Views on Flipping Engineering Thermodynamics

James V. Canino, Trine University

Abstract

The goal was to implement a flipped classroom in an engineering thermodynamics class to provide a more interactive learning environment and to improve student learning. A flipped classroom means the students watch recorded lectures at home, thereby freeing up class time for working problems or other activities. Software programs required for flipped lectures, such as BB Flashback Express and Camtasia for producing the screencasts and Vimeo as the video hosting site, are discussed. Specifics on how the flipped classroom was implemented include the use of fill-in-the-blank notes, classroom worksheets, and classroom rules. The results from student questionnaires gauging student satisfaction with the flipped classroom along with the instructor's own views on the success and failures of this effort are shared. Future plans for the flipped thermodynamics class might focus more on applying knowledge and less on course content through the use of open ended problems, experimental investigations, and other interactive activities.

Introduction

For two-thirds of a fall semester 2012 thermodynamics course at Trine University, a flipped classroom paradigm was used. In a flipped classroom, videos or screencasts of the lectures are created by the professor that students then watch outside of class. Class time, therefore, is used for activities other than lecture, which serve to reinforce the ideas contained in the lecture. Often times, as was the case for this thermodynamics class, class time is spent on homework problems or worksheets with collaboration from the faculty member and other students. The underlying idea of a flipped classroom is that listening to a lecture requires little effort by the students, while doing homework problems is a thought-intensive activity. Thus, it would be most useful to the students if the faculty member was available when they were working on problems. The flipped classroom allows the professor to be available to the students when they need him or her the most.

Additionally, this particular professor flipped his course for a more personal reason. As a parent of a Montessori school student, he believes that Montessori teaching methods are superior to the traditional classroom in allowing the students to develop critical life skills beyond the simple content of the class.[1] In spite of this belief, his thermodynamics' classroom looked similar to the lecture-based classrooms representative of most American universities. Upon gaining a deeper understanding about Montessori education, however, the professor wanted to try incorporating some of these new educational methods into his college curriculum. Thermodynamics was selected due to the instructor's familiarity of the course (i.e., having taught it four times previously in the past three years) and since all the lectures were already prepared (albeit in traditional lecture style). This allowed the author to focus solely on flipping the classroom without developing the content of the class from scratch.

Creation of the Screencasts

In the author's traditional lecture-based classes, fill-in-the-blank notes are provided to all of the students. During the lecture a Tablet PC which is attached to the classroom projector is used by the professor to complete the missing information, much like one might use an overhead. The blanks in the notes are usually key concepts or example problems. This allows the students to continue to be active in class while providing them with graphics and tables that would be difficult or impossible to reproduce on a whiteboard.

To prepare for implementing the flipped classroom, the thermodynamics lecture notes were divided into approximately 10 minute chunks. A 10 minute target was selected after noting that many of the videos on Khanacademy.org (a popular online education site) seemed to be about that length. When the material demanded it, the screencasts were allowed to be longer than 10 minutes. For example, some of the example problems concerning vapor power cycles were approximately 25 minutes. It did not make sense to attempt to break up this example problem, so the 10 minute guideline was ignored.

Once the notes were divided into chunks, the screencasts were recorded using BB Flashback Express. BB Flashback Express was selected because it was free and simple to use. After BB Flashback Express is downloaded a user can record a screencast by simply pressing the large red record button, and the software will record everything that happens on the screen. Additionally, a microphone headset was needed, so that BB Flashback Express could record audio as well.

Similarly, Camtasia was used to produce a few screencasts. Camtasia had a superior ability to BB Flashback Express to zoom in on particular sections of the computer screen after the screencast was recorded. This zoom ability was especially valuable during the demonstration of MATLAB since it was easy to zoom in on the commands as they were being typed. The downside to Camtasia, however, was that with increased post-processing options, the time to make a screencast increased. For instance, it took about 30 minutes to record a 10 minute screencast in BB Flashback Express (excluding the time required to export the screencast). With Camtasia, in contrast, it took approximately 60 minutes to produce a 10 minute screencast. Again, the additional time resulted from the complexity using the zoom tool during post-production. In the end, it was decided that while the zoom tool was a beneficial feature it took too long to produce the required screencast and Camtasia was no longer used.

Screencasts were then uploaded to Vimeo. Vimeo was selected because each video can be password protected and made private. A private video does not show up in a search result. It was important that the videos be password protected due to the significant amount of copyrighted content used in the fill-in-the-blank handouts. Furthermore, Vimeo is free to use. The one downside in using the free version of Vimeo, though, is that once a video is uploaded to their site it will take approximately 35 minutes before the video is available to be viewed. If a user upgrades to Vimeo Plus, at a cost of approximately $60 per year, then the video can be viewed almost immediately. Once the videos were available to be watched on Vimeo, a link to the relevant videos was provided to the students via Moodle.

Preparing Materials for the Classroom

A worksheet was prepared for the students to do during class time. The worksheets started with two to four basic conceptual questions from the screencast associated with that day's work. Additionally, the worksheets had one or two problems the students could work on during the 50 minute class. Usually the worksheet problems were the previous semester's homework problems. The three worksheets assigned over the course of a week were turned in and graded the following Friday. For example, the worksheets assigned from Monday October 15th thru Friday October 19th were due on Friday October 25th. This was similar to the instructor's practice of assigning homework on Fridays, due the following Friday.

Homework, in addition to the worksheets, could be assigned as deemed necessary. In the roughly 12 weeks that the thermodynamics class used the flipped format, homework beyond the worksheets was assigned about four times. In each case, homework was assigned because all of the previous semester's homework problems were not incorporated into the worksheets. One cautionary note in this area is to resist the temptation to increase each student's workload by assigning the same amount of homework as the previous semester, as well as the in-class worksheets. The guiding principle was to make sure that the students did approximately nine hours of work per week in accordance with the Department of Education's standard definition of a 3-credit class.[2]

In the Classroom

At the beginning of class, the day's worksheet was handed out and the instructor asked if there were any questions on the previous night's screencasts. Only in a handful of cases did the students ask questions about the videos they had watched. It is unknown if this failure to ask questions was the result of 1) not watching the videos, 2) because the students understood the material that had been presented, 3) or because the students simply wanted to get started on the worksheets. Once any questions were answered the students were encouraged to get into groups and begin on the worksheets. To the surprise of the instructor, students initially seemed reluctant to engage with each other on the worksheets. It took several class periods for groups to form, and even then there were a few students who did not connect with a peer group.

Over time the way class time was managed by the professor changed as well. At first, the instructor believed that if students got stuck they would ask for assistance; this was an inaccurate assumption. Although the professor was there for the sole purpose of assisting with problems (and was not doing any other work, such as grading), students still did not seem comfortable asking for help. Over the first few class periods students seemed to struggle with the material without asking for assistance. While allowing a student to struggle with material might be beneficial to the student's learning, it seemed to go against the basic idea of a flipped classroom. After all, the primary purpose of flipping the classroom is so that students can get assistance quickly when they need it the most. Therefore, it was determined that every student in the class would get at least one personal contact by the instructor during each class period. To this end, the instructor moved about the classroom asking students if they were having any trouble with the material. The students seemed to answer this question in one of three ways:

1. No, I understand the problem and solution method.
2. Yes, but I think I can figure it out on my own.
3. Yes, please help.

It was the second answer, which was given frequently, that was the most surprising. It seemed that the students had a good idea of when they needed assistance, but also, and perhaps more importantly, when they believed that thinking about the problem a little longer would allow them to puzzle out the answer.

This personal interaction with each student was easy to implement given that there were only 13 students in the class. In most class periods the professor interacted with each student multiple times. Therefore, it seems likely that an instructor could have a personal interaction with approximately 50 students in a 50 minute class.

Additionally, three basic rules regarding the use of class time developed organically over the semester. First, since group work was encouraged, some socializing was acceptable. It seemed that the students were more likely to interact with each other on the thermodynamics worksheets if they spent a few minutes socializing. Overall, most students worked for greater than 45 minutes on the worksheets. The second rule was that students must work on thermodynamics, but not necessarily on that day's worksheet. Often times students wanted to complete the previous day's worksheet before moving forward. This seemed reasonable and was allowed to continue. The final rule developed was that quizzes about previous night's screencasts were not given. It was observed that some students decided to learn the material by reading the book. In one case, a student spent almost all of the class time reading the book, and was able to answer the conceptual worksheets questions. This particular student did very well on the exams, thus, it seemed unnecessary to require the students to watch the screencasts if they could acquire the requisite knowledge in some other way. Also, it was important that the student not be given extra work simply because of the flipped classroom.

Effect on Learning

Since only one section of thermodynamics was taught in the Fall of 2012, a direct comparison between a class that received standard lectures and a class that used the flipped model was not possible. In an effort to compensate for this, the material for the first exam was taught using the standard lecture method, while the material for the second exam was taught using the flipped model. Then the mean performance of the students from the Fall 2012 class were compared to the mean performance of the Fall 2011 and Spring 2012 students where only a standard lecture method was used. The results of this analysis are presented in Table 1.

Table 1. Comparison between using only lectures (Fall 2011 and Spring 2012) and lectures for Exam 1 and flipped for Exam 2 (Fall 2012)

	Flipped Class (Fall 2012, N=13)	Standard Lecture Class (Fall 2011 + Spring 2012, N=33)
Mean grade for Exam 1 (Standard Lecture)	80.2	78.9
Mean grade for Exam 2 (Flipped or Lecture)	76.3	70.6
Mean increase/decrease	-3.8	-8.3
Standard deviation in the increase/decrease	18.2	20.3

The final exam grades of the standard class and the flipped Fall 2012 class were both 77.5%. The data indicates that the flipped classroom may have increase student learning some, however, there is a significant standard deviation in the increase/decrease from exam 1 to exam 2 for both sets of students.

Moreover, it must be understood that no attempt was made to control confounding variables such as class GPA. Therefore, it is difficult to draw any definitive conclusions based on the above data. However, it is the author's opinion that if GPA had been controlled for, there would be little difference between the two groups' (standard versus flipped) performances. This opinion is based on the fact that if a student is proceeding through the mechanical engineering curriculum at the standard pace, they should be in thermodynamics in the Spring semester. Therefore, it is likely that some of the students in the Fall class had failed previous classes or were off track for some other reason. This hypothesis is reinforced by knowing that the Fall 2011 and Spring 2012 student's performance (both using the standard lecture model) were significantly different from one another. Specifically, the mean final exam grades for the Fall 2011 and Spring 2012 students were 69% and 80.2%, respectively. Nevertheless, additional research is needed to support this hypothesis and, in doing so, to determine the effect of a flipped classroom on student achievement.

Student Response to the Flipped Classroom

Students who experienced the flipped classroom received two anonymous surveys. The first survey was administered after the material for the second exam was completed, but before the students had taken the second exam. In this survey only one question was asked: "Do you want to continue with the flipped classroom model?" Eleven of the 12 students who responded to the survey answered yes—they wanted to continue with the flipped classroom. As will be discussed later, their enthusiasm for the flipped classroom seemed to wane over the semester.

The second and more extensive anonymous survey with 21 questions was available online to the students during the last two weeks of the semester. Only 8 of the 13 (62%) students responded to the survey, however, these eight students had a divided perspective of the flipped classroom model. For instance, Table 2 shows that only half of the respondents would want more of their engineering classes to use the flipped classroom model. Similar results were obtained when students were asked if they would recommend a class that used a flipped classroom to their friends.

Table 2. Responses to "I wish more of my engineering classes would utilize the flipped classroom model."

Response	Average	Total
Strongly Agree	12%	1
Agree	38%	3
Neutral	12%	1
Disagree	25%	2
Strongly Disagree	12%	1

Part of the change in attitude might have to do with students getting behind on watching the screencasts outside of class. As Table 3 shows, only three of the eight students (38%) watched all of the screencasts with one student watching fewer than 25% of the videos. When students got behind on watching videos they found class time to be pointless. After all, they could not answer the questions on the worksheets without watching the videos or reading the book.

Table 3. Responses to **"**Approximately what percentage of the lecture videos did you watch?"

Response	Average	Total
100%	38%	3
75-99%	38%	3
50-74%	12%	1
0-24%	12%	1

In private conversations with the friends of students that experienced the flipped classroom, the friends indicated to the professor that getting behind on watching the videos was a major problem. Other instructors address this issue using daily quizzes (so called "entrance quizzes"). This idea, though, seems to undermine the didactic notion that students should take responsibility for their own learning.

It was hoped that one of the outcomes from using a flipped classroom would be that students would develop independent learning skills. In fact, as Table 4 shows, 63% of the students believe they were more independent learners after taking thermodynamics (although no student "strongly agreed" with this statement). If this were the only positive outcome of using a flipped classroom it would still be an important one. In particular, this clearly helps students as they proceed through the rest of their college curriculum. Furthermore, it aids in fulfilling ABET's requirement that students engage in lifelong learning.

Table 4. Responses to "I believe I am a more independent learner than I was previous to the flipped thermodynamics class."

Response	**Average**	**Total**
Agree	63%	5
Neutral	25%	2
Disagree	12%	1

The screencasts resulted in another advantage to the flipped classroom, which was the ability for students to watch the lectures multiple times. As seen in Table 5, six of the eight students (75%) replayed some portion of the lecture. Somewhat surprising, though, only one student replayed the videos before the exams. Therefore, it seems that students were replaying the videos because they missed some information in the screencast. Having the videos available to the student allows them to re-watch something they might have missed without the fear students usually have of making a fool of themselves for asking the professor to repeat something.

Table 5. Responses to **"**On average, how often did you replay portions of the lecture?"

Response	**Average**	**Total**
Never	25%	2
Once	38%	3
2-4 times	25%	2
More than 7 times	12%	1

Instructor Response to the Flipped Classroom

Some instructors believe that students will not attend class if they can watch the videos online, but that was not the case in this thermodynamics class. As shown below only one of the eight students survey participants said that they skipped class more often.

Table 6. Responses to **"**Was your class attendance affected by using the flipped classroom model?"

Response	**Average**	**Total**
Yes, I attended class less often	12%	1
No	88%	7

As a matter of fact, the professor found the availability of the videos to be very beneficial when students missed class due to illness. In one case a student was sick for a week, but was able to stay up with the lecture material while recovery in his dorm room. This meant that the student did not have as much work to make up once he was healthy.

A second benefit was the additional personal interaction that the professor had with each student in the class. Interacting with the students every class period made it easy to determine which concepts were understood and which concepts needed more focus. This allowed the opportunity to provide greater clarification of any misunderstandings using concept questions or problems on the next worksheet. Also, increasing contact with the students made the class more enjoyable since the instructor was involved more directly with learning as opposed to restating the same general lectures he had presented for the past two years.

Nevertheless, there were some perceived negatives to using the flipped classroom. First, very few students came to office hours. Students in thermodynamics came to office hours approximately three times during the semester. This might have been because students knew they could have their questions answered during class time or because the interactions with the instructor during class meant that all of their questions were already answered. The exact reasons for the decrease in office hours visits should be addressed in future research.

Second, the instructor missed telling "stories." Professors often tell stories to demonstrate how key concepts relate to the real world or to highlight their own personal experiences regarding the importance of a topic. A thermodynamics instructor might, for example, point out that many power plants are near bodies of water due to the requirements to reject heat. Since the students were not present when the screencasts were recorded, it did not seem appropriate to add these stories. It simply felt strange to tell a story when no one was present to hear it in real time. Therefore, the instructor went through the material in a straight forward manner eliminating these anecdotes. The effect of eliminating these anecdotes is unknown, but the author does feel that perhaps the students missed something because they were not told these anecdotes.

Finally, creating all of the screencasts and worksheets for a flipped classroom takes a significant amount of time. The screencasts were done during the semester and were often done on Friday nights so they would be available to the students over the weekend. A typical lecture would consist of three 10 minute screencasts. As stated previously, it would take about 1.5 hours to record these lectures. Once the screencasts were made, a lag-time of approximately two hours existed before BB Flashback Express converted these videos to a format that could be uploaded to Vimeo. With current high speed internet connections it takes nearly 10 minutes for the videos to upload to Vimeo, but there is still an additional 40 minute wait before the links to the videos can be shared. Thus, on average, the time between starting to record the video and finally posting the link to Moodle was around five hours. Granted, other work could be accomplished during some of this time, but the whole process still takes the entire night to complete. Despite these drawbacks, this instructor would still try a flipped classroom again because of the increase in interaction with the students.

Changes to Future Flipped Classroom Experiences

The following changes will be given serious consideration for future flipped classrooms.

- Encourage more student interaction by arranging the room so as to be conducive to collaboration. For example, in future flipped classrooms it would be better to have round tables that students could work at in groups than the standard longs tables that were present in the classroom.
- Determine if it would be possible to set up a system where students move at their own pace. In this scenario all of the videos and worksheets would be available to the students at the start of the semester with instructions on which screencasts are required to understand subsequent screencasts. So that multiple exams over the same material would not have to be written, students would likely be required to have completed certain material before a given date, at which point an exam would be given to the entire class.
- Examine ways to incorporate more meaningful experiences into class time that would increase student interaction and learning other than via worksheets. For example, it might be better to use class time for laboratory or design projects. If this option is pursued, great care would have to be taken so that students are still working about nine hours per week and not much more. That is to say that homework and design projects should, therefore, not be given at the same time.

Conclusion

The flipped classroom method was used for two-thirds of a thermodynamics class at Trine University. A simple analysis of the students’ grades was performed to determine if learning was improved. Unfortunately, since confounding variables were not controlled for, it was difficult to determine if the flipped classroom alone augmented learning. Nevertheless, the data indicate that the flipped classroom did not hurt students’ learning of the course content and that it did aide in increasing students’ ability to learn independently. The author and half of the student respondents stated they would like additional engineering classes to utilize the flipped classroom. This seems like a positive enough response to make some improvements, and then to offer other classes using the flipped classroom model. Hopefully by increasing the interactions during class time, additional students will find the experience valuable and student achievement will increase. Ideally, in future use of flipped classrooms, the instructor would be able to control for potentially confounding variables, such as class GPA in order to provide a better understanding of how a flipped classroom affects student learning.

References

1. Lillard, Angeline and Else-Quest, Nicole, "*Evaluating Montessori Education*", Science, Vol. 313, 19 September 2006, 1893-1894. http://www.montessori-ami.org/research/ScienceLillard060929.pdf (accessed January 27, 2013).

2. Definitions, 34 CFR 600.2, (2011)

Biographical Information

James V. Canino is an Assistant Professor at Trine University where he teaches in the thermo-fluids and aerospace engineering fields. He can be reached at caninoj@trine.edu.