On Moving a Face-to-Face Flipped Classroom to a Remote Setting.

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Introduction

Driven by the high-profile meta-analysis (Freeman et al., 2014) of 158 undergraduate STEM courses conducted by Freeman et al., active learning is becoming a standard in higher education pedagogy. One way to provide active learning is the flipped classroom — "Flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (Talbert, 2017, Flip Learning, 2019).

The above definition of flipped learning has been quoted mainly to clear up any misconceptions about the modality of flipped learning. At the same webpage (Flip Learning, 2019), the four pillars (Figures 1-4) of flipped learning are enumerated – flexible environment, learning culture, intentional content, and professional educator. If interested in the flipped classroom, the framework is given so that the reader would keep these pillars central to the course. But they are also cautioned not to be extreme in the adoption of these tenets. For example, with the author having taught the Numerical Methods course at least 50 times now, he recognizes that some topics have to be introduced to the student as a minilecture; too many of them would be abnormally frustrated otherwise. There are several other myths surrounding the flipped classroom, and the purists have even propagated some. One common myth is that students do all their homework in class, and they are constantly given feedback on their mistakes or as soon as they get stuck. That is far from reality as it is impossible to do so in large enrolment classes, and even if it were a smaller enrollment class, it is not recommended. One could use the think-pair strategy (Lyman, 1987), where before pairing students, they work out the in-class problems individually. Students also need to do post-class work, including problem sets and projects that reinforce higher-order thinking skills, take time, and force learning from failures. Another common myth is that the teacher does not play a central role. The keyword is "central" - the teachers play a prominent role but mainly in the background. On behalf of an instructor, it takes more organization, effort, and resources in a flipped classroom than in a traditional lecture-based classroom. Lastly, the popular myth is that students learn by themselves. In a well-designed flipped classroom, the pre-class work only includes learning the basics of a topic and getting refamiliarized with the prerequisite course materials. In a proper flipped classroom, the objectives, assignments, and tasks are expected to be clearly delineated for pre-class, in-class, and post-class learning.

Meta-Studies on Effectiveness of Flipped Classrooms

Research on the flipped classroom has been increasing exponentially (Talbert, 2018). A 2019 meta-analysis (Lag and Saele, 2019) based on papers in eight electronic reference databases found an average effect size of $d=0.24$ ($n=272$) for cognitive learning in favor of flipped classes over traditional ones. The average effect size on student satisfaction was smaller at $d=0.16$ ($n=69$). A 2018 meta-analysis (Hew and Lo, 2018) of health profession education courses found a similar average effect size of $d=0.33$ ($n=28$). A 2015 literature review paper (O'Flaherty and

Phillips, 2015) points out that a "flipped classroom seems to provide a viable route that is likely to affect student learning positively."

F Flexible Environment

Flipped Learning allows for a variety of learning modes; educators often physically rearrange their learning spaces to accommodate a lesson or unit, to support either group work or independent study. They create flexible spaces in which students choose when and where they learn. Furthermore, educators who flip their classes are flexible in their expectations of student timelines for learning and in their assessments of student learning.

F.1	☐ I establish spaces and time frames that permit students to interact and reflect on their learning as needed.
F.2	☐ I continually observe and monitor students to make adjustments as appropriate.
F.3	☐ I provide students with different ways to learn content and demonstrate mastery.

Figure 1. Pillars of Flipped Learning - Flexible Environment (Attribution: Available at https://flippedlearning.org/definition-of-flipped-learning/ under Full Terms at Creative Commons license CC BY-NC-ND 4.0 https://creativecommons.org/licenses/by-nc-nd/4.0/)

L Learning Culture

In the traditional teacher-centered model, the teacher is the primary source of information. By contrast, the Flipped Learning model deliberately shifts instruction to a learner-centered approach, where in-class time is dedicated to exploring topics in greater depth and creating rich learning opportunities. As a result, students are actively involved in knowledge construction as they participate in and evaluate their learning in a manner that is personally meaningful.

L.1	☐ I give students opportunities to engage in meaningful activities without the teacher being central.
L.2	☐ I scaffold these activities and make them accessible to all students through differentiation and feedback.

Figure 2. Pillars of Flipped Learning – Learning Culture (Attribution: Available at https://flippedlearning.org/definition-of-flipped-learning/ under Full Terms at Creative Commons license CC BY-NC-ND 4.0 https://creativecommons.org/licenses/by-nc-nd/4.0/)

I Intentional Content

Flipped Learning Educators continually think about how they can use the Flipped Learning model to help students develop conceptual understanding, as well as procedural fluency. They determine what they need to teach and what materials students should explore on their own. Educators use Intentional Content to maximize classroom time in order to adopt methods of student-centered, active learning strategies, depending on grade level and subject matter.

I.1	☐ I prioritize concepts used in direct instruction for learners to access on their own.
I.2	☐ I create and/or curate relevant content (typically videos) for my students.
I.3	☐ I differentiate to make content accessible and relevant to all students.

Figure 3. Pillars of Flipped Learning – Intentional Content (Attribution: Available at https://flippedlearning.org/definition-of-flipped-learning/ under Full Terms at Creative Commons license CC BY-NC-ND 4.0 https://creativecommons.org/licenses/by-nc-nd/4.0/)

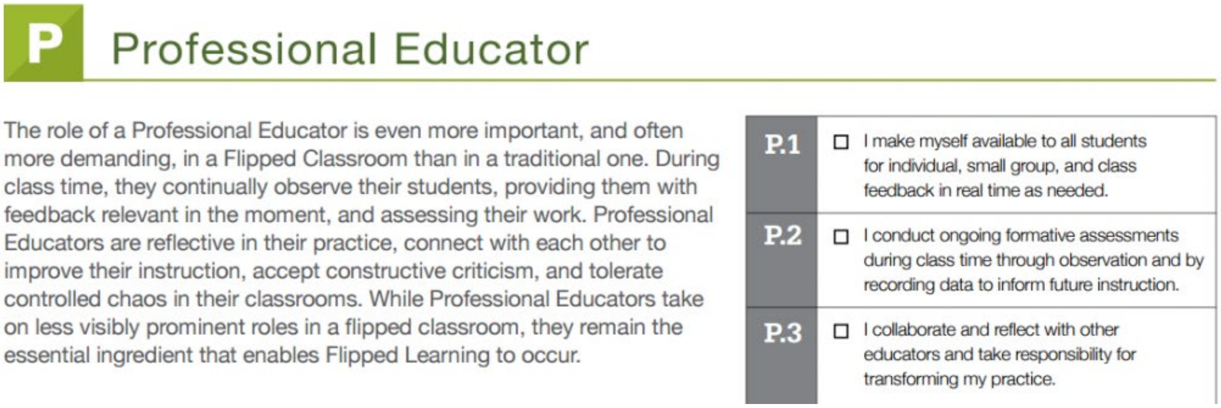


Figure 4. Pillars of Flipped Learning – Professional Educator (Attribution: Available at https://flippedlearning.org/definition-of-flipped-learning/ under Full Terms at Creative Commons license CC BY-NC-ND 4.0 https://creativecommons.org/licenses/by-nc-nd/4.0/)

In March 2020, the COVID19 pandemic instantly affected 14 million higher-education students in the USA. The switch to remote instruction caught instructors and students off-guard – teachers had to change their techniques, approaches, and course content rapidly (called "panicgogy" (Kamenetz, 2020)), and students had to adjust to remote instruction in a hurry. Hoping that the pandemic would not last too long, most had expected to return to the regular face-to-face class format at most by the Fall 2020 semester. That expectation was quickly shattered as the summer semester of 2020 progressed, and the pandemic did not recede.

If one were teaching a face-to-face classroom in a flipped modality, it would be even more challenging to teach a flipped class now in an online environment. In this paper, we discuss how a flipped classroom that was taught in a face-to-face modality was made viable in an online environment in Fall 2020 for the whole semester. We will first discuss how the flipped classroom was taught in a face-to-face mode (Fall 2014/Fall 2015) before the pandemic and how it was taught fully online (Fall 2020) during the pandemic.

About the Course

The course discussed in this paper is a core course taught at a junior-level in the Mechanical Engineering department at the University of South Florida. About 100 students enroll in the class every semester. The main topics of the course are to develop and use numerical methods for the following mathematical processes – Differentiation, Nonlinear Equations, Simultaneous Linear Equations, Interpolation, Regression, Integration, and Ordinary Differential Equations. Throughout the course, emphasis is also placed on calculating errors, their relationship to the accuracy of the numerical solutions, writing computer programs to reinforce the fundamentals of the course, and solve open-ended real-life problems. The course grade is calculated using pre-class and post-class assignments, several unit tests, programming projects, a concept inventory test, and a final examination.

Face-To-Face Flipped Classroom (Fall 2014/Fall2015)

The F2F flipped classroom has activities outside of the classroom, both for pre- and post-class, and inside the classroom. The cohort for this modality is from several years ago as since then, the course has been assessed and taught using other variations of active-learning based modalities such as semi-flipped (Clark, Kaw, and Besterfield-Sacre, 2016), flipped with pre-class learning via adaptive lessons (Clark and Kaw, 2019), blended (Clark et al., 2018), and hybrid.

Pre-Class Learning

The students were assigned modules for the upcoming week. The modules covered content from two to three chapters out of a total of 30 for the course. For each chapter, short YouTube video lectures made by the author were assigned to be watched by students. Pages from the textbook were also given as an alternative or additional way to learn the content. To ensure students' preparation for in-class activities, the students took online quizzes through the learning management system (LMS). These quizzes had about three questions per quiz, and most of them were algorithmic. The students also responded to an open-ended question about the most difficult or interesting topic in a chapter. The performance in the quizzes and the answers to the open-ended question informed the in-class activities of the instructor.

In-class activities

The in-class activities in the F2F flipped classroom generally had three components.

1) First, conceptual questions were asked using a hand-held personal response system (Turning Technologies, 2020). Most of the questions were carefully chosen to go beyond recall and definitions. An example of a conceptual question from the topic of *Prerequisites to Interpolation* is shown in Figure 5.

If a polynomial of degree n has more than n zeros, then the polynomial is A. oscillatory B. zero everywhere C. quadratic D. not defined
Figure 5. A typical conceptual question asked via a personal response system

2) The second component is where the students solve free-response questions in a think-pair format (Lyman, 1987). For this activity to work, groups of two students each were made in the beginning of the semester. The groups of two remained the same throughout the semester. The prescribed questions were first solved by individual students. This followed by them being asked to pair up with their group member. To avoid a student being without a partner on a particular day because of their absence, two groups worked together as a single group of up to four. During the group activity, the instructor and two TAs roamed around the class to gauge the progress of the students and answered any questions the students would have. To avoid having a student keep their hand raised if they have a question, a card (red on one side and green on the other) was given to each group of two. The default was the green side, where they were not seeking help, and they would turn it over to the red side when they needed help. This served two additional purposes – one was that they could continue to work on a different problem while waiting for help, and second, was that it also alleviated the anxiety of introverted groups.

Several times during the semester, the free-response questions were replaced by short in-class projects which they would start using MATLAB programming and outlined for a post-class activity. Examples of such problems include

a) computing the length of a curve drawn using a sewing-ruler-flexible curve on an engineering graph paper,

b) finding the volume occupied by a complex-shaped three-dimensional object such as a champagne glass via only measurements made using a scale and a caliper.

3) The third component of the in-class session was minilectures. Over 33 years of teaching the course, the instructor has developed a keen sense of the topics students get frustrated by and need an initial understanding of. Examples include floating-point representation with biased exponents, nonlinear regression models without transformed data, state representation of coupled and higher-order ordinary differential equations. These topics were discussed through short lectures. Other minilectures were based on topics that got identified through the assessment results of the pre-class activities of the online quizzes and the answers to the discussion question about the most challenging concept in a chapter.

<u>Post-Class Learning</u>

As much as the flipped classroom may be considered to be done with once the in-class activities are over, it is far from it. Post-class learning is critical to involve higher-order thinking, and we do this in the form of programming projects, short projects that may or may not involve programming, and student preparation through solving the end-of-chapter problem sets.

Online Flipped Classroom (Fall 2020)

In March 2020, when all classes were taken remotely, the spring 2020 offering initially was of a face-to-face blended format. For a blended modality, the in-class activities were similar to a flipped classroom except that students were not required to do pre-class learning other than for the prerequisite course content. The in-class activities had more lecture content, and accordingly, lesser time was spent on active learning exercises. Moving quickly to the online format was not an issue other than figuring out technology for synchronous sessions. The active learning exercises were limited to doing clicker and free-response questions as individual students.

The course was taught next in a 10-week Summer 2020 semester by the author. In this semester, the course was moved to an online hybrid format where students were assigned to do all the pre- and post-class activities for the week on their own through the recorded YouTube lectures. Once a week, at the end of the week, the author held a 110-minute session of minilectures of difficult topics and answered questions from the students. Clicker and free-response questions were also included.

Based on the lessons learned from the sudden-remote modality of Spring 2020 and the trial of using a hybrid modality in Summer 2020, a more straightforward path got revealed to the author on how to teach the online version of a flipped classroom in Fall 2020. It was decided that the F2F procedure would be duplicated in the online version as much as possible. The pre- and post-class activities would stay the same as the F2F flipped modality. It was the in-class activities of the online flipped classroom that needed to be carefully curated to make the outcomes of the experience, if not the experience itself, to be as close as to the F2F format.

Pre-Class Learning

These activities were similar to the F2F flipped online class.

In-class Activities

The online classes were held synchronously during class meeting time and were held using Blackboard Collaborate Ultra (BBCU) and had the same three major components as the F2F class but needed alternate implementation.

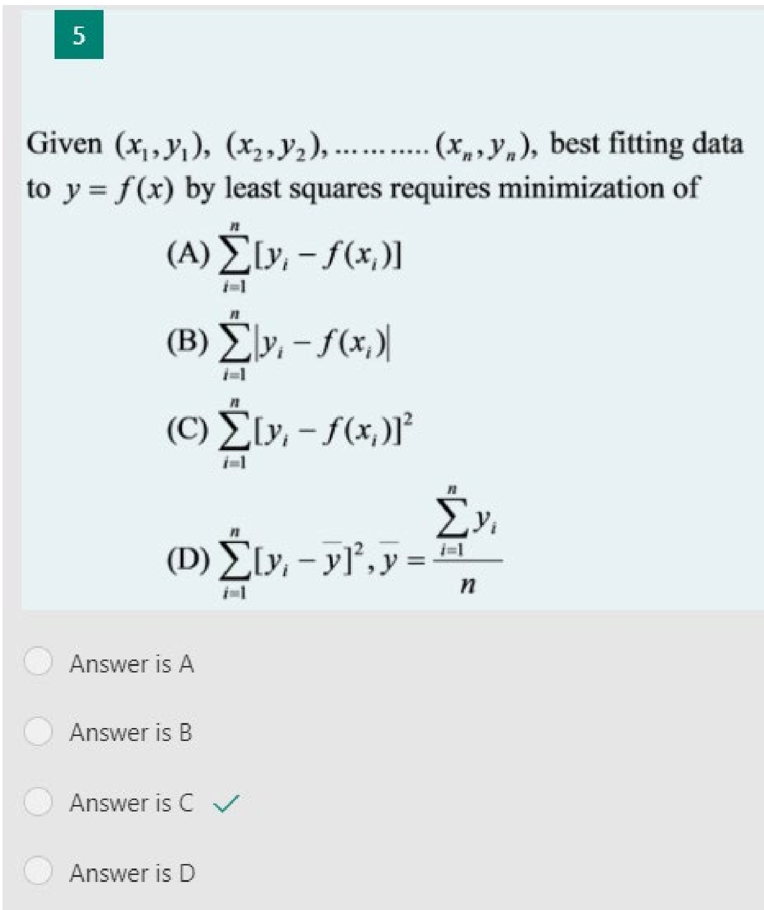
1) The first component was to duplicate the personal response system questions posed to the students. Since the physical clickers could not be used and we also wanted to have a cost-free solution, we chose Microsoft Forms as a replacement. There were some extra advantages of choosing Microsoft Forms, as a student could access the questions on any platform or device via a link or a QR code. The students were given a set amount of time to answer the questions. About 3-6 questions would be asked and would need to be answered in 5-10 minutes. The responses get tallied and are visible in real-time for the instructor, and if needed, they can increase the allowed response time.

Although there are limitations (one cannot use more than one image in the question stem, no images are allowed in the choices of a multiple-choice question, complex scientific equations cannot be displayed, etc.) in entering STEM-based questions on Microsoft Forms, we found workarounds. These hacks and the general use of Microsoft Forms to replace clickers are described at length in the author's blog with an accompanying YouTube video (Kaw, 2020). For example, in a question that has images and complex equations in both the stem and the options, one can save both as a single image. In MS Word, cut and paste the question stem and the options as a single picture, right-click or use the snipping tool (Snip, 2021) to save the picture as an image, and then use the options within MS Forms to direct to the choices (see Figure 6).

The challenges of images not getting displayed on some of the students' devices was an occasional problem. In such cases, the instructor would show the question on the BBCU interface. However, as of the writing of this paper, these issues have been resolved.

2) The free-response questions were held as a think-pair activity in the F2F class. In the online class, a PDF handout of the free-response questions was distributed online via a link in the chatbox of BBCU. The students were asked to attempt the problems by themselves first for about 15 minutes. After the time was over, the online breakout rooms were opened for another 10 minutes. Because of the significant enrollment nature of the course, these assignments of students to a particular breakout room were made randomly. About 24 breakout rooms were made, and I assigned eight each to myself and the two TAs. Breakout rooms could use their microphones, chatbox, and a whiteboard. Typically, about 1/3rd of the rooms were not using any form of communication, and on dropping by into these rooms, there would be no response. We would sometimes drop into the breakout rooms, but it felt intrusive. Later on, in the semester, we found that a student in a breakout group could raise their hand to be visible to the moderators. This feature allowed the instructor or one of the two TAs to join that group to answer their

question. At the end of the breakout room session, the instructor outlined the solutions to the questions and answered student questions. To better conduct breakout rooms in an online environment, many categorical suggestions have been made available in an article in December 2020 by McMurtrie (2020). The author is using several recommendations in the current Spring 2021 semester offering of the course. These include more frequent and shorter breakout room sessions for keeping the discussion centered. Some suggestions the author was already using included the right group size (two to five), mixing it up by using randomized groups, using shared docs, and having the assignment in writing. Several other suggestions not used by the author include assigning roles, giving each group a different assignment, and asking unrelated-to-classwork questions that create connections.



5

Given (x_1, y_1), (x_2, y_2), ……….. (x_n, y_n), best fitting data to $y = f(x)$ by least squares requires minimization of

(A) $\sum_{i=1}^{n}[y_i - f(x_i)]$

(B) $\sum_{i=1}^{n}|y_i - f(x_i)|$

(C) $\sum_{i=1}^{n}[y_i - f(x_i)]^2$

(D) $\sum_{i=1}^{n}[y_i - \bar{y}]^2, \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n}$

Answer is A

Answer is B

Answer is C ✓

Answer is D

Figure 6. Using a workaround for presenting a question with complex equations in question stem and options in Microsoft Forms.

3) The third component was the same as was in the F2F flipped class, which involved conducting minilectures on the most challenging topics as observed through instructor experience, performance in pre-class quizzes, and the student answers to the most difficult topic discussion board entries. The implementation of asking short questions during these minilectures via chat box was modified by asking students to wait for my signal to press send on their answers. This small change increased the number of students engaging in such an interactive activity.

Post-Class Learning
These activities were similar to the F2F flipped online class.

Comparing F2F and Online Flipped Classrooms

The intent of this paper is more about how the flipped classroom was taught in the online setting.

Several constraints to compare the F2F and online flipped classrooms need to be mentioned. First, the final exam as given to the control group of the F2F flipped class could not be given to the online flipped class as we were protecting the academic integrity for future research. The F2F final exam is given in a physical classroom and is not returned to the student. In an online environment, such protections are not fully available while the posting of the online exams on course content aggregation sites (Foderaro, 2009) is pervasive. Secondly, the exam had to be made open notes for the online modality. It would be hard to monitor a closed-book test even when a learning integrity platform software such as Proctorio (Proctorio, 2020) was used. Our university subscription to Proctorio does not include the "record room scan" option. Moreover, best practices for online courses include avoiding closed-book testing (Vazquez, Chiang, Sarmiento-Barbieri, 2020).

For the benefit of the reader, we are comparing the two groups within the constraints mentioned above. The control group of the F2F flipped classroom belonged to the Fall 2014 and Fall 2015 semesters, and the experimental group was Fall 2020 online flipped classroom. Figure 7 shows the raw final total grade distribution comparison between the two modalities (n=98 for F2F Flipped, n=89 for Online Flipped).

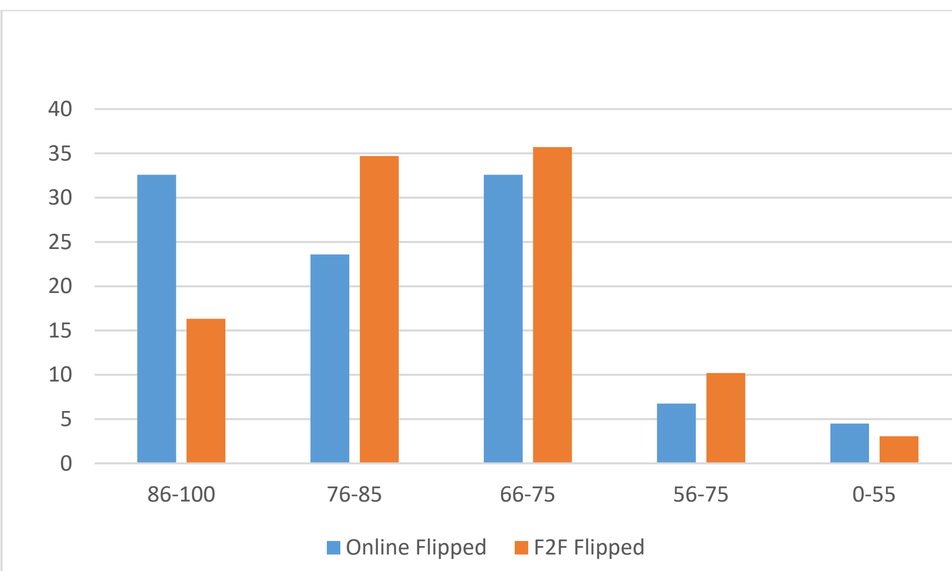


Figure 7. Raw final total grade distribution (percentage of class enrollment) comparison between online and face-to-face modalities (raw final totals are without extra credit given for completing study surveys in both treatments and the use of replacing, if it made a positive change, the lowest test score by the final exam score in Fall 2020 as part of taking care of the extenuating circumstances brought upon several of the class students due to the pandemic).

An independent-samples t-test (Thorndike and Thorndike-Christ,2010) was also conducted to compare the final grades for the online flipped and F2F flipped modalities. There were statistically no significant difference in the scores for online flipped (M=78.6%, SD=12.2%) and F2F flipped (M=76.5%, SD=10.5) modalities; t(175)= 1.248, p = 0.2135 (Table 1). These results suggest that we cannot reject the null hypothesis that the online flipped classroom performance is the same as that of the F2F flipped classroom. For the pragmatic difference, Cohen's effect size was d=0.18 in favor of the online flipped mode.

Table 1. Descriptive statistics of total raw score out of 100 comparing the face-to-face and online flipped classrooms.

	F2F Flipped Modality	**Online Flipped Modality**
Average (M)	76.5	78.6
Standard Deviation (SD)	10.5	12.2
Sample size (n)	98	89

The author has attempted to compensate for the accommodation of open-notes tests by writing different classes of test questions, such as reducing the number of declarative knowledge questions asked and replacing multiple-choice questions with multiple-answer questions. It would take several semesters of online testing data to create equivalency between examinations that are not the same and where allowable resources are different (Ryan, 2016).

Suppose the author was to comment on possible reasons for the high number of A grades in the online group. In that case, one could "possibly" point to the general higher self-efficacy of academically bright students in an online environment. More of them (Giancola and Kahlenberg, 2016) belong to the upper-income quartiles and can afford better resources and environment to flourish in the online environment.

Individual grade components (tests, homework, projects) also show no statistically significant or pragmatic differences between the two groups except for the homework assignments. The online flipped class students scored 13% more than the F2F flipped classroom, which translates to the 2.6% more on the overall grade.

Conclusions

This paper gives a model of how a flipped classroom that met face-to-face was revised to be conducted online. The pre- and post-class activities of both modes were kept similar, and the three major components (clicker questions, free-response questions in a think-pair format, and minilectures) of the in-class activities were followed.

The in-class activities needed to be approached differently in the online format though – clicker devices were replaced by online quizzing systems using MS Forms, group work was replaced by breakout rooms with random groups, and minilectures were made engaging using the chatbox.

Comparisons of the groups were made, but because the online environment forced changes in the format and previously used content of the highly secured final examination of the control group could not be used, the results of this paper need to be interpreted in that light.

Major lessons learned and used in future online flipped classrooms are limited to the in-class activities. Those include additions to how the group work would be conducted – use assigned roles and have shorter and frequent breakout room sessions.

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