

FLIPPING SIGNALS AND SYSTEMS – COURSE STRUCTURE & RESULTS

Mark L. Fowler

Dept. of Electrical and Computer Engineering, Binghamton University, Binghamton, NY

ABSTRACT

The flipped classroom approach is being used in many engineering courses. This paper describes an approach used for flipping a large Signals & Systems class. The structure of the out-of-class and in-class materials is described with comments about what issues are felt to be important. Student survey results are presented that help determine how students respond to the flipped approach as well as what factors they feel are important. Grade analysis results show significant gains on problem-based exams but no gain on conceptual-based exams.

Index Terms— Flipped Classroom, Active Learning, Signals & Systems, Signal Processing Education, Engineering Education

1. INTRODUCTION

Although the flipped classroom idea has been around for quite some time ([1] is one of the earliest references) it has recently been getting much interest for use in engineering courses at the university level [2] – [6]. The basic premise of the flipped classroom is that active learning in the classroom is superior to passively listening to lecture. There is no doubt that active learning is effective, see [7] where a strong case is made for its effectiveness in general and [8] where its usefulness in teaching signal processing is established. However, active learning in the classroom was difficult to implement until easily accessible video creation and distribution methods became available. The flipped classroom has become virtually synonymous with the outside-of-class delivery of video lectures, which frees up class time for active learning exercises. Despite the solid research in active learning [7], [8] there is still great uncertainty as to *how* to flip a course, *what* factors matter, and how do various aspects of the flipped approach impact the different aspects of student learning.

The very recent paper by Van Veen [6] (actually arrived during the writing of this paper) details his approach but concludes by pointing out that there is still much feedback needed to refine the approach for signal processing education. In this paper we provide some additional feedback (surveys and grade analysis) that also shows the effectiveness of the flipped method. But it also shows a potential pitfall (students may have decreased conceptual understanding) as well as providing some feedback on how the students view the approach (i.e., appropriate video lengths, etc.)

These results were obtained during Fall 2012 when I first flipped my required junior-level 4-credit signals and systems course. The class had 115 students roughly evenly split between electrical and computer engineering students. The class meets for 4 hours each week (two 1.5 hour classes and one 1 hour class). Grade data from the previous four years (not flipped) have been

compared to the grade data for the flipped class. In addition an extensive survey of the students in the flipped class was taken to determine the effectiveness of flipping in general and also to tease out what aspects of the flipped approach were most helpful.

2. MATERIALS DEVELOPED

Regardless of the assertion that “it is not really about the videos,” it is important to provide a means for students to get the equivalent of classical lectures outside the classroom in order to free up class time for active learning. Thus, as has become the standard in the flipped classroom approach I decided to make videos of my lectures.

I set out to create modules that focused on a single topic or sub-topic and were on the order of 15 – 20 minutes long. The critical (and time consuming) part was planning the division between modules and thinning my lecture material while still ensuring sufficient coverage. In my opinion, effort spent here is much more fruitful than fussing over “production-quality” videos.

I trimmed my lecture notes down into 40 focused modules (see “Lecture Notes and Video Lectures” in [7]). On the course webpage they are grouped into titled larger units to help students better see the overall structure of the course. The notes rely heavily on graphical and conceptual presentations rather than repeating the more detailed developments available in the textbook; I still expected (and encouraged) students to read the textbook. I strived to cover only the key ideas, to eliminate long derivations (I pointed students to the appropriate sections of the textbook for those), and also had few (if any) example problems.

The videos were created using Camtasia Studio [10] that is quite simple yet powerful. The videos were created on a Samsung Series 7 Slate PC that has a stylus for writing directly on the Powerpoint slides during presentation. I used a headset microphone to capture my voice directly while recording the video. After a bit of research on the pros and cons of the various video formats I settled on MP4 format because of its projected lifetime and its flexibility to be used with virtually all video players.

Even though Camtasia Studio provides significant editing features, I adopted the philosophy of creating each video in “one take” and applied no post-recording editing. While making the videos it is important to remember that the flipped classroom approach is “not about the videos” – as has been echoed time and again on websites about flipped classrooms. Thus, less focus on “production values” and more focus on development of high-quality in-class activities is likely a better approach. The 40 video modules had an average duration of 25 minutes and only four of the 40 videos longer than 35 minutes. The videos/notes were posted to my website [7]; the videos were also posted on YouTube for easy access.

3. COURSE MECHANICS

To help students keep track of what videos they are expected to watch for a specific class meeting it is extremely helpful to provide a detailed outline of the course structure. I posted this on the Course Management System (Blackboard in my case) rather than on the open course webpage – my general tactic is to post static material on the open webpage and material that changes each year on Blackboard. Figure 1 shows a portion of that course outline, which shows Video assignments for each class as well as the total video duration for that week. It should be noted that the average weekly video duration was 1:17. (The longest duration week was 1:35 and the shortest was 0:50.) Thus, on average students in the flipped class engaged in passive consumption of lecture material for only 1/3 of the time that the students in the non-flipped class did. In return for that they benefited from having four hours per week to do in-class active-learning problem solving.

In addition to watching the videos outside of class, the students were assigned a small number of homework problems each week. Initially no homework was assigned but it became clear from performance on quizzes (as well as student requests!) that homework was needed but less of it than when not flipping.

4. CLASSROOM ACTIVITIES

As mentioned above, the flipped-classroom approach is “not about the videos” but rather is about the in-class activities that the videos enable. Thus, the success of the method depends heavily on the design and delivery of these activities. The activities used during the Fall 2012 flipped class were focused largely on (i) solving problems and (ii) demos using MATLAB to illustrate application of theory to real-world problems.

To encourage students to watch videos, most class meetings started with a two-minute quiz on the day’s video(s). The questions were intentionally kept conceptual and such that they couldn’t be answered by simply browsing through the notes during the quiz (these are not closed-book since requiring that would add some extra overhead in transitioning from quiz to the activities). These quizzes are mechanized using the iClicker system [11] to ease the overhead cost on class time and the burden of grading them.

After the quiz I provided a one-slide summary of the video material – this is kept at the highest level and only occasionally includes equations. This allows the biggest ideas to be stressed and connected and also opens the door to questions students may have on the material from the day’s video(s).

After the summary and questions, a set of problems were given for the students to work on (but sometimes the classroom time was used for real-world demos). I chose to project the questions on the classroom screen. The first problem was usually quite simple but then they progressed in difficulty; the goal was to hit all the key ideas of the lecture material.

While students worked on the problems the course assistants and professor cycled around the classroom to help the students. In addition to the assigned graduate TA, I recruited course assistants from students who took the class the previous year. I have found that it is possible to easily handle a class of 130 students with only 2 – 3 assistants (the Fall 2012 class had 115 students and the current Fall 2013 class has 130 students).

| EECE 301 Course Outline Fall 2012 | | | | | |
|-----------------------------------|------------|-------------|-------------------|-------------------|-------------------------|
| Week # | Week Of... | Tuesday | Thursday | Friday | Video Duration (Hr:Min) |
| 1 | 9/3/2012 | Note Set 01 | Note Sets 02 & 03 | Note Set 04 | 0:50 |
| 2 | 9/10/2012 | Note Set 05 | Note Set 06 | Note Set 07 | 1:16 |
| 3 | 9/17/2012 | No Class | Exam #1 | Note Sets 08 & 09 | 0:47 |
| 4 | 9/24/2012 | Note Set 10 | Note Sets 11 & 12 | Note Set 13 | 1:27 |

Figure 1: Course Outline.

One crucial aspect for the success of flipping is the characteristic of the classroom. The room used for the Fall 2012 class was a large, tiered lecture hall with each tier being one long row – thus we could provide direct help only to those students on the row edges. This necessitated running the problems in a “synchronous” fashion: one problem was displayed at a time and then after some time I went over the solution, then the next problem was displayed, etc. Unfortunately, this synchronous approach instigated many students to just wait until they were shown how to do the problem – not really active learning.

The Fall 2013 offering now underway is in a new room where students sit at 4-seat tables – this allows easy access to all students and enables the problems to be run asynchronously. This also enables collaboration, which is encouraged – although each student is expected to complete their own written solutions. Nonetheless, I do tend to go through the solution of the first problem after about 10 minutes – this seems to provide well-needed guidance to many of the students who need to see an example first before they can begin solving problems on their own. It is still necessary to provide motivation to get some students to actually work on the problems. One tactic that has been effective this year is to sporadically collect the problems without letting students know if you plan to do that or not. It is also important that the professor and course assistants actively engage with the students rather than just wait for questions – this helps prevent students from passively waiting for the solution. Toward the end of the class session I go over the solutions in detail and provide comments that link the problems to the key ideas of the topic being covered. After the class I post the summaries and solutions on Blackboard (not on the open course webpage).

5. ANALYSIS

This section presents survey results and grade analysis that provide insight into the effectiveness of the flipped approach as well as illuminating aspects that work and some that don’t.

5.1. Student Survey

On the last day of the Fall 2012 flipped-classroom course I gave a 24-question survey. There were 78 students who responded out of the 115 students in the course (usually attendance was much higher but it was the last day of class!). The 24 questions focused on three different aspects: (i) the general flipped-classroom approach (Q1 – Q7), (ii) the videos used in the course (Q8 – Q16) and (iii) in-class activities in the course (Q17 – Q24).

Student Survey Questions

- The flipped classroom approach helped me to learn...
 - Much Better
 - Somewhat Better
 - About the Same
 - Somewhat Worse
 - Much Worse

2. The flipped classroom approach motivated me...
a) Much More b) Somewhat More
c) About the Same d) Somewhat Less
e) Much Less
3. In the flipped classroom, my grades were...
a) Much Higher b) Somewhat Higher
c) About the Same d) Somewhat Lower
e) Much Lower
4. The flipped classroom approach will allow me to retain the learned material...
a) Much Longer b) Somewhat Longer
c) About the Same d) Somewhat Shorter
e) Much Shorter
5. The flipped classroom approach held my attention during class...
a) Much Better b) Somewhat Better
c) About the Same d) Somewhat Worse
e) Much Worse
6. The flipped classroom approach contribution to the quality of this course was...
a) Significant b) Important c) Neutral
d) Not Important e) Insignificant
7. Should other Engineering/Math classes switch to the flipped classroom approach?
a) Definitely b) Probably c) Maybe
d) Probably Not e) Definitely Not
8. The technical quality (e.g., clarity of sound and picture) of the videos was...
a) Excellent b) Very Good c) Acceptable d) Poor
e) Very Poor
9. The explanation of concepts in the videos was...
a) Very Good b) Good c) Average
d) Poor e) Very Poor
10. The average duration of a single video was...
a) Way Too Long b) A bit long c) About Right
d) A bit short e) Way too short
11. The average time to watch videos each week was...
a) Way Too Long b) A bit long c) About Right
d) A bit short e) Way too short
12. I watched the videos prior to coming to class with this regularity:
a) 80% - 100% b) 60% - 80% c) 40% - 60%
d) 20% - 40% e) 0% - 20%
13. Prior to each exam the percentage of the relevant videos I'd watched was...
a) 80% - 100% b) 60% - 80% c) 40% - 60%
d) 20% - 40% e) 0% - 20%
14. The number of times I watched a specific video was usually...
a) More than 5 b) 4 - 5 c) 2 - 3
d) 1 e) 0
15. I re-watched the videos while preparing for an exam...
a) Always b) Usually c) Occasionally
d) Rarely e) Never
16. My style of watching the videos is best described as...
a) Active b) Semi-Active c) Semi-Passive
d) Passive e) Did not watch the videos
17. The iClicker questions provided how much motivation to watch the video before class?
a) Much b) Some c) A Little
d) Marginal e) None
18. The summaries provided during class were...
a) Very Helpful b) Helpful
c) Little Helpful d) Marginally Helpful
e) Not Helpful
19. The problems covered during class were...
a) Very Helpful b) Helpful
c) Little Helpful d) Marginally Helpful
e) Not Helpful
20. Having a room that would allow the professor to interact directly with each student would be ...
a) Very Helpful b) Helpful
c) Little Helpful d) Marginally Helpful
e) Not Helpful
21. Regarding the style of coverage of in-class problems, which is most helpful
a) Professor leads class through all problems
b) Professor leads class through a few problems then students work independently on one problem
c) Professor leads class through one problem then students work independently on a few problems
d) Students work independently on all problems
22. Which method of presenting classroom problems do you prefer?
a) Synchronous b) Asynchronous
c) Either d) A mix of the two
23. Having outside-of-class homework assignments was ...
a) Very Helpful b) Helpful
c) Somewhat Helpful d) Marginally Helpful
e) Not Helpful
24. Having one HW assignment each week was...
a) Way Too Much b) A Bit Much c) About Right
d) A Bit Too Little e) Way Too Little

All the results in Figure 2 are skewed to the left: thus the students felt strongly positive about the flipped-classroom approach. In particular, their self-assessment of its helpfulness (Q1) in learning is quite strong. Similarly, they felt strongly that the flipped approach had a significant contribution to the quality of the course (Q6). They also felt strongly that the approach should be used in other engineering and math course (Q7). Although the response about retention (Q4) is not as strong as the others it still indicates that students feel there is great value in the approach.

The results in Figure 3 focus on the videos. The overall quality of the videos was regarded quite highly (Q8 & Q9). The duration of each video and the duration each week were deemed about right (Q10 & Q11). Although the results on "consumption" of the videos (Q12 – Q15) was not that positively skewed it still shows that most students made significant use of the videos, though not necessarily for studying for the exam.

The results in Figure 4 focus on the in-class structure. The iClicker quizzes provided moderate motivation to watch the videos (Q17) but the in-class summaries and problems were significant in helping students learn (Q18 & Q19). The students wished they had been in a room that allowed more interaction with the professor (Q20). Students want to have at least some examples

done for them in class before they have to work on the problems (Q21). Students found the homework helpful but thought that an assignment each week was a bit much.

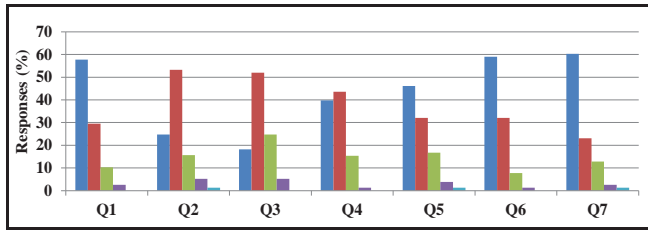


Figure 2: Survey results on general flipped approach. Bars left to right are (a) – (e) responses.

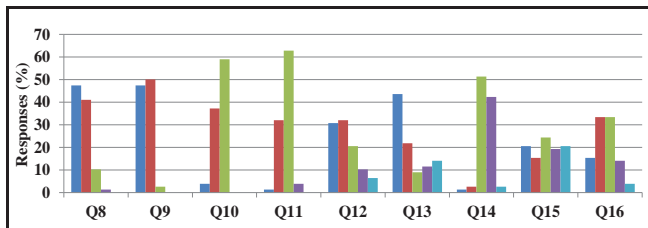


Figure 3: Survey results on video used in course. Bars left to right are (a) – (e) responses.

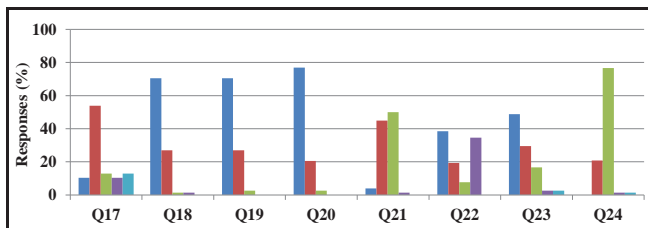


Figure 4: Survey results on in-class activities used. Bars left to right are (a) – (e) responses.

5.2. Grade Analysis

Figure 5 shows the results of an analysis of the midterm grades for Fall 2009 through Fall 2012; Fall 2012 was offered in the flipped format as described here and the previous years were offered in a traditional lecture format. In each year there were five midterm exams and the results shown here are the averages of student grades on the five midterms. The midterms were different each year but were felt to be equivalent in scope and difficulty. The midterm average grade for Fall 2012 was 4.5 points higher than the average of the previous four years' averages; thus, if the final grade were based only on these midterm averages the average of the previous four years corresponds to a C+ and Fall 2012 would correspond to a solid B – two notches higher. This data provides additional support for the potential benefit of the flipped classroom in signal processing, as was seen in [6].

However, the midterm exams assessed only problem solving skills. Thus, Figure 6 shows results on the final Concept Inventory Exam given in the course are shown in. This is patterned after the

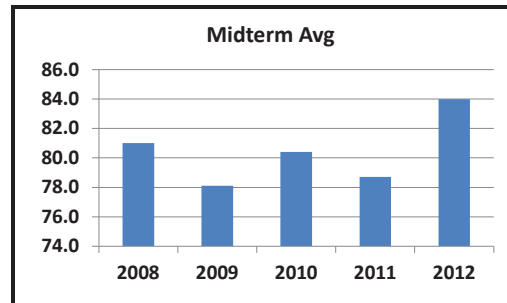


Figure 5: Analysis of midterm exam averages

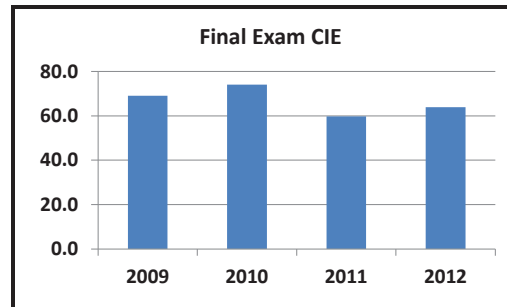


Figure 6: Grade analysis of final Concept Inventory Exam

standard CIE available for signals and systems [12] but is not exactly the same; however, the same questions are given each year (care is taken to control access to the questions). Unlike in the usual use of CIEs, it was not offered at both the beginning and the end of the semester. Surprisingly, the performance by the flipped-classroom students did not show the same significant improvement as they did on the problem-based midterms. In fact, they only did better than one of the previous four years (and just barely). Thus, it seems that one potential downside of problem-based in-class activities is that students' conceptual understanding does not improve and may even suffer. This may be due to the flipped classroom driving students toward the view that if they can "do" the problems they don't need to "understand" the concepts; this issue needs to be further addressed. In my current Fall 2013 offering I have tried to stress the concepts more: some in-class "problems" are more concept oriented and I try to stress the concepts more in the in-class summaries.

6. CONCLUSIONS

This paper has provided details on one way to flip a signals and systems course. Survey results show that the flipped-classroom approach has great appeal to students and they wholeheartedly "buy into it". Analysis of problem-based midterm exam grades showed that the students' performance significantly increased with the flipped classroom: grade letter-grade notches from C+ to B. However, Concept Inventory Exam results decline for the flipped class.

Some of the keys to success with flipped classes are (i) ensure you have a suitable room that allows easy access to all students, (ii) put maximum effort into the creation of effective in-class activities, (iii) don't worry too much about the "production quality" of the videos, and (iv) seek effective ways to emphasize conceptual learning.

7. REFERENCES

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