Student Adaptation to the Modular Use of the Flipped Classroom in an Introductory Biomedical Engineering Course

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Abstract

The Flipped Classroom model moves direct instruction outside of the classroom, allowing more time for student-centered in-class activities. Guides to Flipping the Classroom suggest investing time at the start of the course to promote the Flipped Classroom model to students. However, this may not be the best use of time if the instructor only plans to use the Flipped Classroom model to teach a small portion of the class. Reasons for not flipping the entire course include deciding that only portions of the course would benefit from the Flipped Classroom model, or perhaps as a pre-cursor to flipping the entire course in subsequent offerings. Students in an Introductory Biomedical Engineering course were taught using the Flipped Classroom model only for the Biotransport module (2 class periods out of 19 for the term) in the middle of the semester. Aside from instructions to watch screencasts of lecture material and complete online quizzes before class, the Flipped Classroom model was not promoted to students. After the module, students were asked to complete a survey about their perceptions of the module. Classroom observations were recorded, and YouTube Watch Time data were obtained. The survey results show that the majority of the students found the transition to the Flipped Classroom easy or somewhat easy to adapt to despite not receiving information about the benefits of this pedagogical model. Students indicated that having clearer instructions about what is expected of them would further smoothen this transition. These findings suggest that instructors may be able to successfully use the Flipped Classroom model in a modular fashion when expectations for students are clearly communicated.

1. Introduction

The Flipped Classroom is a pedagogical model that moves direct instruction outside of the classroom to allow more time in class for student-centered activities such as group work or peer-instruction. Bishop and Verleger define the Flipped Classroom as “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom.”[1]

The Flipped Classroom model began gaining popularity among K-12 education circles in the late 2000s when online lectures by two high school chemistry teachers, Bergmann and Sams, started spreading beyond their school [2]. Since then, the Flipped Classroom model has been adopted by some educators in higher education as a possible means of improving student engagement and learning. In a recent scoping review, O’Flaherty and Phillips found that there is
already a significant amount of evidence, albeit indirect, suggesting that the flipped classroom model does improve student academic performance in higher education [3].

In spring 2015, we decided to use the Flipped Classroom model on the Biotransport module of our introductory biomedical engineering class, since the concepts and equations covered in this module are challenging for students to understand and apply. We believed that shifting the introduction of the concepts and the derivation of equations outside the class would allow us to better use class time by letting our students practice applying these concepts and equations, as well as addressing any student misconceptions.

However, given that a number of guides on flipping the classroom suggest spending a significant amount of time on the first day of class answering questions about the flipped classroom and convincing students of it merits, we became concerned about the feasibility of implementing it for only a small portion of the course [2], [4]. Considering that the Biotransport module comprised only two 75-minute long class periods, spending even 15 minutes to sell the idea and address student concerns seemed like a huge time investment.

A literature search on the flipped classroom in higher education mostly turned up studies on courses that have been either partially or completely flipped for the entire semester, or partially flipped for a few classes [5]–[11]. All these studies show that students generally responded positively to the Flipped Classroom model, but only one (a complete flip for the entire semester) explicitly mentioned an attempt to convince students of the merits of the Flipped Classroom – through the use of a “comprehensive syllabus” [5]. The students in this study were also provided a guide that emphasized what student were responsible for in and out of class. In addition, two other studies, both also featuring courses that have been completely flipped for the entire semester, recommend providing students with “some structure and guidelines” and “well-structured guidance” [6], [7]. For the studies in which the instructor completely flipped only a small portion of the course, students still responded positively, although it was not clear if any of the instructors first spent time selling the idea to students [12], [13]. Perhaps telling the students to watch the video lectures before class was all the instruction they needed prior to class?

The purpose of this study is to find out how easily students would adapt to the Flipped Classroom model if it was implemented without first convincing them of its benefits, as well as what students would have liked to have known prior to its implementation. This information would be useful to educators who want to completely flip only a small portion of their class, for reasons ranging from wanting to try the Flipped Classroom model, or deciding that only specific sections of the course would benefit from it. For this study, the flipped Biotransport Module comprised video lectures and online quizzes outside class, and group-based problem solving inside class. This study was granted exemption status by Cornell’s Institutional Review Board.

2. Methods
All first-year students in the college of engineering are required to take an “Intro-To” class, of which ENGRI 1310: Introduction To Biomedical Engineering is one of the nineteen options available. However, the class is also open to any student at Cornell University. The course was divided into 5 modules of varying lengths. Two modules were taught by guest instructors, one of which was the Biotransport module that was taught by the first-author.

In this Introductory Biomedical Engineering Course, the typical class period involved the instructor introducing and explaining new concepts to the students. The lessons typically include two to three multiple-choice “clicker” questions, either interspersed throughout the lecture, or saved for the very end of the lecture. To answer these “clicker” questions, students would use their personal response systems that have been preregistered with the class to submit their answers. The instructor would then display a histogram of how the class answered, before querying the students for explanations. Students were awarded points for participating, regardless of the veracity of their answers.

### 2.1 The Flipped Biotransport Module

The Flipped Biotransport Module comprised two class periods, each 75 mins long, during the 9th week of a 16-week semester. The first author was the instructor for the Biotransport module. Video lectures (Figure 1) were made using a Wacom Intuos Pro Tablet and the Ink2Go screencast software, and uploaded onto YouTube unlisted. This meant that only people with the link are able to view the video.

![Figure 1: A screenshot of the Intro To Biofluid Transport video lecture.](image)

Student responsibilities before class were to view a series of video lectures, which come up to about 30 minutes per class. After watching the videos, students had to complete an online quiz, which comprises 3 questions, one of which is a “muddiest point” question.

During class, students reviewed specific quiz responses as a class to address misconceptions. They then proceeded to apply the video lecture material though solving practice problems in groups.
2.2 Data collection

To answer the research question, the following qualitative and quantitative data were obtained and used.

2.2.1 YouTube Viewership Data

The number of unique views, total views, and average view duration of each video were counted from the day the video was uploaded to the day of the corresponding class period, i.e. 3 for first class period, 2 for the second class period.

2.2.2 Online Survey

Students were specifically told that the online survey was anonymous and voluntary. The survey began with Bishop and Verleger’s definition of the Flipped Classroom to ensure that participants understood exactly what the term refers to in the survey (see Appendix A).

For the Likert-like questions in the online survey, a neutral option was deliberately put in place to reduce agreeable bias.

To analyze the open-ended questions in the online survey, the responses were reviewed by the first author for general themes. The first author then went through all the responses again, and looked specifically for evidence of each theme in each response and labeled them accordingly. The number of times a theme was brought up was tabulated.

2.2.3 Classroom Observations

The instructor recorded his observations and reflections after each class period. The instructor also invited a peer to observe the first class period.

3. Results

3.1 Results from online survey

Of the 44 students in the class, 33 students participated in the survey, giving a response rate of 75%.

3.1.1 Demographic Information

Of the survey participants, all were freshmen save one, who was a sophomore. The gender breakdown was 73% female, and 27% male. In terms of college affiliation, 88% of the participants belonged to the College of Engineering, 6% to the College of Arts and Sciences,
while the remaining participants had not yet declared a major. As for the racial composition of the class, 59% identified as Caucasian, 19% as Black or African American, 19% as Hispanic, 15% as Asian, and 4% as Native American. Participants who declared multiple racial identities were counted in all the races they identified with. When participants were asked what grade they expected in the class, 45% expected an A, 45% expected a B, while 10% expected a C.

3.1.2 Prior Experience with the Flipped Classroom Model

The majority of survey participants had experienced the Flipped Classroom model in some capacity prior to the Biotransport module – 33% first experienced it in high school, 37% first experienced it in college prior to the Biotransport module. For 30% of the participants, the Biotransport module was their first experience with the Flipped Classroom model. None of the participants reported that they had experienced the Flipped Classroom model in middle school.

3.1.3 Student Perceptions about the use of the Flipped Classroom model for the Biotransport Module

The quantitative survey data on student perceptions are Likert-type data and have been presented in diverging stacked bar charts to highlight the spread of the positive and negative values, with the neutral point as the baseline [14].

The survey respondents generally perceived the use of the Flipped Classroom model for the Biotransport Module positively (Figure 2). The majority of the participants agreed or strongly agreed that the Flipped Classroom was engaging (70%), enjoyable (54%), and valuable (66%). Less than 10% of participants disagreed or strongly disagreed that the Flipped Classroom was engaging (9%), enjoyable (6%), and valuable (9%).

Figure 2: The survey respondents generally perceived the use of the Flipped Classroom model for the Biotransport Module positively.
Of the four aspects of the Biotransport Module, the majority of survey respondents either agreed or strongly agreed that video lectures (91%) helped them learn the material, followed by the instructor addressing responses from the online quiz in class (79%), and solving problems in class (72%) (Figure 3). Only 33% of respondents agreed or strongly agreed that completing the online quizzes helped them learn the material, while 24% disagreed or strongly disagreed, with the remaining 42% having a neutral opinion.

The following aspects of the Biotransport Module helped me learn the material:

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Lectures</td>
<td>6%</td>
<td>3%</td>
<td>58%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Online Quizzes</td>
<td>6%</td>
<td>18%</td>
<td>42%</td>
<td>30%</td>
<td>3%</td>
</tr>
<tr>
<td>Addressing Quiz Responses in Class</td>
<td>3%</td>
<td>6%</td>
<td>12%</td>
<td>55%</td>
<td>24%</td>
</tr>
<tr>
<td>In-Class Problem Solving</td>
<td>9%</td>
<td>6%</td>
<td>12%</td>
<td>39%</td>
<td>33%</td>
</tr>
</tbody>
</table>

Figure 3: Video lectures and addressing quiz responses in class were the most helpful aspects of the Biotransport module in helping students learn the material.

Regarding the transition to the Flipped Classroom model, 51% found the transition smooth or somewhat smooth, and 63% found adapting to the Flipped Classroom model easy or somewhat easy (Figure 4). A sizable minority of respondents found the transition to the Flipped Classroom model disruptive or somewhat disruptive (24%), and found adapting difficult or somewhat difficult (18%).

How was the mid-semester transition to using the Flipped Classroom model for the Biotransport Module?

<table>
<thead>
<tr>
<th>Perception</th>
<th>Strongly Disagree</th>
<th>Somewhat Disruptive</th>
<th>Neutral</th>
<th>Somewhat Smooth</th>
<th>Smooth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disruptive</td>
<td>9%</td>
<td>15%</td>
<td>24%</td>
<td>42%</td>
<td>9%</td>
</tr>
</tbody>
</table>
3.1.4 Student Suggestions to make the Biotransport Module more conducive for learning

The top three themes that emerged from student suggestions to make the Biotransport Module more conducive for learning are as follows:

1. Create more structure for in-class activities (9x).

One student found the class “kind of all over the place which makes it really hard to take notes and organize them later.” Yet another student found the group problem solving “chaotic”, preferring instead to “solve the problems independently and then review the correct answer.” Another student suggested “multiple choice questions instead of free responses,” which may suggest their preference for the order associated with clicker questions used in other modules of the class.

2. Provide more practice problems (7x).

This feedback relates less to the Flipped Classroom model than the class in its entirety, as this has been a common request throughout the semester. In fact, one student expressed that she enjoyed the Flipped Biotransport module because she got to do more practice problems.

3. Recap information from the video lectures in class (5x).

While a number students asked for “brief reviews” or “mini recaps”, one respondent went as far as suggesting the instructor “redo the main derivations in class”. In contrast to the requests for recapping the information from the video, a couple of respondents suggested “less time addressing quiz in class” and “not too much direct repeating of the videos in class, more moving on from the basic material.”

3.1.5 Student Suggestions to make the transition to the Flipped Module smoother

Set clearer expectations for the Flipped Module (5x).
One student suggested that the instructor should “notify students so they don’t think the videos and quiz are as impromptu and supplemental as the random readings we sometimes get…” Another said, “Because we were not notified that this was flipped classroom, I did not pay as much attention as I should have to the videos.” A third student who had a hard time adapting to the flipped classroom commented that the instructor “sort of just posted videos online with no pretext whatsoever. I had no idea what this was about until just now, so it was extremely awful. We jumped into it with no preparation.”

It was interesting that the students did not seem as concerned about the benefits of the flipped classroom, or why they were subjected to it. They instead seemed more focused on knowing what is expected of them, which may be due to the survey not set up to garner such responses.

2. **Flip other modules** in the class (4x).

Four students suggested flipping the other modules in the class as well, although they do not list reasons for their suggestion.

3. Allow **more time** to complete pre-class activities (3x).

Students wanted “more time to watch the videos and answer the quiz.” This appears to be due to the shorter interval between the Tuesday and Thursday classes as compared to the interval between the Thursday and Tuesday classes, which includes the weekend.

3.2 **Results from YouTube Viewership Data**

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Video</th>
<th>Unique Views</th>
<th>Total Views</th>
<th>Video Duration</th>
<th>Average View Duration</th>
<th>Percentage of Video Viewed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biomass Transport</strong></td>
<td>Intro to Biomass Transport</td>
<td>46</td>
<td>73</td>
<td>6:58</td>
<td>4:11</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>Fick’s Law of Diffusion</td>
<td>48</td>
<td>66</td>
<td>12:36</td>
<td>7:11</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>Conservation of Mass</td>
<td>43</td>
<td>56</td>
<td>8:29</td>
<td>4:52</td>
<td>57%</td>
</tr>
<tr>
<td><strong>Biofluid Transport</strong></td>
<td>Intro to Biofluid Transport</td>
<td>41</td>
<td>57</td>
<td>15:21</td>
<td>8:38</td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td>Derivation of Poiseuille’s Law</td>
<td>37</td>
<td>52</td>
<td>13:51</td>
<td>8:40</td>
<td>63%</td>
</tr>
</tbody>
</table>

Table 1: Although the number of unique views of each video is close to the total number of students, the average view duration for each video is only about 60% of the video duration.
Viewership data obtained from YouTube suggest that most students viewed the video lectures, as the number of unique views for each video was close to the class enrollment of 44 students. The average view duration for each video is only about 60% of the video duration. Possible reasons for the low percentage include students re-watching specific sections of the video, as suggested by the total views outnumbering the unique views, or that students only watched portions of the video that they needed to answer the online quizzes. Because the videos were posted on YouTube and were unlisted on search engines, only students with the links were able to watch the videos, but there was no way to track which students watched the videos, and how much of the videos they watched.

3.3 Results from Student Work

The online quizzes had an average completion rate of 98%.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Number Completed</th>
<th>Total</th>
<th>Percentage Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Transport</td>
<td>43</td>
<td>44</td>
<td>98%</td>
</tr>
<tr>
<td>Biofluid Transport</td>
<td>43</td>
<td>44</td>
<td>98%</td>
</tr>
</tbody>
</table>

Table 2: Almost all the students completed the online quizzes. The student that missed the Biomass Transport quiz is different from the student that missed the Biofluid Transport quiz.

3.4 Results from Classroom Observations

Despite being instructed to work in groups of 4 – 5, a number of individuals worked alone or in pairs. If the question was open-ended, students tended to immediately begin discussing the problem; if the question involved mathematical calculations, students tended to work alone before consulting group. Students used their cell phones to research answers for open-ended questions, but also to access social media, specifically Facebook. Students worked at very different paces, with some students struggling, while others were done quickly. This made it challenging to pace the class. A few students did not work on the in-class questions, and only paid attention when the answers were being addressed.

3.5 Instructor Reflections on Flipping the Classroom

The instructor found that creating video lectures was manageable with assistance. Using the tablet and screencasting software to create the video lectures was straightforward after getting guidance from Cornell’s Academic Technologies Center. The instructor also found that scripting the video lecture greatly reduced the need for video editing.

The instructor was able to quickly and easily address misconceptions. Viewing the quiz responses the night before class alerted the instructor to common misconceptions, and gave him time to formulate a coherent response.
The instructor found structuring the in-class activity very challenging. It was difficult to get everyone working in groups, a problem that was exacerbated by the lecture hall setup. Some students who quickly solved the practice questions got bored while students who were struggling were consulting the instructor instead of their peers.

Fielding open-ended questions was also immensely challenging, as it was impossible to anticipate the wide variety of student responses.

Having every student bring a device that can connect to the internet may allow for the entire class to conduct research together. Students can work in groups to ensure that at least one group member has access to the internet. Polling students at the start of class may be necessary to identify students who require assistance in obtaining a device.

4. Discussion

Based on the Youtube Viewership data and the online quiz completion rates, most of the students seem to complete the necessary out of class activities.

While the majority of the freshmen in the class found the transition to the Flipped Classroom module easy or somewhat easy to adapt to, 18% found it difficult or somewhat difficult. While learning about the purported benefits of the Flipped Classroom may help these particular students adapt better, they seem more concerned about the instructor “giving warning” so they do not go in to class “with no preparation.” These ideas were also echoed by students who did adapt easily to the flipped classroom. This group of students appeared more concerned about what was expected of them, and how they can do well in the class.

While the instructor did not detect any concerns regarding the effectiveness or use of the Flipped Classroom model per se, a handful of students expressed interest in how the material covered in the video lectures fit into the big picture. As such, highlighting how this information in the videos lectures may further increase their value to student learning.

This study sought to address if it is possible to implement the flip classroom on a limited scale without selling the idea to students. These data suggest that students will easily adapt to the modular use of the flipped classroom when the instructor clearly informs them of what is expected of them, and what their responsibilities are, not unlike informing students of the rules of an activity.

Limitations of this study were that the first author, who is also the instructor, is a graduate student teaching assistant who had no prior experience teaching this course, and no prior experience implementing the Flipped Classroom model. He did, however, get a lot of guidance from the professor of the course.

The content of the Biotransport Module was developed specially for this class, and there were no prior lectures to copy from. The author’s experience thus more accurately represents the experience of a new faculty member developing the course content for a course they have
been assigned, rather than that of an experienced faculty member wanting to try the Flipped Classroom for the first time.

No attempt was made to evaluate the efficacy of the Flipped Classroom model as this was a new of the class. No comparison with previous years were possible, and there was only one section in the class.

5. Conclusions

The majority of the freshmen in this class found the transition to the Flipped Classroom module easy or somewhat easy to adapt to. Setting clearer expectations for the Flipped Module and creating more structure for the in-class activities may further smoothen the transition. This suggests that educators may be able to implement the Flipped Classroom in a modular fashion, either for appropriate topics or as a step to eventually flipping the entire course.

Acknowledgements

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References


