in Figure 1 to illustrate the Panopto system. Each individual video was bookmarked with descriptive labels to support students searching for previous material or finding the lecture content that aligned with the notes package examples.

Viewing of lectures was a mandatory (and graded) component of the course, though students were given flexibility in terms of when they could watch lectures. At a minimum, students had to complete viewing each week's lectures (approximately 3 per week) by a fixed date/time each week. Lectures were considered "viewed" if 80% or more of the total minutes were watched by the student. These details were recorded automatically using the Panopto system.

This threshold below 100% was selected to accommodate technical issues (minutes not being captured due to an internet outage or missing minutes if students navigate to different parts of the video and miss a short segment). The percent watched of the weekly assigned videos was updated twice per week by the course instructor. The first update was done 1-day before the weekly deadline to provide students a snapshot of their current progress (and serve as a reminder to complete watching any unviewed lectures). The second update after the weekly deadline was the final value used to assess viewing/attendance for grading. Like the face-to-face iterations, students had access to

instructor support with the course materials at 2 weekly, 1-hour virtual office hours sessions (using the Zoom video conferencing platform).

Labs were revised to support remote and virtual participation. Instructions were revised to provide details regarding new materials/equipment for purchase to complete the labs without having to use the physical lab facilities on campus. Students were provided with access to the physical lab facilities and a supporting teaching assistant but with strict requirements on social distancing and reduced student numbers in the labs (resulting from the COVID-19 pandemic). In place of in-person demonstrations, students were required to record and upload a video demonstration to confirm completion of their laboratory activities.

Flipped Style Format: In the semester after asynchronous delivery the course transitioned to a flipped-style class model based on the courses at institution returning to on-campus, face-to-face delivery. In this style of offering, all course lectures were provided asynchronously using the previously recorded materials with scheduled lecture periods used as work periods to support students in completing the course assignments and/or labs. For the flipped style students were given the option to:

i) watch lecture content prior to scheduled course times and use in-class time to complete posted work-period questions (on topics related to the lecture) or assignments/labs with instructor support;
ii) attend the scheduled course times and watch the video lectures (with option to ask questions of the instructor); or
iii) watch the lecture content on their own time and attend lectures only when they had further questions.

While option **i)** meets the criterion of Bishop and Verleger to be classified as a flipped classroom (e.g. out-of-class activities must include required video lectures and in-class activities must be required and involve interactive learning activities) [7], options **ii)** and **iii)** are better considered as high-flexibility, traditional approaches. The intent of the three-option approach was to provide students the flexibility to engage with the course in their preferred style during a semester still impacted by the COVID-19 pandemic and has continued in all flipped format offerings of the course.

For this reason, we referred to this format as *flipped-style*. Beyond the class sessions, the students had access to instructor support with the course materials at 2 weekly, 1-hour virtual office hours sessions (again using Zoom similar to the asynchronous format).

Results and Analysis

From Spring 2018 to Spring 2023 a total of 798 students were enrolled in ECE 383 with the course instructor. Over 7 course iterations in this period, 199 students completed the course in face-to-face format, 81 in asynchronous format, and 218 in the flipped format. The specific details of each iteration and the number of enrolled students is given in Table 1.

Table 1. ECE 383 course details, summary student opinions of instruction, and summary of student performance for 7 iterations of the course offered by the same instructor from Spring 2018 to Spring 2023.

	Spring 2018	Fall 2018	Fall 2019	Fall 2020	Fall 2021	Fall 2022	Spring 2023
Course Details							
Format	F2F	F2F	F2F	Asynch.	Flipped	Flipped	Flipped
Students (#)	60	60	79	81	75	58	85
Summary of Student Performance							
Average Course Grade (%)	86.47 +/- 8.91	84.33 +/- 10.81	83.67 +/- 11.16	79.96 +/- 16.56	79.33 +/- 18.88	82.46 +/- 15.45	81.40 +/- 14.68
Average Final Exam Grade (%)	76.33 +/- 20.05	77.65 +/- 15.82	79.91 +/- 18.39	67.63 +/- 27.20	77.04 +/- 18.23	69.76 +/- 22.98	76.82 +/- 19.97
Summary of Student Opinions of Instruction							
SOI Responses (#)	55 (92%)	60 (100%)	78 (99%)	75 (93%)	63 (84%)	54 (93%)	81 (95%)
Course Rating	4.62 +/- 0.73	4.43 +/- 0.72	4.40 +/- 0.73	4.19 +/- 1.00	4.25 +/- 0.72	4.20 +/- 0.90	4.11 +/- 0.97
Instructor Rating	4.89 +/- 0.37	4.88 +/- 0.37	4.81 +/- 0.43	4.63 +/- 0.80	4.67 +/- 0.65	4.72 +/- 0.60	4.58 +/- 0.76
Communicator	4.85 +/- 0.52	4.95 +/- 0.22	4.88 +/- 0.32	4.73 +/- 0.68	4.78 +/- 0.63	4.83 +/- 0.42	4.69 +/- 0.65
Accessible	4.85 +/- 0.48	4.82 +/- 0.43	4.73 +/- 0.50	4.63 +/- 0.75	4.71 +/- 0.63	4.76 +/- 0.64	4.78 +/- 0.45

To summarize the overall student performance of each iteration, the average final course grade based on assignments, laboratories, examinations, and attendance (for asynchronous/flipped modalities only) are also given in Table 1 for each iteration. Average final grades range from 79.33% to 86.47% which reflects that overall the groups are demonstrating good to very good mastery of the course material. The average final examination grade, which is the final individual assessment of course material, ranges from 67.63% to 79.91% over this same period demonstrating satisfactory (with some weaknesses) to satisfactory performance.

To determine if there were differences in student course performance between iterations from 2018 to 2023 a one-way ANOVA was conducted using the average course grades in Table 1. This analysis reported that the final course grade between semesters was not statistically significantly different; $F(6, 491) = 2.115$, $p = 0.0506$. Interpreted another way, there were no statistically significant differences in the average course grade between course modalities (face-to-face, asynchronous, flipped).

To determine if there were differences in student performance on the final examination (the last individual assessment of student mastery of course content) in ECE 383 between iterations, another one-way ANOVA was conducted using the average final exam grades in Table 1. This analysis reported that final exam grade between semesters WAS statistically significantly different; $F(6, 491) = 3.4761$, $p = 0.0022$. Tukey HSD post-hoc testing was applied to identify individual group differences. The only statistically significant difference identified was between the average final exam grades in Fall 2019 (79.91%) and Fall 2020 (67.73%), with $p = 0.039$. This suggests that the students in the asynchronous iteration of ECE 383 in Fall 2020 had poorer performance demonstrating their mastery of course material then the last face-to-face iteration in Spring 2019 (which had the highest exam score of all 7 course iterations). This will be explored further in the following discussion section.

To compare student opinions of their experiences in the courses across delivery formats, the ratings from the end-of-semester students' opinions of instructor (SOI) survey are provided in Table 1. These surveys are administered electronically by the university administration for approximately 2 weeks prior to the last day of classes each semester. They contain a mix of Likert-scale questions and open-ended questions for students to complete.

The specific subset of questions / comments (and the selectable options) compared in this work are:

- **How would you rate this course?**
  (5 - Excellent, 4 - Above Average, 3 - Average, 2 - Below Average, 1, Failure)
- **How would you rate the instructor of this course?**
  (5 - Excellent, 4 - Above Average, 3 - Average, 2 - Below Average, 1, Failure)
- **The instructor was an effective communicator.**
  (5 - Strongly Agree, 4 - Agree, 3 - Undecided, 2 - Disagree, 1 - Strongly Disagree)
- **The instructor was accessible to students.**
  (5 - Strongly Agree, 4 - Agree, 3 - Undecided, 2 - Disagree, 1 - Strongly Disagree)

Overall, the average scores for each are in the range from 4-5 which suggests that each group of students rate the course as excellent/above average, rate the instructor as excellent/above average and strongly agree/agree that the course instructor was both an effective communicator and accessible to students in all course iterations.

In addition to these ratings a selection of student comments received on the SOIs to the prompt, **Any additional comments about the instructor or about the course,** are provided in Table 2 to give further insight and context to the numerical ratings. The selection of comments aimed to capture (as possible) positive and negative views expressed by the students (and are explored in further detail in the following section).

Table 2. Samples of student responses to open-ended prompts for comments about the instructor or course for ECE 383.

Face-to-Face Format
• The large note packet is not my favorite because I don't learn like that but necessary to reference for the materials. • Perhaps make the notes where you have to write in more. I felt I would stop listening sometimes if I didn't have to write. • The instructor did a good job of compiling notes on the course, offering them as a PDF to students. Parts of the notes would be left incomplete to then fill in during class. While this is a good motivator to attend class, I wish there were completed notes available, even if made available after the exam in order to review and prepare for the final. • My only suggestion would be to utilize panopto more heavily. Even though the course notes are given to us, there are a lot of words said between lines in the notes that I don't think are significant during class but when I went to study or work on homework I needed. • My only critique is that I wish there was a way to access his notes and/or lectures online. I tried to go to class as much as possible but was ill for almost 5 weeks during the middle of the semester. I got notes from friends as much as possible, but sometimes I had to resort to trying to catch up with the material on my own using the textbook. I understand that he gives the bulk of notes in class to encourage attendance, and this is probably the best process, but it still is very difficult to catch up if you miss class.

Asynchronous Format
• Expectations and materials are always posted in a timely manner, and he his always accessible in office hours and via email. The online lectures were extremely beneficial and the best online learning experience out of any class that had to be moved online. • I like the prerecorded videos for class because I can watch them on my own time and at my own speed. They do a very good job of covering the course material, to the point that I rarely had to find other supplemental sources (besides the datasheets). The notes also did a great job of covering the material. • The recorded videos allowed me to go back as much as needed, and I appreciated having the chance to redo homework assignments up to 5 times to see where I went wrong. Since it told you a question was wrong but did not give an answer, I was able to work on what I messing up on and learn from it.
Flipped Format
• The structure of the class, while different from most others I've had, was very good • Interesting way of teaching the class, but it works. • This is definitely a different format of class than I'm used to, but I think that the format works better than most of the other classes that I have. • Not big on the flipped classroom format, but the actual course content was great. • [Instructor] is a guy with a nice personality that's always willing to help. With that being said, I wished he actually taught the class rather than just give us "work periods". • I would prefer if the course required mandatory attendance through live classes. • I don't think the lectures outside of class worked very well for me, and it's just because of me and not the system. I get distracted easily, especially when I am at my computer, so having to sit and watch upwards of 3 hours of lecture on my own time usually did not end very well or took much longer than the video itself with taking notes. I understand why it was done as this course covers a lot of information but I personally am not a fan of watching lectures outside of class. • The course layout was unlike anything I have taken before, and that took a while to get used to. That said, I found the adaptability and flexibility of [Instructor's] instruction methods a godsend when schedules inevitably became tight Firstly, I really liked how the class was set up. It allowed students who had a better background in the course content to minimize wasted time but also allowed students who were new to the course's content to have more time to get help from the professor. • [Instructor] prerecording all lectures made me enjoy the class and learn much more. It allows for flexibility which I think is great. • I really liked his system of the pre-recorded lectures and then when you came to class having a few problems to work on and just giving students the space to ask questions or do work. [Instructor's] prerecorded lectures were also great, especially paired with the notes he gives you on blackboard makes it really easy to follow along and I especially liked how he built in spaces for us to do examples in our notes into the lectures. • The flexibility of the class made it easy to keep up with the material even during days and weeks where life gets in the way. That aspect of the class was greatly appreciated, although I will admit at times it made it easy to put this class on the backburner and lose motivation when other coursework got hectic. • The format of the class I struggled with wanting to attend the class and interact with the professor. Even when I did go I spent a lot of time waiting to get help with the question I had. It seemed like a waste of time to go to class when I would go to ask one question and have to wait 30 minutes to be able to ask it. I would much prefer if he did live lectures the way a normal class is and we are able to ask questions as we go and stop him whenever the class is confused. • The format of this course was different from my other courses, but I would say I preferred this structure. By having lectures posted online, I was able to go at my own pace and use class time to ask questions about anything that was confusing me. • The flipped classroom is an interesting way to do things. I can personally say that I like this method of teaching less, but I do see the advantage to doing the classroom in this fashion. I enjoyed having all materials I need readily available online.

Discussion

Overall, the comparison of ECE 383 student performance between face-to-face, asynchronous, and flipped-style modalities suggests there was not a difference in student mastery of the course content between modalities offered by this instructor. This was unexpected, with the flipped-style class expected to increase student performance due to the increase in active-learning opportunities provided by the work periods and increase in direct contact with the instructor tailored to individual student challenges in the course.

Reflecting on the flipped-style used in this course, this is likely a result of the work-periods being an optional element (without a graded requirement to attend and complete the in-class activities). If few students attended and used the work periods to complete the additional activities and instead focused on assignments and labs, then engagement with course material will be nearly the same in this flipped-style as those students in the face-to-face and asynchronous formats. Prust et. al previously reported similar grades between flipped and standard delivery courses when student engagement outside the classroom did not materialize to a necessary degree [8], which aligns with the similar grades reported here for the students in ECE 383 across the 3 delivery styles. Further insight into why there were no differences is also offered by Strelan et. al in their meta-analysis of the effects of the flipped classroom on student performance across disciplines and education levels [9]. Overall, they reported the flipped classroom had a moderate positive effect on student performance (relative to traditional learning approaches), but minimally flipped classes (like this study) had lower effects. The positive effects are attributed to students having an opportunity to engage in active learning and problem solving with guidance from an expert. While that element was present in the flipped-style courses, it required students to opt-in and participate since it was not a course requirement (which is expected to have moderated the potential positive effects).

While attendance and participation in work periods was not directly measured, students were asked at the end of the semester (on an anonymous class-survey, separate from the SOI feedback) to reflect on how often the used the work periods. The results from this survey for the 3 iterations of the flipped-style class are given in Table 3. Overall, only approximately one-third of students in each iteration reported attending 20 or more workperiods (representing 50% of the nearly 40 through the semester). Two-thirds of students attended less than 50% of work periods and 6%-10% reported not using them at all. This level of participation is likely to account for why there were no differences between course performance in the face-to-face and flipped-style formats.

Table 3. Student responses to anonymous class survey prompt: "How often did you use the work periods with [Instructor] this semester?"

	Fall 2021 (n = 64)	Fall 2022 (n = 51)	Spring 2023 (n = 81)
0	6.25%	9.8%	8.6%
1-5	17.2%	17.6%	30.9%
6-10	21.9%	9.8%	18.5%
11-20	21.9%	29.4%	8.6%
20+	32.8%	33.3%	32.1%
Unanswered	0%	0%	1.2%

Given the option, the majority of students selected to use the high-flexibility elements but did not engage in the additional work-period activities. For insight into the students perspectives on the work-periods and potential reasons for the low participation, a sample of student responses to the prompt:

- Considering your experiences with the work periods this semester was the high-level of flexibility a strength or weakness in this course for you? Compared to your other courses this semester, did you like this delivery format better or worse?

are provided in Table 4. These responses capture experiences ranging from students who strongly preferred this approach to those who strongly disliked it. A strong theme that emerged from these comments include students' appreciation for the flexibility afforded by the flipped-style class to engage with lecture material at their own pace, schedule, and manage commitments they have in their lives. An interesting self-reflection from multiple students notes the high-level of executive function (e.g. planning, focusing attention, remembering, and balancing multiple tasks) and self-regulation (e.g. resisting impulses) required to be successful in this class format. The feedback of students who did not enjoy the flipped-style format suggest that this may also be the source of their dislike.

Table 4. Samples of student responses to anonymous class survey prompt: "Considering your experiences with the work periods this semester was the high-level of flexibility a strength or weakness in this course for you? Compared to your other courses this semester, did you like this delivery format better or worse?"

- As foolish and entitled as this sounds, I think that I need classes to force me to do something that I don't want to do and wouldn't do otherwise in order for me to get the most out of a class. At the same time, I recognize that it isn't your responsibility to make up for your students' lack of self-discipline and commitment, and the high level of flexibility was probably very beneficial for other students.
- The flexibility was very nice to have when I had busy weeks, except I started to fall behind when I stopped coming to the work sessions and not keeping up with the videos. I liked the delivery format better, especially since I was able to watch the videos at my own pace and reference them when I was doing homework/studying. I attended work periods regularly for the first half of the semester, and I thought the work-periods with exercises that had a mix of conceptual and application/math/code problems were the most beneficial. I think if you spent a portion of the work-period working out the problems and going through your thought process for each exercise, that would have encouraged me to attend. I stopped going to the work-periods because I reasoned I could always work the problems out on my own without going, the problems were posted on Blackboard. However, this led to me falling behind in the course.
- I think the flexibility was a bit of both. I loved being able to do it on my own time because a lot of times I'm busy and being able to skip class some days is very useful. but near the end of the semester I found myself slacking a bit. Overall I think this format worked in my favor. I really enjoy the ability to pause lectures and rewatch parts of lectures because in class I always feel like professors move too fast without room for questions and if I zone out for a second, I miss a lot of material and then fall behind. The recorded lectures allow me to learn at a pace suitable for me. I didn't attend too many lectures but I think if practice problems were demonstrated/went over in class I may have come more often.
- I really enjoyed the format of this class; It was a good balance of work at your own pace and guided lectures. It was better than other classes I had this year, and I had fun while I did it. Pretty much everything with the work periods worked smoothly. I wouldn't change anything.
- I felt the flexibility of the class worked really well for me. I have a high enough level of self control to force myself to watch the lectures before each work period, and then attend each work period throughout the semester. This essentially gave me double the practice on the material compared to a regular format class. For other classes where practice problems would have been posted to do on our own time, I probably wouldn't have done them, but having them assigned during a class period made it easier for me to have the motivation to do them. The only thing I wish was different, which was addressed during the semester, was

answers to the practice problems during the work periods. I like to check my answers and sometimes there wasn't a solution posted.

- I will say that this flexibility was a weakness for me at first, but learning how to stay regular in this course helped me grow-up a little more and have more mature and regular study habits. As different as this format was from literally all of my other classes, it fit very well how I could schedule my time. Overall, it was a huge adjustment, but it's an adjustment I am glad I was able to make. As far as work periods, I enjoyed coming to them. It was a place I could not only work with [Instructor], but also with peers, because sometimes all you need is an extra pair of eyes.
- The flexibility has been great, as the pre-recorded lectures essentially allowed for 5 office hours periods per week. Sometimes I have been ahead on lectures, and other times behind. My favorite feature is being able to rewind and pause videos if I ran out of time to write something before you went to next section or when I need to look at a topic again.
- I personally loved it. Gave me flexibility to dodge class on rough days without feeling guilt. It also gave me a convenient time to sit and help folks who approached me looking for assistance with labs or homework. I could also work ahead in the course, so that I could spend the easier weeks keeping up with classes that were killer, such as ECE225.
- The flexibility was a weakness, most weeks (80%) I would put the videos on just so I would get credit then watch them if I needed to for the homework. I would only fill out the note packet as a form of studying for the test as they are open notes. I do enjoy having all the material online though, hearing it explained made studying for this class much easier than other classes as I could be sure that I was getting all the information. I'll be honest, the work periods were not at a good time, as they were 3 hours after my other classes on MWF, so only if I really needed help would I attend. I am not sure what would make me attend as all the information I needed was provided online.

Reports by Buhl-Wiggers et al. of student resistance to flipped class in their randomized controlled trial with first-year undergraduates in a macroeconomics course [10] noted similar themes from students who expressed negative feelings about the flipped class format. Buhl-Wiggers et. al noted students struggled with their new roles in the course and were hesitant to collaborate which often led to non-attendance (which had an impact on their performance). Students in ECE 383 who reported they liked instructor-led formats and desired instructors "to actually teach" are likely to have not attended work periods and benefited from the use of small-group work and access to the instructor for questions.

Returning to student performance on the final exams, the only statistically significant difference in exam scores was between Fall 2019 (79.91%) and Fall 2020 (67.73%), even though overall course grade for these semesters was not statistically significantly different. This suggests that students performed well on the other course elements (assignments, labs) but not on the final examination. One important difference between the asynchronous offering in Fall 2020 and all other iterations is that it was delivered as a timed, online examination using the Blackboard LMS. Online proctoring tools, such as LockDown Browser, were not used to limit feelings of surveillance and invasion during the exam. Instead, the exam questions were given one at a time in randomized order with no back-tracking allowed. That is, after submitting an answer a student could not return to the question to change it. The intent of this process was to prevent sharing all exam questions with external parties and waiting to receive a solution to upload during the exam period. To help students manage their time for each question they were given the total number of exam questions, the weighting per question, and the estimated time they should allocate to each question in the week prior to the exam (and in the exam instructions). As an example, for a question worth 20% of the total final exam grade they were recommended to spend no more than 24 minutes (20% of 2 hours) on the question. This approach to taking an examination prevents students from using test taking strategies such as reviewing all questions

and prioritizing answering them based on their level of confidence. It is expected that this was a significant source of the differences in final exam performance for this semester.

While SOI ratings were high for course rating, instructor rating, communication, and availability, there appears to be a decrease in average scores for course rating (F2F: 4.4-4.62, Flipped: 4.11-4.25) and instructor rating (F2F: 4.81-4.89, Flipped: 4.58-4.72) comparing the face-to-face and flipped-style iterations. This is expected to be another reflection of students resistance to the course changes in the transition away from the instructor-led format, with students perceiving the course as less valuable when they are in a new situation that does not meet their expectations of a learning environment. However, this requires further research to evaluate as the source of these decreases.

Summary

There was not a statistically significant difference in overall student performance (e.g. final course grade) between the ECE 383 iterations in face-to-face, asynchronous, or flipped-style delivery formats. All groups demonstrated good to very good mastery of the course material. The lack of differences between formats is attributed to student's self-selection of the high-flexibility option available with this specific implementation of the flipped-style format; with few students completing the active-learning elements of the work-periods. As a result, students in the flipped-style course are likely to have had the same level of engagement with course material as both the face-to-face and asynchronous modalities.

If the aim of transitioning to a flipped-style course is to increase student performance, it is recommended that in-class activities be a mandatory and graded component of the course. It is important to note that even though student performance did not change, the flipped-style did provide a high-level of flexibility for students which appeared to be greatly appreciated by students based on their SOI feedback and comments regarding the course. For instructors looking to increase the level of flexibility in their courses to support students and their significant levels of commitments, the flipped-style may be an appropriate choice (with no decreases in overall performance observed as a result of this increased flexibility).

References

[1] Shapiro, M., Solano, D.M., Bergkamp, J.J, Gebauer, A., Gillian, E., Lopez, K.M., Santoke, H., Talbert, L.E., "Impacts of converting courses to virtual instruction midsemester at a Hispanic-serving institute," J. Chem. Educ., vol. 97, pp. 2526-2533, 2020.

[2] Bai, Y., Gao, C., Goda, B., "Lessons learned from teaching cybersecurity courses during COVID-19," Proc. Ann. Conf. Information Technology Education, 6 pages, 2020. doi: 10.1145/3368308.3415394

[3] Chhetri, C., " "I lost track of things": Student experiences of remote learning in the COVID-19 pandemic," Proc. Ann. Conf. Information Technology Education, 6 pages, 2020. doi: 10.1145/3368308.3415413

[4] Vielma, K., Brey, E.M., "Using evaluative data to assess virtual learning experiences for

students during COVID-19," Biomedical Eng. Educ., 2020. doi: 10.1007/s43683-020-00027-8

[5] Gelles, L.A., Lord, S.M. Hoople, G.D., Chen, D.A., Alejandro Mejia, J., "Compassionate flexibility and self-discipline: Student adaptation to emergency remote teaching in an integrated engineering energy course during COVID-19," Educ. Sci., vol. 10, no. 11, pp. 304, 2020. doi: 10.3390/educsci10110304

[6] Ramo, N.L., Lin, M., Hald, E.S., Huang-Saad, A., "Synchronous vs. asynchronous vs. blended remote delivery of introduction to biomechanics course," Biomedical Eng. Educ., 2020. doi: 10.1007/s43683-020-00009-w

[7] J.L. Bishop, M.A. Verleger, "The flipped classroom: a survey of the research," ASEE Annual Conf. & Expo, Atlanta, GA, 2013. doi: 10.18260/1-2--22585

[8] C.J. Prust, R.W. Kelnhofer, O.G. Petersen, "The flipped classroom: it's (still) all about engagement," ASEE Annual Conf. & Expo, Seattle, WA, 2015. doi: 10.18260/p.24872

[9] P. Strelan, A. Osborn, E. Palmer, "The flipped classroom: a meta-analysis of effects on student performance across disciplines and education levels," Educational Research Review, vol. 30, 100314, 2020. doi: 10.1016/j.edurev.2020.100314

[10] J. Buhl-Wiggers, L. la Cour, A.L. Kjaergaard, "Insights from a randomized controlled trial of flipped classroom on academic achievement: the challenge of student resistance," International Journal of Educational Technology in Higher Education, vol. 20, no. 41, 2024. doi: 10.1186/s41239-023-00413-6