Testing the flipped classroom approach in engineering dynamics class

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Abstract

The flipped classroom approach has been one of the hottest topics among faculty and students for engineering education. Some like it and believe that it could be one of the best teaching methods because it increases the interaction between faculty and students, and focuses on problem solving. However some faculty and students dislike the approach because they believe that direct interactive lecturing in the traditional classroom approach is more effective. In order to test the flipped classroom approach, we chose one chapter of engineering dynamics and tried the flipped classroom approach in the summer of 2014. At the end of the experiment, a student survey was utilized to collect students’ feedback. This paper presents our experiment with the flipped classroom approach, including preparation, execution, survey results, observations and findings. One interesting observation from this trial was that students with higher grades in the traditional classroom approach liked the flipped classroom approach and students with mediocre grades or lower in the traditional classroom approach disliked the flipped classroom approach. For the faculty without funding support and faculty teaching relief, a partial flipped class is a starting point in order to try the flipped classroom approach. With a partial flipped class, both faculty and students could still test the approach and had much deeper understanding of the approach.

1. Introduction

Engineering education is a student-centered learning process in which students learn a specified set of knowledge, techniques and skills with the guidance and help of instructors. Even though numerous pedagogical approaches have been and will be created and implemented in this noble process, the ultimate goal of the engineering education was, is and will be always the same, which is to prepare them for practice in the field of their chosen careers.

In the engineering education process, there are four key elements. The first key element is the set of knowledge, techniques and skills which is specified by higher levels of engineering education and industry collaboration councils such as ABET. The second key element is instructors (teachers). The third key element is students. The fourth key element is the delivery approaches or the pedagogies, which are the learning environments established between students and teachers.

There are many successfully implemented educational pedagogies. In the traditional classroom approach, instructors prepare and deliver lectures to students in classrooms. During lectures, there is limited interactive between students and instructors for large classes. Students learn through the lecture during classroom sessions and then complete the assignments such as homework or projects outside of the classroom. With the advances in computer technology, worldwide internet and digital techniques, the online course, hybrid course and the flipped classroom approaches have emerged as viable education pedagogical approaches. In the flipped classroom approach, students are required to study and learn independently through posted


lectures outside of classrooms, and participate in hands-on activities inside classrooms\(^{11}\). The flipped classroom approach is a totally different educational pedagogy which has the potential for transforming engineering education and became quite prevalent in the higher education community in recent years\(^{2, 3, 4, 5, 6, 7, 8}\).

The flipped classroom approach has been one of the hottest topics among faculty and students for engineering education. Since the flipped classroom approach is totally different from the traditional classroom approach, the preparation for a fully flipped classroom class usually requires funding support and faculty teaching load relief for initial implementation. It is a big challenge for faculty like us in a small college without funding support and faculty teaching load relief to develop a fully flipped classroom course in the first trial. So, in order to test the flipped classroom approach, we chose one chapter of the Engineering dynamics course and tried the flipped classroom approach in summer 2014. At the end of the experiment, a class survey was utilized to collect student feedback. This paper presents our experiment with the flipped classroom approach, including preparation, execution, survey data, observations and findings from this trial including student feedback.

2. Understanding the flipped classroom approach

What is the flipped classroom approach? The simplest description of the flipped classroom approach is to flip or to invert the traditional classroom approach\(^{1}\). In the flipped classroom approach, students independently study lecture topics outside of classroom and apply the topics to solve problems in classroom while instructors serve as a consultant. The flipped classroom technique consists of two parts: interactive group learning activities inside the classroom (hands-on activities), and direct computer-based independent study instruction outside the classroom (self-directed active learning of the posted lectures)\(^{2}\). It is well documented that students are at the center of engineering education, and active student learning will help foster a deeper understanding of course material\(^{3-7}\). It is obvious that in this approach, students must take control become the center of this learning process. Therefore, the flipped classroom approach is a revolution in engineering education which is becoming widely used at different levels of engineering education. Although the flipped classroom approach is a student-centered active learning educational pedagogy, it cannot be expected that students’ grades will be significantly improved through this approach\(^{8-11}\). After extensive literature review\(^{1-17}\), authors believe that following are the main features of flipped classroom approach:

- The lectures are posted in various media formats and stored on a web-based platform. These lectures are not simply the textbook reading assignment. They should be multi-media forms of the lecture topics prepared by instructors. They can be in the form of video, PowerPoint presentations, IPod or other media formats. These media forms of posted lectures should be short modules dividing a traditional lecture into several short focused lectures.
- Students independently study the posted lectures outside of classroom. Students are in control of their learning process and can study at their own paces.
- There are short online quizzes for fundamental concepts to determine whether students understand the fundamental concepts.
- Students are expected to understand the posted material before they come to class to enable participation in hands-on problem-solving activities, such as doing homework in an
individual or collaborative manner. In the classroom, instructors serve as consultants or facilitators to help students. When it is necessary, instructors can give some short support lectures for tackling some common issues that students might have on a particular activity.

After we developed a better understanding of the flipped classroom approach, we decided to implement the flipped classroom approach in some of our courses.

3. Implementation of the flipped classroom approach in engineering dynamics course

The authors were very interested in the flipped classroom approach and wanted to implement it in one of our courses. Since we never tried this approach before and there was a significant amount of work needed for faculty to prepare lectures and to develop hands-on activities, we ultimately decided to partially flip the course for one chapter. The Dynamics course in 2014 was chosen for implementing the flipped classroom because there were three sections with two faculty who could share in the preparation and implementation efforts. Chapter 15 - Kinetics of a particle: Impulse and Momentum was chosen to conduct the flipped classroom trial.

The tools utilized for this implementation of the flipped classroom were the following:
- The institute utilizes “Blackboard” a web-based platform that allowed faculty to add study resources and online quizzes for students to access online. The lectures and online quizzes were posted through the “Blackboard”.
- The hands-on activities in the classroom were assigned through “Mastering Engineering” which is hosted by Pearson Education.
- During the classroom hand-on activities, the instructor was able to have one-on-one interaction with a student when he or she had any questions. The instructor could also solve some common problems through mini lectures for the whole class when the common issues had been identified.

Following steps were used to implement the flipped classroom approach.
- Faculty involved in the trial had several meetings to discuss how to prepare and plan for implementing the flipped classroom approach. The classes were planned to be flipped during week #10 for the topics of impulse and momentum.
- We collaborated and worked together to prepare lectures and online quizzes along with the associated hands-on activities.
- In week #7, the definition of a flipped classroom was presented to the students. The purpose of this was to help them prepare for this new teaching format and to foster the proper learning environment for the trial.
- In week #8, the detailed plan for the trial was explained and posted, which mainly included the time table of posting lectures and online quizzes.
- In week #9, the lectures and online quizzes were made available to the students on Blackboard. Students were asked to study the material at their own pace identified in the posted lectures. They were also asked to complete the on-line quiz before coming to class.
- In week# 10 students worked individually or collaboratively during class time on the hands-on activities. During class time, instructors were ready to help students as needed. If the
same issues were identified during student interactions, instructors showed whole class how to solve some common problems.

4. Data collection and analysis

After successfully implementing the flipping classroom approach in the dynamics course, a student survey was given in week #11. Survey questions #1 ~#3 along with corresponding data are listed in Table 1, Table 2 and Table 3, respectively.

Table 1 the survey results on the survey question #1

<p>| Question #1: The flipped classroom approach makes it easier to understand the course content |</p>
<table>
<thead>
<tr>
<th>Choices</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Totals</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Strongly agree</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>37.7%</td>
</tr>
<tr>
<td>(b) Agree</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) No opinion</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>11</td>
<td>20.8%</td>
</tr>
<tr>
<td>(d) Disagree</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>22</td>
<td>41.5%</td>
</tr>
<tr>
<td>(e) Strongly disagree</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 the survey results on survey question #2

<p>| Question #2: How does the flipped classroom help you in learning the material? |</p>
<table>
<thead>
<tr>
<th>Choices</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Totals</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Much better than traditional</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>17.0%</td>
</tr>
<tr>
<td>(b) Better than traditional</td>
<td>12</td>
<td>3</td>
<td>5</td>
<td>22</td>
<td>41.5%</td>
</tr>
<tr>
<td>(c) The same as Traditional</td>
<td>7</td>
<td>5</td>
<td>8</td>
<td>23</td>
<td>41.5%</td>
</tr>
<tr>
<td>(d) Worse than traditional</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) Much worse than traditional</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 the survey results on the survey question #3

<p>| Question #3: “I will attend a course in which the flipped classroom approach is used for every class hour.” |</p>
<table>
<thead>
<tr>
<th>Choices</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Totals</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Strongly agree</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16</td>
<td>30.2%</td>
</tr>
<tr>
<td>(b) Agree</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) No opinion</td>
<td>6</td>
<td>5</td>
<td>2</td>
<td>13</td>
<td>24.5%</td>
</tr>
<tr>
<td>(d) Disagree</td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>24</td>
<td>45.3%</td>
</tr>
<tr>
<td>(e) Strongly disagree</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In summary, the survey data revealed: (1) 57.7% of students could accept this flipped classroom approach, (2) 58.5% of students believed that they could learn at least the same material in the flipped classroom approach vs. the traditional classroom approach, (3) 30.2% of students would happily enroll in a fully flipped classroom class. This strongly indicated there was a place for the flipped classroom approach in higher education. The survey data also indicated that the 45.3% of students would not enroll in a fully flipped classroom approach course. Therefore, students should have a choice for accepting or rejecting the flipped classroom approach when they select their courses.
After the flipped classroom approach had been implemented, we interviewed some students about their experience with this new teaching approach. We found that students with higher grades in the traditional classroom approach liked the flipped classroom approach. They liked to learn at their own pace through the lecture material provided and then apply it in classroom with help from faculty. The students with mediocre grades or lower in the traditional classroom setting didn’t like the flipped classroom approach. They complained that they spent too much times in trying to independently understand the lecture material.

After obtaining this negative feedback, we went back to the student survey compared related survey data. Since only one class survey included students’ names, the average student GPA with associated standard deviation vs. the choices of the flipped classroom approach is listed in Table 4. According to Table 4, there is not a statistical significant difference between the choices for “No preference” and “Dislike the flipped classroom approach”. For a one-tailed test with a level of significance of 0.05, the p-value is 0.00014 when the average GPA’s are compared for the choice of “Like the flipped classroom approach” with the choice of “Dislike the flipped classroom approach”. Therefore, there is a sufficient statistical difference between the choices of “Like the flipped classroom approach” and “Dislike the flipped classroom approach”. The survey data supported the student comment that students with higher GPA’s liked the flipped classroom approach vs. students with mediocre GPA’s or lower disliked the flipped classroom approach.

<table>
<thead>
<tr>
<th>Choice of the flipped classroom approach</th>
<th>Average GPA (Max. 4)</th>
<th>Sample size</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Like the flipped classroom approach</td>
<td>3.52</td>
<td>10</td>
<td>0.169</td>
</tr>
<tr>
<td>No preference</td>
<td>3.20</td>
<td>2</td>
<td>0.165</td>
</tr>
<tr>
<td>Dislike the flipped classroom approach</td>
<td>3.13</td>
<td>6</td>
<td>0.340</td>
</tr>
</tbody>
</table>

Survey question #4 was: “Do you prefer the flipped classroom approach or traditional lecture-discussion approach? Why?” Some of students’ comments are listed below and grouped by preference.

Prefer the traditional classroom approach:
- “I prefer the traditional classroom because 1) I am used to a study pattern such as reading the chapter before class, then have the teacher shows examples and explains, then I can review everything before doing the homework, and 2) the teacher explains the subject which allows it to be easier to understand the concept.”
- “I prefer the traditional approach because it is very frustrating if a question arises and you don’t have the ability to ask it right there in the flipped classroom.”
- “I prefer the traditional lecture. Although I did find it helpful to work on the homework during class. I think it is more productive to learn the lecture and do examples during class.”
- “Preferred the traditional approach because in the flipped classroom, students cannot ask lectures online questions, which lead to misunderstanding.”

Prefer the flipped classroom approach:
- “I like the flipped approach because that way I can learn the materials at my own time rather the time when I am tired at 8 am in the morning.”
• “I feel that I learn more when I am solving problems, having the professor around when I need help with a problem is really helpful.”
• “I prefer flipped classroom because it break up the long lectures.”
• “I prefer the flipped classroom because I can study it at my own pace and at the time I want.”

Survey question #5 was: “What do you like most about the format of the flipped classroom?”
The comments from students were grouped in three major themes:
• “I like that while I was doing the homework in class if questions came up I could ask the teacher.”
• “Go at your own pace”
• “Solving problems in classroom. Learning lecture materials in my own time”

Survey question #6 was: “What do you dislike most about the format of the flipped classroom.”
The comments from students were grouped in several themes:
• “If I am confused about something, I have to wait until class to have my question answered.”
• “I dislike that it is online. I prefer the human interaction and learning in a classroom.”
• “Learning the material by myself.”
• “It forces to teach ourselves overnight.”
• “I dislike flipped classroom because core major classes like dynamics cannot be taught by this method because the material is new to the individual and having the lecture and teaching it to ourselves is not the way to learn engineering.”

Survey question #7 was: “What do you like most about the format of the traditional lecture-discussion approach?” The comments from students were grouped in these themes:
• “I like that the teacher explains the concepts and shows how to solve problems as an understanding can form then with that knowledge apply it to the homework.”
• “Easy to ask question while taking notes.”
• “It helps you understand the lecture better than when you try to learn at your own.”
• “It is what we do in every class we ever had. Learn the lectures from the professor.”
• “Teachers answers question as they come up.”
• “It is easier to follow along and be active in the classroom.”
• “That it don’t have to teach myself.”

Survey question #8 was: “What do you dislike most about the format of the traditional lecture-discussion approach?” The comments from students provided these themes.
• “If questions came up while doing the homework, a time has to be set up for meeting with the teacher.”
• “Don’t have time to discuss as many problems.”
• “There isn’t always time to discuss homework.”
• “Can be long and tedious lectures. Hard to focus completely.”
• “Sometime, it would be nice to be able to ask direct question about the questions.”
In summary for the survey questions #4 - #8, students liked the traditional classroom approach because 1) Students were “used to it”, and 2) Instructors could explain topics better. Students did not like it because 1) Lecturing was too long to keep students’ full attention during the lectures, and 2) Lecturing did not discuss the problems they had in completing homework.

Students liked the flipped classroom approach because 1) Students could study the lectures at the time and at the pace they wanted, and 2) Students could get immediate help during the hands-on classroom activities. Students disliked it because 1) They needed to teach themselves the lecture material, and 2) they could not get immediate help during self-directed studying outside of classroom.

5. Discussions and conclusions

After successfully implementing the flipped classroom approach in our course, we had much deeper understanding of the implementation efforts required for this approach. The followings observations, impressions and conclusions were drawn from this partially flipped classroom trial. We are quite sure that we will continue to try and to implement the flipped classroom approach in some of our courses in the future.

(1) We believe that the flipped classroom approach is a revolution in engineering education. The flipped classroom approach is a true student-centered active learning education process. In this process, students will develop strong self-learning abilities, which is the fundamental element of the lifelong learning needed to be successful in their careers.

(2) The role of faculty in the flipped classroom approach must transform from teaching to facilitating or mentoring. However the amount of work for the faculty in this approach is huge, especially for the first time the course is flipped. Careful and proper preparation for the flipped classroom approach is essential. Faculty without funding support and faculty teaching relief might try the partially flipped course first to test the flipped classroom approach and to cumulate some experience.

(3) The role of students in the flipped classroom must fundamentally change from a passive learner in the traditional classroom approach to an active participant in the learning process. Students must take control of the pace of learning. If students aren’t mature and able to focus for an extended period of time a flipped class may not work.

(4) Based on the survey data, the flipped classroom approach may fit with some students, and may not be a suitable for others. Since students must become active participants, it is a good educational model for students who have strong independent-study abilities. The converse is also true, it could be detrimental for students who have lower than average of the independent-study abilities. For these types of students, they can learn more successfully through the traditional classroom approach for engineering education. Our survey supports this conclusion and therefore educators should give students a choice between the flipped and traditional classroom approaches.

(5) One interesting observation from this trial was that students with higher GPA’s liked the flipped classroom approach and students with mediocre GPA’s or lower disliked the flipped classroom approach.
In summary, we view the flipped classroom as one of the best engineering educational pedagogies because it is a student-centered active learning process. Through this approach, students can gain more life-long learning skills and can have much deeper understanding of the topics by becoming active participants in the learning process. Both the traditional classroom approach and the flipped classroom approach should coexist in higher education due to the varying interests and abilities of students in a typical institution. Initial implementation may appear to be an unbeatable burden for faculty without funding or teaching relief to try a fully flipped classroom approach. However, our experiments indicated that partially flipped classroom approach is a good starting point if faculty want to try or test this approach and develop the course incrementally. Even in a partially flipped course, both faculty and students could gain much deeper understanding and appreciated the features of the flipped classroom approach.

6. References


