The Evolution of a Flipped Dynamics Course

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Abstract

The teaching of Dynamics at the United States Air Force Academy, USAFA has changed dramatically due to COVID-19. Initially, when all courses went remote at USAFA, Dynamics was taught using a "flipped-remote" format. In a traditional flipped course, the lecture content is typically delivered asynchronously via videos and the in-class activities are redesigned to be more active. Although many papers have been written on flipping Dynamics, missing from the literature is information on the challenges associated with a flipped course being taught by new instructors who did not participate in the development of the course, who have no experience teaching a flipped course, and who may or may not be convinced as to the benefits of flipping the course, but are willing to try it. In this paper, we will discuss the lessons learned as Dynamics evolved from being remote-flipped to being face-to-face flipped, and finally to being face-to-face flipped taught by instructors who did not participate in designing the flipped class. Each of the courses will be briefly described, and assessment results will be presented on students' perceptions as to which activities they believed to be most beneficial to their learning in the course. Insights from the instructors who taught the course using the flipped materials developed by somebody else will also be presented. The purpose of soliciting feedback from these instructors was to learn how to best design a flipped course so that future instructors can effectively use the materials for a flipped course with little additional work on their part.

Introduction

In 2013 a flipped classroom was described as "a new pedagogical method, which employs asynchronous video lectures and practice problems as homework, and active, group-based problem-solving activities in the classroom" [1]. A summary of flipping classes in engineering and the type of activities used in class is provided in Ref. 2. Ten years after these papers, we do not think it is appropriate to call the pedagogical method "new" anymore, but the number of papers discussing the flipping of Dynamics is limited. The earliest paper focused on flipping Dynamics dates from 2007 [3]. In this study the authors used a tablet PC. All of the lectures were recorded using screen capture and were made available to students online. The in-class portion of the course was 20% lecture and 80% students working on problems using DyKnow Software [4].

Many of the other references that discuss flipping Dynamics only involved partial flipping for a selected number of topics [5-8]. In [5] a total of six topics were flipped. Students watched a video outside of class for each topic, and the in-class time was used for guided student practice of examples and for working on homework problems. Students could work independently or in groups. In [6] the authors tried the flipped approach for just one chapter in the text. They reported that students with higher grades tended to prefer the flipped format. As usual, the chapter content was delivered out of class via videos. For the in-class portion of the class, students could work collaboratively or individually. The authors reported that they received negative responses from students about the flipping. In [7] the authors discuss how they flipped two different topics in Dynamics. The in-class portion involved creating MindStorm Lego

Systems. They reported that the flipping had no effect on student performance in the class. When asked about their preference for a flipped class or a traditional class, 38% said they preferred purely traditional and 48% reported they preferred traditional with only a few sessions (less than five per semester) that were flipped.

Another study, [8], discusses a hybrid course in which 50% of the material was delivered online. Assessment results presented indicate that the videos were, in general, viewed positively. The authors did not check to see if students were actually watching the videos as the course progressed. Some students admitted to only watching the videos before exams or before the homework due date. Similar to the results from other studies, a much larger portion of students, 46%, said they preferred a mostly face-to-face class, compared with 19% who said they preferred a mostly online class.

All of these papers discuss ways of partially flipping a face-to-face Dynamics course. Ref [9] discusses a "flipped-remote" Dynamics course that was implemented due to Covid-19. The out-of-class activities consisted of videos of lectures and example problems that the students watched before the class met synchronously via Blackboard Collaborate during the regularly scheduled class times. The in-class activities consisted of concept questions asked using the polling feature in Blackboard, a quick review of the video material, and breakout rooms where students worked on the homework problems assigned for the day. The breakout rooms were rated as the least useful activity in terms of student learning.

In this paper we discuss the evolution of a flipped Dynamics course over four semesters. In each of these semesters the course was completely flipped, that is, not just selected topics as in many of the previous studies. This study had several objectives:

1. Determine which of the activities in a flipped Dynamics class are most effective, in the students' opinions, in helping them master the course material.
2. Identify practices that help new instructors who are planning on flipping a Dynamics course, especially those who are planning on using materials developed by somebody else.
3. Identify factors and practices that lead some students to prefer a flipped structure in Dynamics and other students to prefer a traditional structure.

Description of the courses

Brief descriptions of how the flipped course has evolved from being in a 100% remote environment to a face-to-face environment to having the course taught by instructors who had no part in developing the flipped materials are shown in Table 1. A comparison of the in-class and out-of-class activities for the four semesters of the course is shown in Table 2. These elements will be discussed in detail in subsequent sections of this paper.

Table 1 – The four semesters of Dynamics that will be discussed in this paper.

Semester	Description
Fall 2020	100% flipped-remote and taught by Instructor 1, who developed the flipped materials
Fall 2021	100% flipped, face-to-face and taught by Instructor 1
Spring 2022	100% flipped, face-to-face and taught by two other faculty members using Instructor 1's materials
Fall 2022	100% flipped, face-to-face and taught by Instructor 1

Table 2 – Summary of out-of-class and in-class activities

Semester	Out-of-class activities	In-class activities
Fall 2020 (flipped-remote)	• Three videos (a mini lecture and two example problems) • Required notetaker (collected) • McGraw-Hill LearnSmart reading assignment • Practice problem from McGraw-Hill Connect • Homework assignment	• Concept questions via polling feature of Blackboard • Quick review • Grade homework • Breakout rooms to work on the homework assignment with other students
Fall 2021 (flipped, face-to-face)	• Three videos (a mini lecture and two example problems) • Required notetaker (collected) • Blackboard quiz before class (graded) • Homework assignment	• In-class quiz (concept questions) at the start of class • Quick review • Grade homework • Boardwork
Spring 2022 (new instructors)	• Three videos (a mini lecture and two example problems) • Notetaker (not collected) • Blackboard quiz before class (not graded) • Homework assignment	• In-class quiz (concept questions) at the start of class • Quick review • Grade homework • Boardwork
Fall 2022 (flipped, face-to-face)	• Three videos (a mini lecture and two example problems) • Required notetaker (collected, self-reported after first exam) • Blackboard quiz before class (graded) • Homework assignment	• In-class quiz (concept questions) at the start of class • Quick review • Grade homework • Boardwork

Pre-class activities

All the semesters used the same videos for each lesson. There were usually three videos posted for each day's lesson. One video was a lecture over the technical material, and the other two were example problems. The videos were typically 7 to 10 minutes long, but some of the example problem videos were as long as 15 minutes. The total running time for all three videos was typically between 20 and 30 minutes, so we emphasized to students that we would give them at least 30 minutes in class to work on the next homework assignment. One of the reasons we did

this was to combat the perception that flipped classes are more work since students are required to watch the videos outside of class.

Students were asked to complete a "notetaker" while watching the videos. The purpose of the notetaker was to help students stay engaged while watching the videos and to ensure they would have a good set of notes. For the lecture material, the notetaker consisted of a copy of the PowerPoint slides with blanks for students to write in key equations. For the example problems, the notetakers consisted of the problem statements and room to write down the solution from the video. The notetakers were also intended to provide some accountability for watching the videos. Students were required to scan and submit completed notetakers before class in the Fall of 2020 and 2021. In the Fall of 2022 students were required to scan and submit it up until the first exam, and after that, they were asked a multiple-choice question on a pre-class Blackboard quiz asking whether they had completed it. In the Spring of 2022, the notetaker was provided, but neither instructor required the students to submit a scanned copy on Blackboard. In addition to watching the videos and completing the notetaker, students were required to write up the homework from the previous lesson.

In the Fall of 2020 students were also given optional LearnSmart Reading assignments and practice problems using McGraw-Hill Connect to do before class. The feedback on these assignments was quite negative [9], so they were not assigned in subsequent years.

In-class activities

In general, the in-class activities were similar all four semesters, but the way they were implemented was different during the Fall of 2020 when the class met online in a Blackboard Virtual Classroom. When the course was taught face-to-face, the class typically started with an in-class low-stakes "quiz" that was based on the material in the videos. Some of the questions were multiple-choice concept questions, whereas others might ask students to draw appropriate diagrams, for example a free-body diagram and a kinetic diagram necessary to solve a problem. The quiz was started individually, but after about 5 minutes, students were allowed to work with the people around them. When the class was 100% remote, this quiz only had multiple-choice concept questions that were asked using the polling feature in Blackboard. Following the quiz there was typically a very quick (less than five minutes) summary of the key ideas from the videos, and there was some time for students to ask questions. For Instructor 1, there were usually very few questions, but this was not true for the other instructors as discussed near the end of this paper. Then, if homework was due, it was graded in class. Finally, the remainder of the class, typically at least 30 minutes, was used for "boardwork." When the class was remote, instead of boardwork, students were placed in breakout rooms as discussed in Ref [9]. During boardwork, students were asked to get out of their chairs and work on the whiteboards in groups of two or three students, although depending on the size of the class, sometimes the groups were four students. Boardwork is possible at USAFA because our classes are typically less than 30 students per section and the classrooms have whiteboards on multiple walls. Students were not allowed to work on their own, and they were given instructions that the goal of the boardwork was not only to complete as much of the homework as possible, but also to make sure everybody

in the group understood the material. At the end of class, students would take a photo of their boardwork for when they wrote up the homework.

Discussion and Results

Pre-class activities

On the last day of class students were asked to complete an anonymous questionnaire about the course. Response rates are shown in Table 3. The response rate was smallest the year the class was 100% remote. Each of these semesters, students were asked "How often did you watch the videos before class and "How helpful were the videos in helping you learn the material?" The results for these questions are shown in Figures 1 and 2, respectively. In the Fall of 2022, the questions were modified to ask about the lecture videos and the example problem videos separately. It can be seen from Figures 1 and 2 that the vast majority of students watched the videos "always" or "usually" and found them "helpful" or "very helpful." The response rate for those indicating they "always" watched the videos as well as those who found them "very helpful" was largest in the year the course was taught in a 100% remote environment. Only 60% of the respondents in the Spring of 2022 (when the course was taught by two instructors who did not develop the flipped materials) indicated that they "always" watched the videos, but the percentage who found them "very helpful" was similar to the percentage in the other semesters when the course was taught face-to-face.

Table 3 – The four semesters of Dynamics that will be discussed in this paper.

Semester	Number of responses to survey
Fall 2020	14/29 (48.3%)
Fall 2021	23/26 (88.5%)
Spring 2022	45/56 (80.4%)
Fall 2022	16/18 (88.9%)

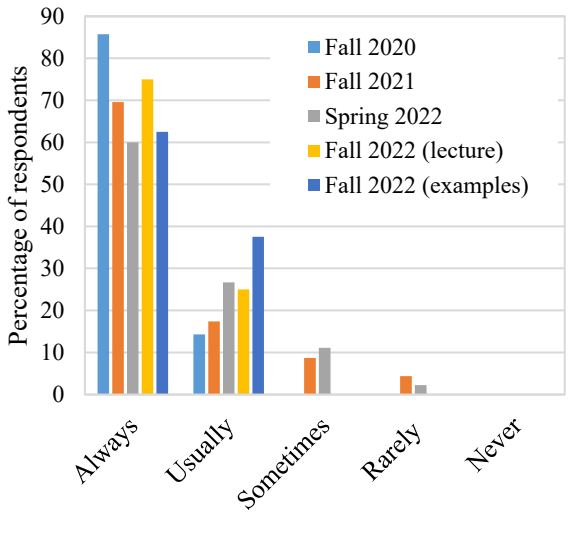

Figure 1 – Answer to the question "How often did you watch the videos before class?"

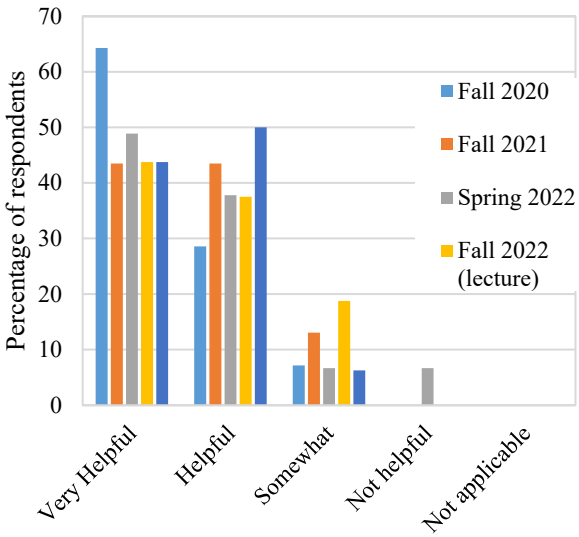

Figure 2 – Answer to the question "How helpful were the videos in helping you learn the material?"

Students were asked "Did you complete the notetakers as you watched the videos?" The results from this question are shown in Figure 3. From Figure 3 it is clear that even though students were not required to submit the notetaker in the Spring of 2022, a similar percentage of students indicated that they "always" or "usually" completed it compared to the semesters when it was required. In Figure 4 is shown the results of the question "How helpful were the notetakers in helping you learn the material?" This question was not asked in the end of semester survey for the Fall of 2020, and in the Fall of 2022, the question was modified to read, "How helpful were the notetakers in keeping you engaged while you watched the videos?" The rewording of the question probably accounts for the increase in students answering "Always" for the Fall of 2022. There was clearly a significant number of students who did not consider the notetakers to be helpful.

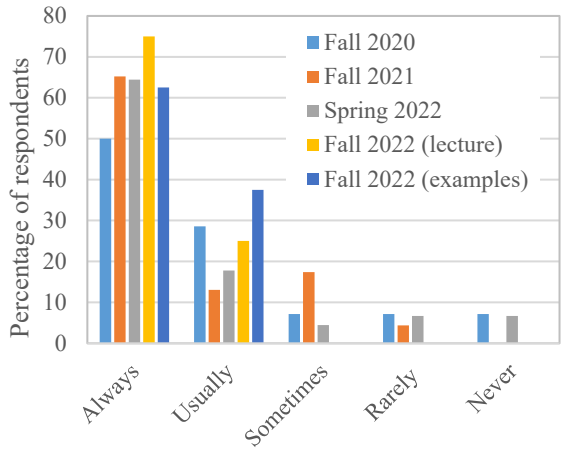

Figure 3 – Answer to the question "Did you complete the notetakers as you watched the videos?"

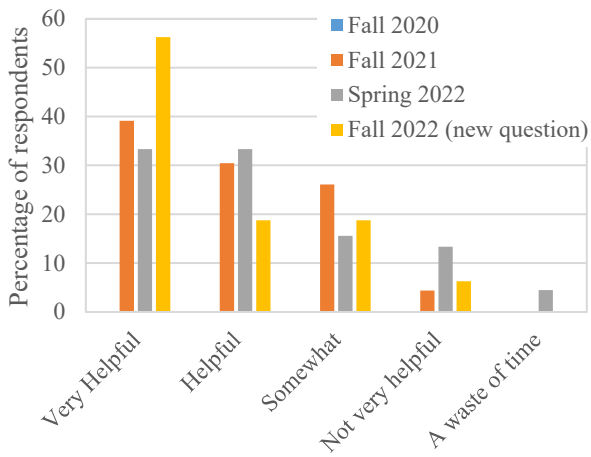

Figure 4 – Answer to the question "How helpful were the notetakers in helping you learn the material?" This question was not asked in the Fall of 2020, and in the Fall of 2022 it was changed to "How helpful were the notetakers in keeping you engaged while you watched the videos?"

In-class activities

In addition to asking students about the out-of-class activities, we also asked them to evaluate the in-class activities. As discussed earlier in this paper, the in-class activities included an in-class quiz (often concept questions), a quick review of the lecture material, grading the homework, and active engagement via breakout rooms (remote environment) or boardwork (face-to-face classes). Figure 5 shows the responses to the question, "How helpful was the quiz at the start of class in helping you learn the material?" and Figure 6 shows the response to the question, ""How helpful was the quick review at the start of class in helping you learn the material?" In general, the quiz was viewed positively. Over 90% of the students said it was "Very Helpful" or "Helpful" except in the Fall of 2022 when the number was only 80% and 20% said the quiz was

"Somewhat Helpful". The question was modified slightly in Fall 2022 to be, "In terms of learning the material, that is, preparing you to solve ME320 problems (boardwork, homework, GRs), how helpful were the in-class quizzes?" Since a lot of these questions were more conceptual in nature, the students may not have thought that these quizzes actually helped prepare them to solve dynamics problems. As shown in Figure 6, the responses to the question, "How helpful was the quick review at the start of class in helping you learn the material?" was quite varied. Based on students' comments, one reason some students did not view the review positively was because they had already watched the videos and were prepared for class, so the quick review was unnecessary.

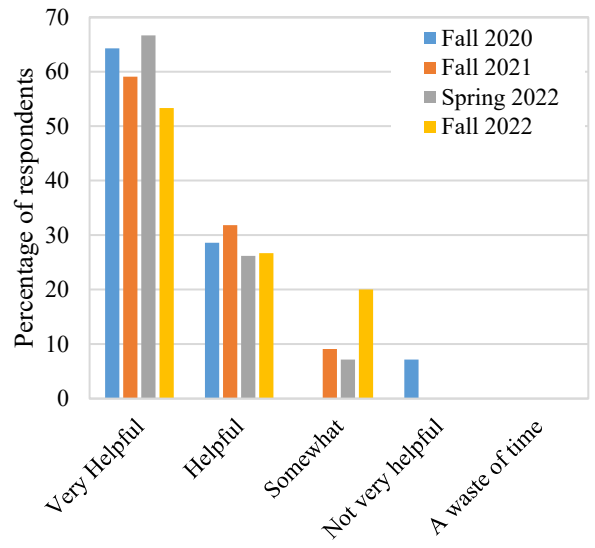

Figure 5 – Answer to the question "How helpful was the quiz at the start of class in helping you learn the material?"

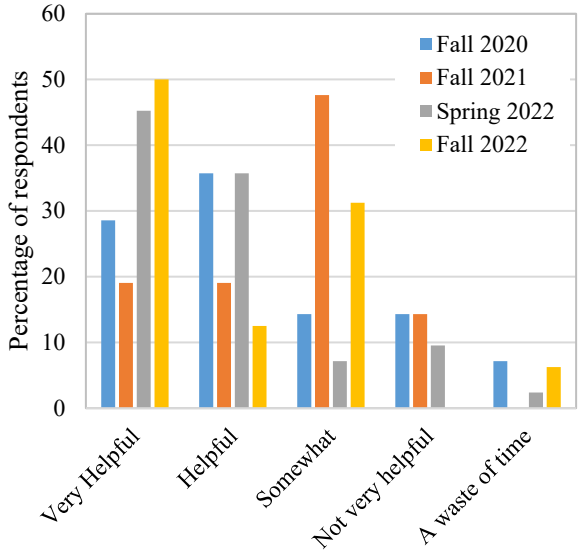

Figure 6 – Answer to the question "How helpful was the quick review at the start of class in helping you learn the material?"

The primary in-class activity was "boardwork," that is, students working in groups on the homework assigned that day. Figure 7 shows the results of asking students how helpful the breakout rooms (Fall 2020) or the boardwork (the other semesters) was in helping them learn the material. From Figure 7, it is clear that students did not feel the breakout rooms were helpful. This is discussed more in Ref. [9]. For the face-to-face semesters, students indicated that the boardwork was "Very Helpful" or "Helpful" 86.4%, 95.2%, and 93.8% for the Fall 2021, Spring 2022, and Fall 2022 semesters, respectively. The first semester the flipped course was offered face-to-face (Fall 2021) was not as positive as the other semesters. It is possible the instructor was not yet effective in communicating the purpose of the boardwork and the flipped class.

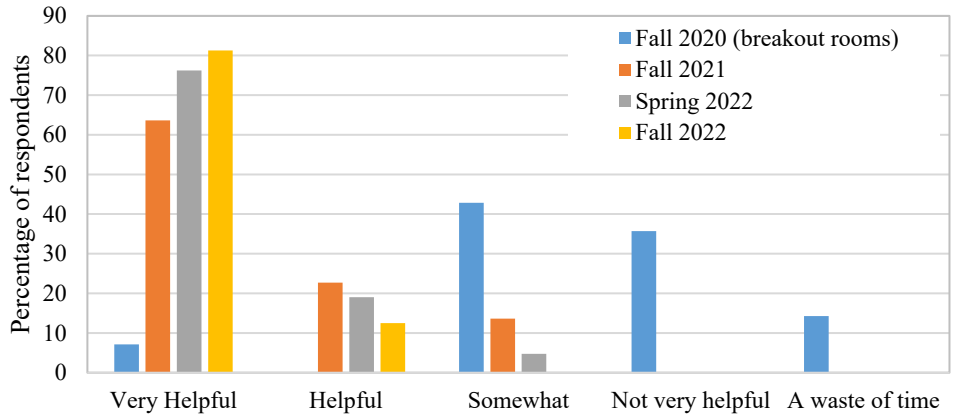

Figure 7 – Answer to the question "How helpful was the boardwork in helping you learn the material?" For the Fall of 2020, the question asked about the breakout rooms since the class was 100% remote.

Additional results from Fall 2022

In the Fall of 2022, the end of semester questionnaire included additional questions to try to understand why some students preferred the flipped format and others did not. Figure 8 shows the responses to the question, "After taking this class, do you prefer a flipped or a traditional structure for a STEM course?" Unlike the results from many of the previous studies that discuss flipping Dynamics (or at least flipping topics in Dynamics), students preferred the flipped format by 66.7% to 26.7%.

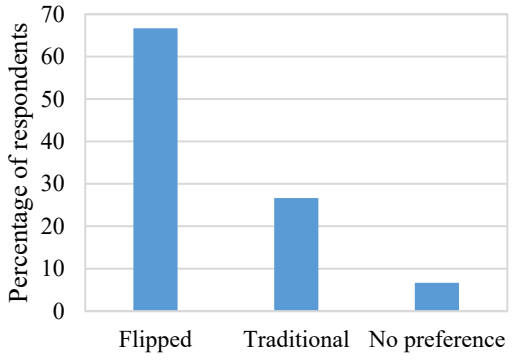

Figure 8 – Answer to the question "After taking this class, do you prefer a flipped or a traditional structure for a STEM course?"

We looked at the relationship between preferring the flipped structure as a function of watching the videos or filling out the notetakers, but we didn't see any correlation, that is, a similar percentage of students indicated that they watched the videos and completed the notetakers in both groups. One survey question for which we did observe a difference between students who preferred the flipped structure and those who preferred a traditional structure was the one asking students how helpful the videos were in enabling them to solve dynamics problems. For this question, the students who found the videos "Very Helpful" were more likely to prefer the flipped structure as shown in Table 4. This was true for both the lecture videos as well as the example problem videos. Another major difference between the groups in answers to the survey questions was when we asked them "In general, what was your approach when doing the assigned homework?" As shown in Table 4, a much larger percentage of students who said they preferred the traditional structure indicated that they just copied the photo of the boardwork while doing homework rather than only looking at the photo for help. Finally,

there was also a difference in terms of how the students rated their experience in the class. In Figure 9 is shown the response to the question, "How would you rate your experience in this flipped class compared to a conventional course?" It is clear from Fig. 9, that 50%, that is, two out of four, of the students who said they preferred a traditional structure indicated their experience in the class was only "satisfactory."

Table 4 – Answers to survey questions where there was a noticeable difference between those who preferred a flipped structure over a traditional structure. A total of 15/18 students completed these questions.

	Number of students			
Preferred structure	Found lecture videos "very helpful"	Found example videos "very helpful"	Only looked at photo of boardwork for help when doing homework	Copied the photo of boardwork when doing homework
Flipped (N=10, 66.7%)	6	6	5	5
Traditional (N=4, 26.7%)	0	1	1	3
No preference (N=1, 6.7%)	1	0	0	1

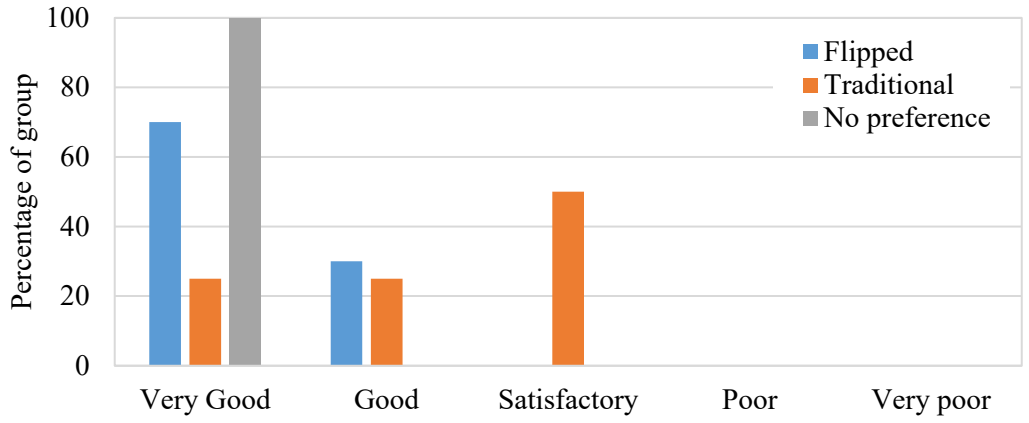

Figure 9 – Answer to the question "How would you rate your experience in this flipped class compared to a conventional course?"

The final set of data we examined was the final grades in the course. We could not correlate a student's grade in the course to their survey responses since the survey was anonymous. Table 5

shows the incoming GPA and the final overall GPA of the class. There were no statistically significant differences in performance that we observed.

Table 5 – Comparison of incoming GPA and final overall class GPA.

Semester	Incoming GPA	Class GPA	Description
Fall 2020	3.31	2.35	100% flipped-remote and taught by Instructor 1 who developed the flipped materials
Fall 2021	3.31	2.52	100% flipped, face-to-face and taught by Instructor 1
Spring 2022	3.35	2.74	100% flipped, face-to-face and taught by two other faculty members using Instructor 1's materials
Fall 2022	3.40	2.76	100% flipped, face-to-face and taught by Instructor 1

Observations from instructors

In this section we will present some observations from the faculty members who taught the course, but who did not contribute to the development of the flipped course materials. We will refer to them as "Instructor 2" and "Instructor 3." Both instructors have many years of teaching experience.

Instructor 2

Overall, I found this to be a very rewarding way to teach Dynamics. There were a few issues that cropped up along the way, but generally, students responded well to the flipped classroom, primarily due to the fact that during class they often completed at least one of the two homework problems assigned each lesson. This gave the students time back in their schedule as a trade for watching the lessons the evening before. The first time I taught using the flipped class, several students got off track because they stopped watching the lectures and example problems the day before each class. Partially, this was because the in-class portion was also virtual, due to COVID classroom restrictions. However, when we met in person the flipped approach worked very well. Students came to class prepared, and after some warm-up concept questions, we generally jumped straight to boardwork and the homework problems. One issue that we had to address was consistency in how problems were solved. Because students watched videos the evening before where example problems were solved by one instructor, it was important that we used similar solution techniques/problem set-up in class to reinforce the concepts. There were a few times I didn't watch the lecture/example problem videos and was out-of-sync with the students in class.

For the first few lessons of the semester, I asked for a show of hands as to who had watched the videos prior to the start of class. This set an early expectation that this was required, and once the students realized the benefits, we had almost 100% view rates prior to the start of class. Indeed some students would "self-report" when they had not watched the videos and asked if they could still attend class. In general, students gave very positive feedback and appreciated the approach. As the instructor, I found the workload to be significantly less since the videos were already recorded. I would anticipate that these videos will need to be updated occasionally.

I think an important factor in making this a successful way to teach Dynamics was the rapport developed with the students. It was essential that they buy into the flipped classroom in order for it to be successful, and I believe that the instructor was the key to make that happen. This was the largest difference between the two times I taught this course in a flipped format, the first being 100% flipped-remote and the second being face-to-face flipped. In the first case it was much harder to get buy-in from the students due to the remote nature of the course. Based on this limited experience I would question the value of a remote-flipped course unless the instructor had previous experience with flipped classes.

Instructor 3

I had not taught Dynamics for many years, but I found teaching this class to be less work than I expected. Because I didn't have to put as much time into lecture preparation, I spent that time doing the homework problems. It was the first time in many years that I did every homework and example problem that the students were assigned. That's very rare for me. As a result, I felt extremely prepared to answer their questions and help them with the work. I did watch every video, but usually at a high speed. I would sometimes complete the notetaker, but usually only if there was a lot of content/equations to record. I would always try to do the example problems myself, then check the video to verify the process.

In general, there were few challenges for me as I taught this class, but one aspect of the course sticks out. For the concept questions that I did not create, it was sometimes difficult to explain to the students the "why" of a certain outcome. It would be helpful for the creator of the question to write a short narrative explanation of why the answer is what it is. Many of the questions are self-explanatory for a seasoned Dynamics instructor, but in some cases, I had to admit that I was scratching my head. In theory, every problem should be clearly understood with a good FBD and a kinetic diagram, but not always. I should add that these concept questions stimulated the most engaging discussion I had in class, and I often found in my section that we would only have 15-20 minutes for boardwork because we spent a lot of time discussing example problems, homework, and the concept questions. Early in this paper it was mentioned that Instructor 1 typically did not have a lot of questions or discussion. This was definitely not my experience. These turned into great debates and discussions.

I felt that the information provided to me before teaching this class was more than adequate. The content creator was very helpful in setting up the Blackboard page with the videos and lesson plans. This made it very easy for me to prepare for class by watching the same videos as the students, doing the reading, example problems and homework. I only had to add my personal experience to the lesson and be ready to answer questions.

What I love about this approach is that we had time to really dig into the physics and think about what is happening. My previous experience teaching Dynamics in a traditional way involved mostly racing through a lecture, trying to get all my lesson notes transferred to the whiteboard so the students could transfer it to their notes. The flipped format is a much more efficient way to deliver fundamental content so that we can spend class time on more interesting cases and

applications. I suppose that is the intent of having students read the textbook, but I found that students were much more willing to engage with a video lecture than they are with a book.

I have one caution about the flipped class. There's a big difference between struggling with a workout problem yourself and watching someone else do it in a video. Therefore, I think the example problem videos are somewhat problematic because they can potentially create a false confidence in the students. The students often reported easily understanding the video examples, then having no idea how to start the homework problems. In a live lecture, the instructor can force students to wrestle with critically thinking about the problem and deciding what steps to take. This did occur during the boardwork portion of the class. Despite that issue, the example problem videos were certainly valuable and useful, but I think there is an opportunity to improve how they are delivered to force and encourage students to put forth some mental struggle on their own before revealing the successful approach. One possible method would be to embed questions that students were required to answer before they could continue with the video.

Conclusions

In this paper, we discussed the evolution of a Dynamics course from being remote-flipped to being face-to-face flipped, and finally to being face-to-face flipped taught by instructors who did not participate in designing the flipped class. We learned that, in general, students watched all the videos and completed the notetakers even when the notetakers were not collected. The in-class activity viewed most favorably was the boardwork, that is, students actively working on the homework in groups on whiteboards. We have anecdotal evidence that it was important for professors who did not create the videos to watch them before class in order to be able to reinforce the problem-solving approach presented in them. For the Fall of 2022, we found that over 65% of the students preferred the flipped class to a traditional class. Not surprisingly, students who indicated that they found the videos "Very Helpful" were much more likely to prefer the flipped format.

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