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Flipped Classes: An Opportunity for Low-Stakes Group Problem Solving

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Flipped Classes: An Opportunity for Low-Stakes Group Problem Solving

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We share a flipped class approach to university calculus-based general physics that shows increased learning and high student satisfaction compared to traditional lecture classes.

Introduction

Class contact time spent in interactive engagement has been shown to enhance understanding of physics concepts.[1–3] Finding time to incorporate such activities into traditional lecture-focused classes is challenging. To free up class time for more interactive activities, many alternatives have been designed that shift a significant portion of content delivery to outside of class, whether through increased emphasis on reading texts before class, watching lecture videos, or other strategies. Approaches include Just-in-Time Teaching,[4] Studio Physics,[5,6] SCALE-UP,[7] and flipped classes.[8-12]

A broad range of instructional techniques have positive impact on student problem-solving skills.[13] Flipped classes present an opportunity not only for more student time spent in interactive engagement, but also for more student time spent in ungraded problem solving. Assignments outside of class must compete with other demands on students' time. Students have incentives to prioritize work on assignments that affect course grade over those that do not, so grading homework is important. Grading class work is less important for keeping students on task. Thus, class time provides a unique environment in which students may be expected to work diligently on challenging problems and questions without the incentive of grades.

Studies of motivation from psychology and management suggest that providing opportunities for ungraded problem solving may be especially valuable for growth in skills and understanding. While rewards improve performance on simple manipulative tasks, rewards have been shown to diminish performance on cognitive tasks, in both humans and other primates.[14,15] Further, external rewards cause loss of intrinsic motivation for such activities.[15,16]

With all the above in mind, the authors over three years restructured five class sections to provide substantial time in class for interactive activities such as small-group problem solving and discussion of concepts. Flipped class sizes ranged from 14 to 28, while our traditional classes ranged from 35 to 51.

Class format

Before class

Students first encounter each topic by watching one or two online lecture videos. These videos typically last six to twelve minutes. The authors or others in our department created most of these lectures, but we also used other publicly available videos from the web. Our experience is that a topic covered in 30 minutes of traditional lecture-oriented class time reduces to roughly six minutes of video. When leading a room full of students, one naturally repeats the same concept, giving students time to take notes and come to understand concepts. During lecture video, such repetition is less important, as students can use the powerful technologies of "pause" and "rewind" as needed.

Students are assigned two or three reasonably straightforward online homework problems on the topic introduced in the video and given seven opportunities to answer each correctly. We have seen that without these homework problems, students may watch the video but are less likely to study the video closely. Homework problems are due before the next class.

During class

Class meets twice per week for two hours each. Of these four hours, typically 75 minutes are spent on laboratory activities. The remaining 165 minutes are the focus of our change. (The traditional lecture format that this replaces consists of 150 minutes of class and 120 minutes of laboratory; our flipped sections have less contact time to balance the requirement to study lecture videos outside class.)

Students arrive in class having watched—and studied—the video lecture and worked a few problems on the topic of the video. During class, students are divided into groups of three, each of which has its own large whiteboard. Activities alternate between clicker questions in the style of Peer Instruction ConcepTests[17] and group problem solving. Group problem solving involves either traditional textbook problems, at a more difficult level than the post-video homework, or interactive tutorials similar to those of McDermott et al.[18] During class, we supplement the instructor with teaching assistants who facilitate the small-group problem solving. Their principal value is in asking leading questions, etc., to assure that students do not long remain on the wrong path. The instructor and teaching assistants each support nine students—three groups of three. For example, we use an instructor and two TAs for a class of 27.

Having some groups finish much faster than others is less of a problem than we expected. The slower groups receive more attention. Groups can be constructed to assure a mix of skill levels.

Whiteboards are critical for how we facilitate group problem solving. We can see from several feet away any groups that are making baseless assumptions or going down blind alleys. We drop into discussions, ask them to justify their steps, and provide guidance. We do not allow students to solve these problems on paper; students who want a record may take photos of their whiteboard.

Students are given only participation grades for in-class problem solving. They receive credit if present, reasonably prepared, and engaged.

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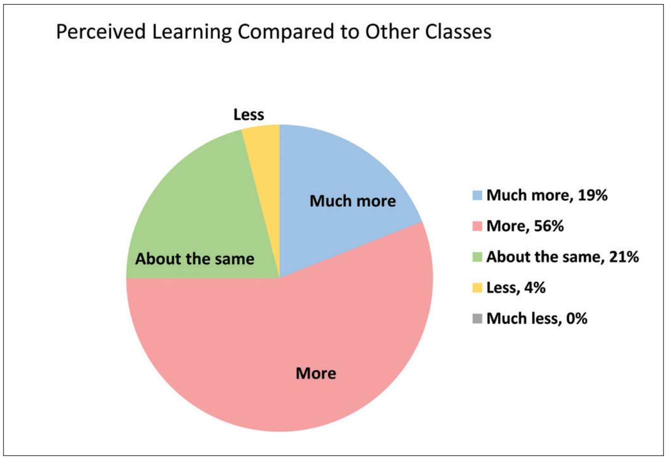

Fig. 1. Student responses on anonymous end-of-course surveys to the question, “How much do you feel you learned in this course compared to most of your courses?

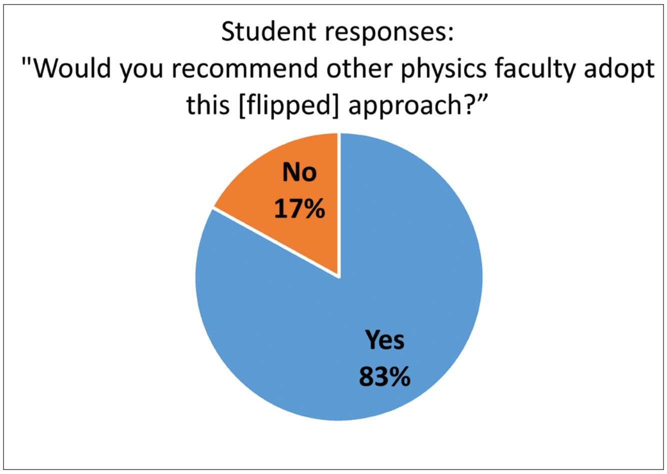

Fig. 2. Student responses on anonymous end-of-course surveys to the question, “Would you recommend other physics faculty adopt this approach?”

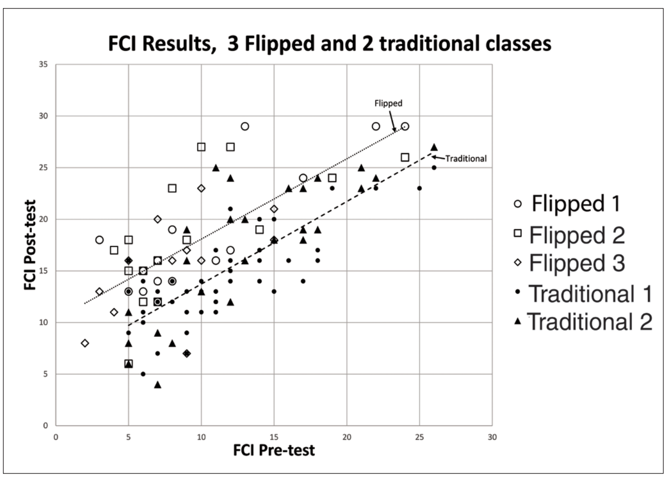

Fig. 3. Student pretest vs. posttest scores on the Force Concept Inventory. Outlined shapes show the performance of students taught in the flipped format, and solid shapes indicate the performance of students taught in the traditional format. The higher trendline is an indication of the flipped students’ greater normalized gains on the FCI.

After class

After class, students are assigned more online homework on the current topic. These problems are more challenging than the initial set following the lecture video. We offer office hours by the instructor and tutorials led by teaching assistants, so students have ample opportunity to learn how to solve every problem before exhausting their allowed attempts.

The cycle repeats. The students will watch the lecture video on the next topic, followed by an online homework assignment of straightforward problems, preparing the students for the following class.

More on lecture videos

We experimented with different formats, including narrated slides, slides presented adjacent to video of the instructor, audio narration while capturing writing on screen (in the style of Kahn Academy[19]), and Lightboard[20] videos. Students are forgiving of low production quality of our videos. The Lightboard videos are the easiest for most instructors to create, since they build upon instructor experience of lecturing while writing on a board, but they require a Lightboard, lights, and camera. Students anecdotally seem to prefer the handwriting and drawing on screen over narrated slides, in spite of often poor handwriting of one of the authors.

Assessment and observations

Anecdotal observations

A fear going in was that without the incentive of grades, students would not embrace in-class activities. In fact, students worked very hard and were highly engaged. For example, students could use laptops and smartphones as resources, but they rarely opened them. They were simply too busy and engaged to use their devices. On the few occasions students opened laptops, it was most often to share with the class a relevant video they recalled.

We have a strong sense that students in our flipped classes performed better than in classes we taught in a traditional format. We perceive improved attitude and confidence compared to other classes we have taught. Our subjective impressions are consistent with the improved Force Concept Inventory[1] (FCI) results we observed.

Teaching in the flipped format allowed us to engage topics in greater depth. For example, we addressed more realistic forces using coding activities. Rather than being taught precession, students predicted precession on their own via a series of in-class problems. We were able to introduce vector calculus and lead students to discover electromagnetic waves through another series of in-class problems.

Student satisfaction

Initially, we were concerned that students would dislike this format. We gave in-class end-of-course anonymous surveys to 59 students in three flipped classes. Students in three sections were asked, “How much do you feel you learned in this course compared to most of your courses?” Responses are shown in Fig. 1. Students were also asked, “Would you recommend other physics faculty adopt this approach?" Responses are in Fig. 2. All students present responded. This generally favorable response eliminated our concerns of negative effect on students.

Force Concept Inventory

One of the authors taught General Physics I over five semesters alternately in the aforementioned flipped format and in traditional lecture-based style with limited interactive activities. Students taught in three flipped classes showed an average normalized gain of 0.42 on the FCI,[1] more than twice the average gain of 0.19 shown by students in the two traditional classes. These gains are consistent with those reported by Hake[1] for other interactive engagement classes. The average class size of the three flipped sections was 15, while that of the two traditional classes was 36. Figure 3 shows a plot of FCI posttest vs. pretest for all student scores, with least-squares trendlines for the three flipped and two traditional classes. This figure shows that for our classes students of all pretest levels benefit from this change of format.

Summary

Flipped classes offer several advantages over traditional lecture-oriented classes. Pushing content delivery out of class frees up contact time for interactive activities proven more effective for student learning. Students may view lectures as often as they like; "pause" and "rewind" are powerful technologies for learning.

Flipped classes allow ample time for interactive engagement. Further, they offer extensive time for students to tackle difficult questions and problems without the risks and rewards of grades, with ready access to their teacher. Our experiences show that students embrace these times, work very hard, and enjoy the process. What we observe in our classes is consistent with psychology and management research on the negative effect of rewards on drive and performance on cognitive tasks, as well as with research on the impact of class time spent in interactive engagement.

Our students show better performance on the Force Concept Inventory even as we include more challenging topics in our syllabi. Our students report high satisfaction with this format.

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