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Using a ”Flipped Classroom” Model in Undergraduate Newtonian Dynamics

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Flipping a Newtonian Dynamics Classroom

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Abstract

A flipped classroom approach was applied to a select number of topics in a sophomore level undergraduate Newtonian dynamics course. Although the theory and benefits of the flipped classroom model are discussed, the primary focus of this paper is to present the approach and the practical implementation of using this model. Advantages, such as student retention and reduced faculty tutoring, are discussed, as well as disadvantages, such as the investment of time needed for making the videos and the amount of time needed to learn the software. Lastly, best practices and lessons from the experience are shared.

Background and Theory

In recent years the concept of the flipped classroom has gained popularity and has been shown to improve student learning [1]. We decided to integrate this approach into our undergraduate Newtonian dynamics class to leverage technology, optimize active learning with instructors present, and reduce faculty tutoring loads. In this method of teaching, the in-class time is dedicated to active learning, while the lectures leverage technology to supplement in class time with on-line videos.

The lower levels of learning in Bloom's taxonomy [2], such as remembering and understanding, are delivered to the students through on-line lectures. The higher levels of learning, such as applying, analyzing, evaluating, and creating, take place in the classroom with the instructor as a guide. To achieve this, in class time is devoted to guided instruction where students work through problems and examples with the instructor present to provide assistance and answer questions. Figure 1 shows a simplified illustration of the flipped classroom paradigm.

The current college age students have been dubbed the Millennial Generation. Howe and Strauss [3] document the seven core traits of the millennial generation. One of these traits, that is of particular interest to us, is that millennials are more team oriented than prior generations. More students report socializing in groups and fewer students feel lonely. With advances in peer-to-peer technology, such as Facebook and Twitter, students are even more connected to each other. In 1959 James Bryant Conant's report, "*The American High School Today*" [4], promoted an educational structure where honors students were tracked into more advanced classes than some of the other students. Many Baby Boomers and most of Generation X grew up in this structure. Today, especially in the younger grades, schools are combining students into environments were collaborative learning happens. [5] Since the students have grown in the team environment, it is natural for them to feel comfortable using technology in a learning environment.

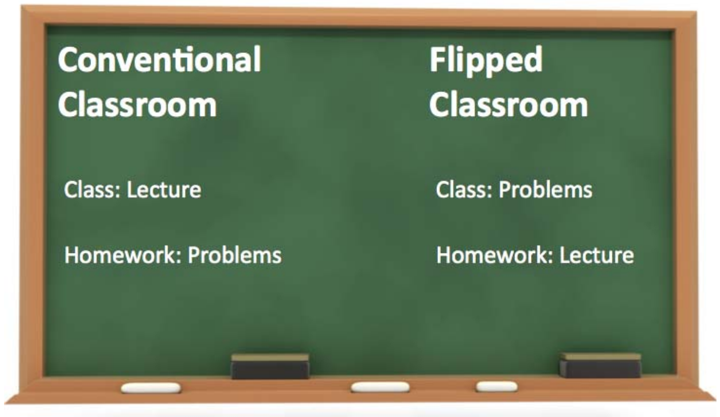

Figure 1: Flipped Classroom Paradigm

Millennials have also been dubbed “Digital Natives” [6], i.e., people who grew up in the digital world. Older generations are “Digital Immigrants”, or people who had to adapt to new technology. Millennials are comfortable with technology and enjoy the integration of this technology into their learning environment. For a generation that grew up “in technology” there is a natural extension to using technology in their classes.

In 2010, Poh et al. [7] studied the electrodermal activity (EDA) of MIT students over the course of a typical week. EDA is a sensitive index of sympathetic nervous system activity and a high level of EDA indicates when a person experiences physical, cognitive or emotional stressors. The study showed that students had significant EDA activity when they were doing homework and taking exams, but only moderate levels of activity when they were being social and in laboratories. The students had the lowest level of activity when they were in class; these levels were similar to the levels seen when the student was watching television. From a pedagogical perspective, this is concerning; at the times we expect our students to be learning, their EDA is at its lowest. The flipped classroom the students would be most engaged with working problems when they are interacting with the instructor.

At the US Coast Guard Academy (USCGA), like many other schools, the students are overcommitted. Over 70% of our students participate in varsity athletics. On top of normal student activities, like academics and athletics, our students also have additional military duties and responsibilities. As a result, USCGA students are often sleepy in class. One primary reason we considered this new model for teaching was to mitigate this atmosphere; we want to have the instructors engage with the students when they were the most active.

This model offers advantages not only in improved student-teacher interactions, but also in student retention [8]. Lang and McBeath, [8], suggested people only retain 5% of a lecture and 30% of in-class demonstrations. Retention has been shown to be significantly greater when classroom instruction includes group discussion (50%), individual practice (75%), and opportunities to teach others (90%). Additionally, the model offers the opportunity to leverage technology in a setting where undergraduate students are attuned to using technology, more teamwork oriented and have a disposition to using technology in a student-centered learning environment.

Most examples of the flipped classroom paradigm have been applied in science courses, but far more rarely has it been applied to engineering courses. As a result, the application, implementation and cost benefit of this model in engineering courses is not well documented. At the USCGA, students in the Civil Engineering, Mechanical Engineering, and Naval Architecture and Marine Engineering majors are required to take an undergraduate course in Newtonian dynamics. Typically, the course has been taught in smaller sections (20 person average) using a classical approach and delivered by traditional lecture. Because of the smaller class size, three to four instructors usually teach one or more sections each. While each instructor prepared their own lecture, lecture notes and examples were often shared to ensure consistency between the sections.

Since the USCGA is only an undergraduate institution, there are no graduate students and no teaching assistants to aid in the tutoring or grading for courses. Newtonian Dynamics at the USCGA has traditionally had an abnormally high tutoring load for instructors (often greater than 10 hours per week per instructor) due to the difficulty of the material and the lack of teaching assistants.

In the spring of 2013, the dynamics course was taught by four instructors across six different sections. In an effort to maximize the student-teacher interactions in each class afforded by the flipped classroom model, enrollment in each section was limited to 17 students. The flipped classroom model was not used for all topics and classes; instead, the model was used at targeted times when multiple lecture periods were spent on the same topic. In these cases, the initial lecture for each topic was presented to the class in a traditional lecture style while subsequent lectures on the topic were videotaped and watched by the students outside of class time. The specific details of the approach and implementation follow.

Approach

In order to assess the utility and cost-effectiveness of this approach for both faculty and students, we decided to implement this new model in a tightly controlled manner. For this initial study, only six topics of twenty were selected for presentation in the flipped classroom paradigm. When looking at our syllabus, we identified core topics in the Newtonian dynamics class which we had historically taught over multiple lecture periods. We wanted to choose topics that had more than one day on the topic so that we could cover theory on the first day on the topic using a traditional lecture style. We then used the follow on days to video tape examples and have the students watch them as homework, and we used the lecture time for the students to work problems. The six topics were spread throughout the semester, with the first occurring in the third week of the semester, and then occurring approximately every two to three weeks. The topics chosen were:

1. Particle Kinematics
2. Particle Kinetics

3. Rigid Body Translation and Rotation
4. Rigid Body Kinematics
5. Rigid Body Kinetics
6. Oscillations

Since this was our first application of this model, we employed a standard flipped classroom format. In this protocol, a video lecture was recorded and placed online for students to view outside of the classroom. During the next scheduled class meeting, the video would be briefly discussed and questions about the topic material were answered. As an additional incentive to watch the video, students were also required to take a short quiz. The quizzes generally lasted less than five minutes and focused more on dynamics general concepts than specific or theoretical details, i.e., the goal of the quiz was to encourage the viewing of the video more than the assessment of learning. We found that basic and broad questions on the material required students to view the videos, but did not burden them with remembering minutiae of the material presented. In some cases we even asked video-specific questions, e.g., who presented the video lecture. To add further incentive, the impact of quizzes on the final course grade was also increased from previous offerings of the course.

We also provided the students with example problems, which were to be completed in class during the next course meeting, before they watched the lecture. To promote active learning, we encouraged students to attempt the problems before they got to class. At a minimum, the students were expected to complete a free body diagram and an inertia diagram. Following the in-class quiz, students worked through these example and homework problems with the oversight and assistance of instructors (guided practice problems). Students could work independently or in small groups; in either case, instructors were available during these classes for questions or clarifications on the individual problems or the subject matter in general.

Implementation

The flipped classroom model consists of both and in-class and out-of-class components. While the in-class component is well defined and generally accepted as guided student practice; the shape that the out-of-class component takes is not well defined and can be somewhat elusive. The out-of-class component can be as simple and informal as recording ad hoc lesson summaries (audio only) to a more formal and involved treatment of course material in fully recorded video lectures (with or without post-production editing). Unfortunately, the breadth and scope of out-of-class audio-video content often appears to be a function of production and time limits, e.g., ease with production equipment, rather than institutional goals and/or student need.

At the Coast Guard Academy, a large element of our student experience involves student interactions with faculty advisors and leaders. Through these mentoring opportunities, students are exposed to new ideas and different ways to approach problems. In order to maintain this level of interaction, an in-kind replacement of traditional lectures with video lectures would be unsatisfactory. Instead, our aim was to produce video segments that supplemented classroom lecture material and demonstrated sound engineering solution approaches by means of example and review problems.

To this end, each video was constructed in the following format:

1. Review of Key Concepts. The review of key concepts included an overview of the topic at hand and the discussion of the material presented in class. Questions that had been brought up in the traditional lecture on this topic were addressed. The mathematical derivation of theories, laws and or formula was also reviewed.

2. Simple Example Problem. The first problem covered in the video sequences was easier relative to the second one. In many instances this was a more straightforward or direct application of the principle.

3. Complex Example Problem. The second problem was usually more involved often requiring multiple steps or concepts.

Although research indicates that this model is advantageous to both students and faculty, the overhead associated with developing and leveraging this type of approach was daunting. One drawback of the flipped classroom can happen when instructors invest too much time making high quality full length videos. One of our major concerns was the amount of time required to develop, record, edit and produce the video. Depending on the length and scope of the video, research indicates that production time can range from one hour and fifteen minutes for 30 minutes of simple video [9] to ninety minutes of production time to record 5-10 minutes of summary lecture [10]. These figures presume that the lecturer had the required technical skills necessary to produce the video or a technician available for assistance. Post-production editing can also add time and expense to the video production costs. Chandra [11] reports that the in-house Audio/Visual department at the University of Notre Dame charges $100/hr for video recording and an additional $120/hr for editing and digitization of the video. A typical 30 minute video with one hour of editing and digitization can cost an average of $400.

In the videos, our goal was to keep the attention and focus of each student while demonstrating the logic and process used to solve each problem. Since this was a prototype evaluation of the flipped classroom approach, the authors deliberately chose commercial hardware and software familiar to them. The course videos were recorded using Camtasia Studio software installed on a MacBook Pro laptop. This software is fairly easily to use, tenders relatively low production costs, and it can capture any media present on the computer itself, e.g., audio, video, text, freehand, etc. We used a WACOM Bamboo tablet with WACOM native “Notebook” software to interactively generate our lecture notes and example problems. Notebook software allows the capture of freehand text and includes a robust variety of editing and creation features including shape templates, stylus patterns and line colors. These features helped to highlight different aspects of the example problem and helped to achieve consistent format throughout each video series. For example, free body and inertial diagrams were always created using a blue and magenta pen color combination; critical terms of each governing equation were highlighted in green ink. Figure 2 shows a screen capture of video lecture that illustrates the different editing features used in the development of the video lectures.

We performed minimal post-processing editing on the videos after they were recorded to avoid spending a significant amount of time for only a potentially small gain in our eyes. For example given the short preparation time the majority of the online notes were handwritten and diagrams hand drawn, the video presentations were made in one long take and briefly edited to remove any errors. In keeping with recommended practice, we aimed for a maximum video length of 30 minutes. In addition, the videos were created in smaller segments for easier student access, viewing and recollection. In the end, the theoretical review of the material and review of key concepts averaged12 minutes, the first simple example problem averaged 8 minutes and the more challenging problem averaged 14 minutes of video time. Although these times were slightly longer than we had anticipated, the relative emphasis and proportion of the time to each topic seems appropriate.

Once the videos were produced, a viewing hyperlink was provided to students via the Desire2Learn Learning Management System used for this course. Videos were also posted on YouTube. The near ubiquitous availability of the videos helped our extremely busy students access the videos from nearly any location at any time. Students appreciated the ability to download videos to tablets and phones to watch off line during bus trips or off-campus activities.

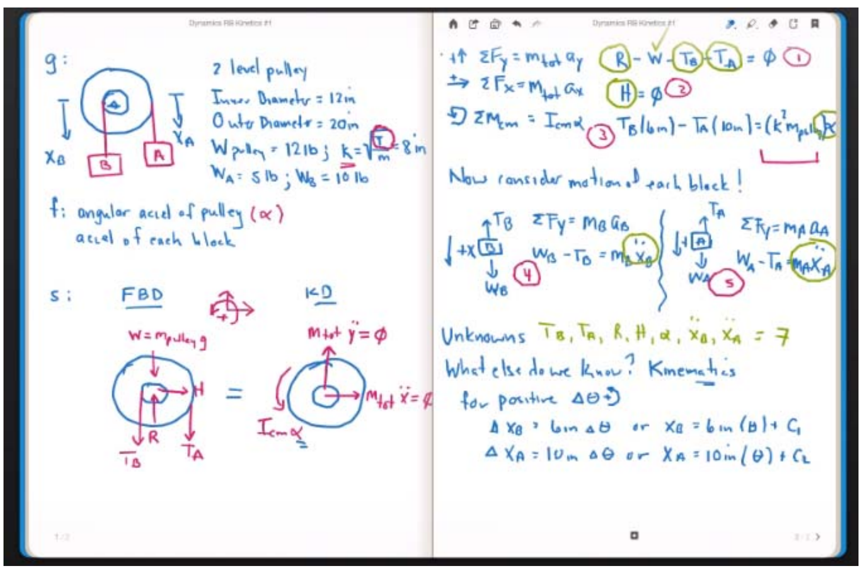

Figure 2: Screen capture of video lecture

Outcomes and Feedback

Student feedback, taken both during the semester and at the end of the semester, about the flipped classroom model was generally positive. Informal and anecdotal discussions with students about this approach were very positive. Students also completed an end of course, anonymous on-line survey. While the students were not specifically asked about the flipped classroom model (limits of the standardized survey used for all engineering courses), many students elected to comment on the approach in the free response section of the survey. Some student feedback included:

- “More "Flip the classroom" days where video lectures are [the] homework. Those lessons were very effective for me and made it easier to get help.”

- “The videos were really helpful because you could go back and look at them again if you were confused; so, as many of those as you can get in, the better.”

- “I did find the videos sent out to be highly beneficial. Even if they didn't substitute homework [for in-class time], I would have gladly viewed more of them on my own to understand the material better.”

Unfortunately, we did notice that as the semester progressed, student preparedness for the in-class segment of the flipped classroom model decreased. At the beginning of the semester, the students came to class prepared; most, if not all had watched the required video and the majority had started the sample problems. As the semester progressed, only the highly motivated students started the example problems before class; as a result, we feel that they received the most from the flipped classroom model. The less motivated students, and those students overwhelmed by other obligations, generally came to class unprepared. Not surprisingly, these students were often the ones who struggled the most with the course material. Although the flipped classroom model did not appear to hinder these students, they did not appear to gain as much from the method as the more highly motivated students. When we use this method again, we will need to find a different way to incentivize video viewing for this group of students.

Data across the 2011-2012 and 2012-2013 academic years highlight benefits of this approach. In these academic years, two of the dynamics instructors had classes with very similar ability levels. The cumulative GPAs of the students in these classes were within 0.2 of each other. When looking at Prof. Swithenbank and Prof. DeNucci’s classes the averages before the final exam in 2012 were 78.2 and 79.5, whereas in 2013 the averages were 77.1 and 80.7. The grades during the term did not appear to be affected by the flipped classroom model. Since different homework problems, quizzes and exams were used it is hard to compare these values. The final exam was constant between from 2011 through 2013. The same final exam was used during these academic years and the final exam was held on the last day of the exam period in both years. The same instructor corrected the final exam both years as well. For the classes that were analyzed, in 2012 the exam averages were 69.4 and 65.1, whereas in 2013 they were 75 and 73.8; a rise of over five points in all sections analyzed. Since the prior year students were not allowed to see the exam after they took it, and with a strict honor code, the probability of students having prior knowledge of exam content was extremely small. A more controlled longer term study is needed for definitive number, but on the surface this appears to be an improvement in the students' ability to retain and apply the information learned in the course, especially during a cumulative and comprehensive final exam.

The flipped classroom was not the only course change between the 2011-2012 and 2012-2013 academic years. Although the course material was the same, an optional recitation section was added to the course. The recitation section provided additional opportunities for students to seek extra help and assistance from an instructor. The additional recitation sections may also have contributed to the improved long-term retention of the material and increased grades on the final exam.

We feel that increased student-teacher interaction generally benefits the student regardless of its application; the flipped classroom paradigm is one approach that encourages this. Since one goal of the flipped classroom was to improve student-instructor interaction and active learning, the instructors felt that the addition of this optional recitation was aligned with this philosophy. Student-instructor interactions, whether by formal recitation or during informal office hours, improves active learning and should be explored further in the future.

Best Practices and Lessons Learned

While the pedagogy and reasoning for using the flipped classroom were abundant, details on how to approach the flipped classroom were more difficult to find. One of the objectives for this paper was to document the details of what we did to implement the flipped classroom, including details such as software choices, video length, and topic used. Here are the things that we learned and wished that we had known when we started this.

1. Do not be afraid to try new things. When Prof. DeNucci, first brought this idea to Prof. Swithenbank, she was not excited about this. It was new and different, but after further reflection, she thought "why not give it a try?" This may work for you and it may not, but it was definitely worth trying. We would use this method again after trying it while incorporating some of these lessons learned.

2. Preparation will reduce the amount of time it takes to produce the videos. Since most professional academics are not savvy at improvisation, having a plan is important in terms of both cost and personal comfort. One successful approach involves scripting from a set of well-written notes.

3. Do not be a perfectionist when recording or editing the videos. When we lecture in class, there are always unexpected errors or goofs that occur. These things will undoubtedly happen in the videos, so do not worry. You can fix nearly anything with editing; and most everything else is probably just okay.

4. You need to find the right incentive for getting your students to watch the videos. There are many methods involving both positive and negative rewards, but what matters most is

what works for YOUR students. Since the USCGA is a unique military environment, what works here, e.g., extra sleep, extra food, etc. may not work elsewhere. Find what works for you and go with it!

5. Make sure to hand out the in-class examples ahead of time. The students who had started the problems and came to class engaged and ready to ask questions got far more out of the experience than the students who first read the questions when they arrived in class.

6. Don’t be afraid to change your approach. Seek feedback. If 15 minute videos are not working for your students, then find out what does! Remember, this is as much a learning experience for you as it is for them.

7. Do not get discouraged! There is a definite learning curve for both instructors and students; this is often coupled with a mental shift away from the more traditional approaches to classroom instruction. Finding out what works for both of you may take a little time. Give the method a chance to fully develop before you decide whether this works in your environment on not.

Conclusions and Future Work

The student and instructor feedback to the flipped classroom model was positive. The students enjoyed the increased instructor interaction in the classroom and the leveraging of technology. The students indicated that this approach made more efficient use of their time, especially in light of their busy schedules. The instructors experienced a reduced tutoring load with improved scores on the final exam. Although, this exam showed some evidence that the students retained more information than in previous semesters, a longer study with more controlled variables is needed.

The most difficult aspect of this approach was incentivizing the watching of the videos. We used in-class quizzes, but we are not sure that they truly captured whether the students had watched the videos or not. One option may be to include in-situ quizzes during the videos. Other forms of incentives should also be considered.

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