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Effect of flipped teaching on student performance and perceptions in an Introductory Physiology course

Chaya Gopalan

Departments of Applied Health, Primary Care and Health Systems, Southern Illinois University Edwardsville, Edwardsville, Illinois

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Gopalan C. Effect of flipped teaching on student performance and perceptions in an Introductory Physiology course. *Adv Physiol Educ* 43: 28–33, 2019; doi:10.1152/advan.00051.2018.—Flipped teaching (FT) has caught educators' attention due to its success in engaging students through pre- and in-class activities. To learn if FT improved student performance, scores from the quizzes and exams of a fully flipped classroom with retrieval exercises were compared with those of five semesters of traditional lecture-based [unflipped (UF)] teaching in an undergraduate sophomore-level physiology course. Student attitude surveys were also evaluated. Student performance on both the quizzes and exams was significantly higher in the FT class in general compared with that of the UF teaching. Interestingly, however, when the individual exam scores were compared between the two styles, the scores for students in the FT were significantly higher for *exams 2* and *3*, yet lower for *exam 1*. The shift in performance from *exam 1* to *exams 2* and *3* is likely explained by the need for time to adjust to the new teaching style. Students reported an overall positive perception of FT in their course evaluations at the end of the semester. In conclusion, FT improved student performance compared with that of lecture-based traditional teaching practice, but required some time to adjust in the beginning of the semester.

flipped teaching; lecture-based teaching; student perceptions; student performance

INTRODUCTION

Replacement of didactic lecture with alternate student-centered activities is an ongoing journey in higher education that has been rewarded with accelerated student learning (9, 26). One paradigm, however, is that some alternate teaching methods pose limitations in adequate content coverage (5). Flipped teaching (FT) is one form of active learning that offers a solution to the concern of adequate content coverage because it shifts lecture out of the classroom in the form of assigned homework, and class time is spent implementing and processing the content (14). Although FT has been practiced by educators, the term “flipped” was not coined until recently. Evidence suggests that this method is particularly useful for teaching difficult concepts that require significant time to interpret and master (18). The FT approach also requires students to take responsibility for the basic knowledge and comprehension of content (15, 22). Furthermore, this student-centered teaching format offers an opportunity for student

self-pacing and provides class time for development of a more thorough and deep understanding of content through application and analysis (8, 12, 20, 21). Faculty also benefit from the FT method, as it allows flexibility in content delivery. Thus FT has become the latest buzz word in higher education in terms of both teaching and research.

Before the scheduled class time, students in the FT class have access to the course content in the form of reading assignments, lecture videos, lecture slides, concept maps, and/or sample problems (15). Consistently advancing educational technology in recording software and hardware, as well as convenient platforms to host videos such as course management systems, along with the ability to access these resources using mobile and computer devices, make it convenient for instructors to digitally capture and provide lectures (16). Students can access the information at any time and from anywhere to learn the material at their own pace. Thus digital advances have brought boundless opportunities for students to assume a more active role in the learning process (16, 23).

Studies have shown that students are more prepared and engaged while in a FT classroom setting than in a traditional classroom (11, 19, 20). It is not surprising that FT is being adapted by many educators, perhaps due to two key reasons: it replaces the passive didactic teaching and also allows students self-paced preparation (6, 15). Day and Foley (6) compared student performance between a FT and an unflipped (UF) class over an entire semester. Grades from the FT class were higher than from the traditional lecture class, and the students from the FT class reported increasingly strong positive attitudes about the FT approach. Although there is strong evidence in support of FT in the place of didactic traditional lecture, there are contradictory findings. Blair et al. (1) reported a significant drop in highest achievement with FT compared with a traditional lecture (UF) approach. Yet another study found no significant difference in academic performance between students in the FT vs. UF (3). Researchers in this study explained that a lack of preclass preparation accountability for a difficult subject matter appeared to be the cause of such poor performance with FT (3).

The present study was designed as students in the UF class implied the need for more learning resources (Table 1) before class as well as the latest shift in teaching trend toward FT. This study was aimed to test the impact of FT on student performance, comparing scores from quizzes and major exams with those of five semesters of lecture-based UF teaching. Student perception between the two teaching formats was

Address for reprint requests and other correspondence: C. Gopalan, Dept. of Applied Health, Primary Care & Health Systems, Box 1066, Southern Illinois University Edwardsville, Edwardsville, IL 62026 (e-mail: cgopala@siue.edu).

Table 1. *Student questionnaire*

Semester 1 81 responses	Semester 5 74 responses	Semester 6 35 responses
Not enough time to complete in-class assignments ($N = 30$): “I do like group work, but I wish we would get more time to work on it.” “... we have a hard time coming up with the answers in the short amount of time we are given.” Students like quizzes and preclass readings ($N = 34$): “I really like the daily quizzes because it helps me keep up with my reading.” “I like being forced to read every night.” Lack of additional preclass material: “I wish we had some form of prelecture that went over what the quiz material would be.” “We don't really have many opportunities to apply the information we learn because we mostly spend time having to learn the information.” “I would give the students some form of prelecture material to study before classes ...” “We can get the facts from the readings, and so I believe if we focused more on the concepts in lecture it would be beneficial.” “It's difficult to really understand the readings without listening to someone talk about them.”	Liked the e-textbook (69%): “You get rid of all the nonimportant information and just leave behind the important text.” “... there are links to online videos on it ...” “Easy and convenient access to material.” “It helps me with the lecture material.” Approval of readings before class (91%): “Basic terminology and concepts are explained. Then, in lecture, deeper discussion can be made.” “The reading assignments ... allow me to note down any questions I may have.” “... you can form questions beforehand.” “I can read at my own pace beforehand ...” “... when I come to lecture, I hear the information again and explained differently.” “The information is then better understood and Dr. Gopalan can discuss more complicated subjects ...”	Overall approval of flipped teaching (71%): “It was a better form of learning.” “I think it helped me read and prepare before the class and have you reemphasize the material again, which allowed me to remember and understand the material better.” “It makes studying for exams much easier.” Students noted the repetition in their study habits ($N = 11$): “... it was repetitive.” “... it was beneficial to see the information multiple times.” “I like that we get a chance to review the material multiple times ...” FT held students accountable with their studying ($N = 10$): “I kept up with the reading so when I had to study all I had to do was review instead of learning right before the exam.” “I started studying Physio everyday ...” “The flipped classroom helped me to remain caught up ...” “I had to study before class ...”

N, no. of students.

compared using a student questionnaire. FT implementation was in combination with retrieval exercises, where students were allowed to recall information instead of using their notes and other resources. FT was implemented for the entire length of a course and was expected to improve student performance due to the repetitiveness it offers compared with the UF teaching approach.

METHODS

After approval from the Institutional Review Board, a total of 653 students, aged 19–23 yr, taking the Introductory Physiology course during the second year of their prepharmacy program at a midwest college of pharmacy were included in the study. This course was offered during a regular spring semester of 16 wk. It was taught by the author all six semesters, either as one section or two separate sections in two consecutive class periods, depending on the availability of other faculty members to handle the teaching load. The class met for 50 min, 3 days/wk. In addition to three lectures per week, the course consisted of weekly 2-h laboratory sessions. The textbook, *Human Physiology from Cells to Systems* by Lauralee Sherwood (25), was used for the first three semesters and was replaced by the in-house digital text that was developed by the author. Data collection included exam scores, quiz scores, and anonymous student surveys.

Students were enrolled in the Introductory Physiology course for the first time after they had completed a prepharmacy professional sophomore level anatomy course. The number of students ranged from 77 to 190 per class, depending on whether the course was taught as two sections or as one of two or three sections. When two or three sections were offered for this class, the author taught one of those sections, whereas the other sections were taught by other instructors. Data presented in this study were collected by the sections taught only by the author alone.

Two teaching assistants per section were recruited to support the activities related to the course throughout the semester. They were chosen based on their high grades in this course in their previous years. They were assigned tasks such as proctoring in-class comput-

erized quizzes and exams, distribution and collection of paper copies of the group work, and grading of the same.

Each quiz consisted of five questions related to the content that was already covered in class for the UF method or as preclass assessment for the FT method. As one of the first activities during a 50-min class session, quizzes were taken in class via Moodle, the course management system, using college-supported computers. Each exam consisted of 50 multiple-choice questions to be completed in 50 min. For this study, only the first three of four exams were used, along with a comprehensive final exam. *Exam 4* and the final exam were given on the same day during finals week, and thus the student circumstances while taking *exam 4* were vastly different than those during the other three exams. Studying for several exams within the finals week as well as turning in several major assignments were expected to impact student performance compared with the quizzes and exams given during regular weeks.

The class content remained the same over all six semesters of teaching. It was a set standard that was strictly followed by all instructors teaching the course. Whereas 70% of the test items remained unchanged over the time of the study, 30% of the items were modified slightly. The revised questions maintained the levels of Bloom's taxonomy (2, 3, 27) throughout the study. For example, if a question was related to the functions of insulin in one semester, it would be testing the functions of glucagon in another semester.

Study Design for the Traditional Lecture-Style or Unflipped Teaching

Throughout the first five semesters of the study, the traditional classroom session included a quiz over the previously covered material. This group (students in the UF setting) received reading assignments and lecture outlines before each lecture (Fig. 1). The lecture was given in the podium style, and an opportunity was given for students to ask questions; however, students asked few questions. The in-class lectures were recorded in real time using Panopto and were made available to students immediately after lecture if they wanted to review. The use of lecture capture in teaching this class is reported as a separate study (13). The availability of recorded live lectures, as one may suspect, did not affect student attendance due to the in-class quiz

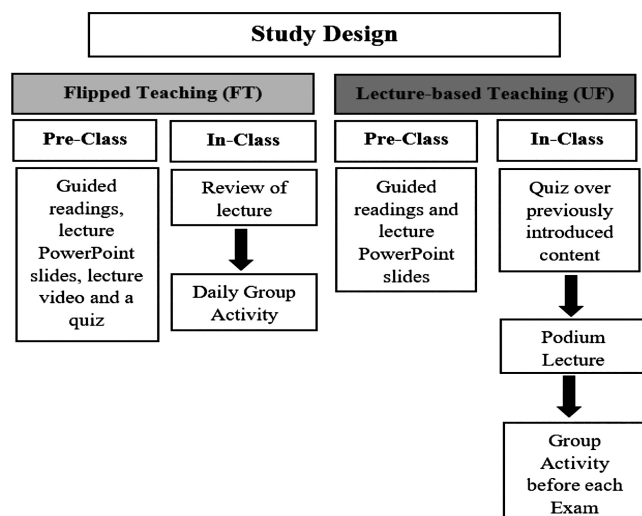


Fig. 1. Study design of flipped and unflipped teaching methods.

in every class. The quizzes served as a formative assessment. The answers to the quiz questions were discussed soon after the quiz ended.

Practice questions and an answer key were posted for students to work through outside of class. No grade was assigned for completing these practice questions. Before each major exam, one class period was set aside for group work to review topics covered since the completion of the previous exam. Students were not given access to any study material during the quiz or group activity to encourage retrieval of information from their own learning. The groups were formed in the beginning of the semester using specific criterion, such as their grades, gender, and ethnicity, to diversify to the maximum extent (10). There was one peer evaluation close to the end of the semester. Students were informed about peer evaluation in the syllabus. Peer evaluation helped engage group members to participate in group work.

Study Design for Flipped Teaching

Posted at least 48 h before the scheduled class, students in the FT group received guided readings, lecture PowerPoint slides, and a lecture video that was produced by the author. The lecture videos were ~30–35 min long and were created using a video recording software, Camtasia. During the class period, the instructor briefly reviewed the key concepts of the lecture and addressed questions that were received before or during class. Students, however, rarely asked questions before or during class. An average of two questions per lecture was the pattern. Once the lecture review was completed in the first 10–15 min of the class, students were ready to begin group work (Fig. 1).

Individual assessment in FT. Each student completed a timed online assessment related to the class content. The quiz questions, however, were at the level of factual detail or comprehension based on Bloom's taxonomy (2, 3, 27). The questions in this assessment were randomized and came from a pool of questions to minimize cheating. Respondus Lockdown Browser application was utilized during every online quiz, as well as in all of the exams.

Group work in FT. Groups were constructed using a number of criteria, as described previously (10). In short, each instructor-assigned group consisted of four to five students, who remained as a group for the entire semester. Each group activity typically included five application, analysis, and/or interpretation questions. Once the class completed group work, the instructor discussed these questions and answers.

Statistical Analysis

Any identifiable student information was replaced by numeric codes before data analysis. One-way ANOVA was used to compare five semesters of student performance on the first three exams in the UF style vs. one semester of FT. Similarly, the individual exams from *exam 1* to *exam 3* from the UF teaching were compared with that of the FT. Statistically significant main effects were further assessed with post hoc Bonferroni tests and statistically significant interactions with analyses of simple effects. All tests were conducted with an experiment-wise α -level of 0.05.

RESULTS

The results are summarized in Figs. 2, 3, and 4. We compared the combined scores from the first three exams of FT with that of UF. Except for two semesters (*semesters 3* and *4*), the exam scores from the FT were significantly higher than for the other semesters of UF (*semesters 1*, *2*, and *5*; Fig. 2). When the individual exams were compared between the UF and FT methods, students in FT performed better on *exams 2* and *3*, but not on *exam 1* ($P < 0.0001$). In fact, the scores from *exam 1* were higher in the UF than in the FT group ($P < 0.05$).

An additional difference in trends was observed. The exam scores for students in the UF classroom were highest on *exam 1* (mean = 83.25%) but decreased with *exams 2* and *3* (mean = 76.04% for *exam 2* and mean = 76.72% for *exam 3*).

Quiz grades between the first five semesters of the study where it was taught in the lecture style (UF) were compared with one semester of FT. In the UF teaching method, the quiz was conducted during class time, whereas, with the FT method, the quiz was given online, utilizing a lockdown browser, and was timed. The quiz scores were significantly higher with the FT mode of teaching compared with all five semesters of UF [$F(5,24) = 1.437$; Fig. 4].

Student attitude surveys were gathered during both UF and FT modes of teaching. As shown in Table 1, students felt rushed during UF teaching and were seeking additional pre-class resources besides reading. Sixty-nine percent of the students completing the survey welcomed the in-house e-text that was developed by the author. When students were asked if FT changed their method of learning, 71% of the students

Comparison of Five Semesters (S1–S5) of Unflipped Teaching with One Semester (S6) of Flipped Teaching

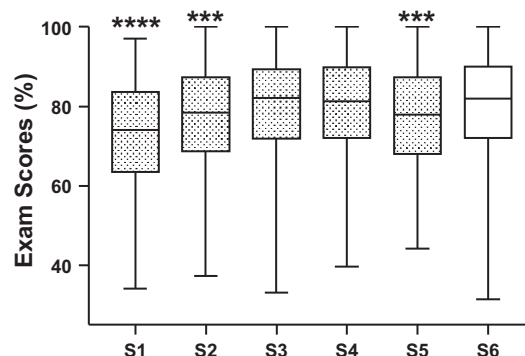


Fig. 2. Comparison of the first three exam grades in the five semesters of unflipped teaching with that of one semester of flipped teaching. S1–S6, *semesters 1–6*. $N = 352$ students for S1, 738 for S2, 516 for S3, 364 for S4, 308 for S5, and 323 for S6. $F(5-2,595) = 19.04$. **** $P < 0.0001$ between S1 and S6. *** $P < 0.001$ between S2 and S6 and between S5 and S6.

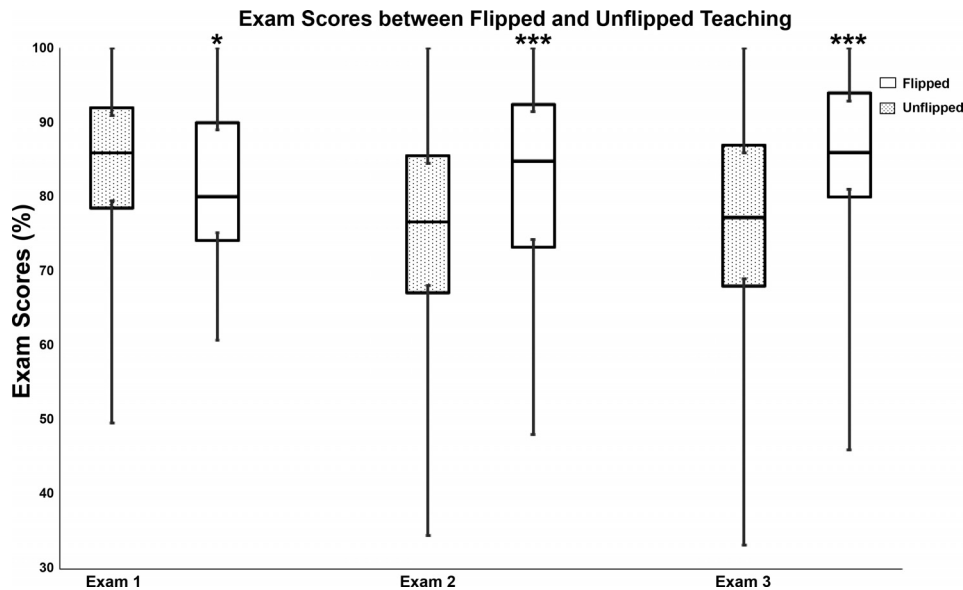


Fig. 3. Comparison of individual exam scores between traditional lecture-based (unflipped) and flipped teaching. *N* for *exam 1* unflipped = 577 students, flipped teaching = 82; for *exam 2* unflipped = 576, flipped teaching = 82; for *exam 3* unflipped = 572 and flipped teaching = 81. * $P < 0.05$ between *exam 1* scores; *** $P < 0.001$ between *exam 2* and *exam 3* scores.

completing the survey agreed. They also recognized the student accountability, as well as the repetition FT structure offers.

DISCUSSION

A study utilizing one entire semester of FT was compared with five semesters of UF teaching previously reported that FT overall benefits students in terms of academic performance (Figs. 2 and 4). These results reiterate similar findings from a number of other studies that FT helps improve student performance (1, 11, 12).

The quiz grades from the FT class were significantly higher compared with all five semesters of UF teaching (Fig. 4). It is possible that an increase in quiz grades could be mainly due to the FT approach, as it allowed the content to be available to students before their class meeting, which, in turn, made students prepare better from these resources. However, several other variables could have explained the higher quiz grades. Students in the FT class took their quizzes online before the in-class meeting. The quizzes were timed and given in the

Respondus Lockdown mode, which limits students from accessing other sources on their computers. Quiz questions were randomized and released from a pool of questions so that the questions were different for different students. Despite these attempts to control accuracy, it is possible that students had access to study material around them. It is also possible that several students were taking the quiz at the same place and time and helping each other identify correct answers. Student surveys from the FT class, however, suggested that they were accessing material on a regular basis, and this was different from their previous study habits (Table 1).

When the individual exams were compared between FT and UF classes, *exam 1* performance was different from that of *exams 2* and *3*. In *exam 1*, the UF teaching method had higher scores than in the FT group, suggesting that students learned better from the UF teaching style. Later higher scores in the FT group suggests that the students were perhaps still transitioning into the new teaching style in the first part of the semester, as reported by others (4, 7, 17, 24) and, therefore, having difficulty adjusting to the new learning approach. Moreover, *exam 1* covered topics such as homeostasis and cell biology content, which was more or less a review for students, since it was also covered in their anatomy course, a prerequisite for the Introductory Physiology course, as well as their biology course in their first year of prepharmacy curriculum. Newer and more detailed content was introduced in *exams 2* and *3* where students were able to benefit from FT more than the lecture-based UF teaching. It could also be true that students were more used to the FT approach as the course progressed.

A trend in the gradual decline in the exam scores from the first to the third exam in the UF style of teaching (Fig. 3) could be related to several variables. One explanation for the decreasing scores is the increased level of difficulty as newer content was introduced. Yet another reason could be the students' lack of motivation as the semester progressed. It is possible that the students became busier with outside activities or course work in other classes. One striking observation was that, when FT was implemented, the trend was reversed. Although the performance on the first exam of the semester was lower in FT

Comparison of Five Semesters (S1-S5) of Unflipped Teaching with One Semester (S6) of Flipped Teaching

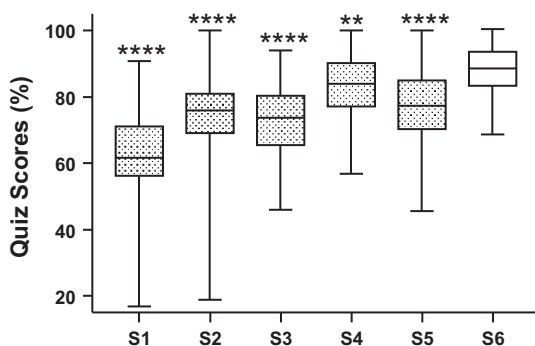


Fig. 4. Comparison of the quiz grades in the five semesters of unflipped teaching with that of one semester of flipped teaching. S1–S6, semesters 1–6. *N* = 88 students for S1, 190 for S2, 128 for S3, 91 for S4, 77 for S5, and 82 for S6. $F(5-24) = 1.437$. ** $P < 0.01$. **** $P < 0.0001$.

than in the traditional UF classes (mean = 81.13% in *exam 1*), there was a steady increase in exam grades on subsequent exams, showing the best academic performance on *exam 3* (mean = 81.82% for *exam 2*, mean = 85.59%). The trend observed with FT demonstrated a pattern that was not seen in the individual exams in any of the traditional UF semesters (*semesters 1–5*). This evidence suggests that FT reinforces regular study habits, which helps students continue to do well on exams, whereas students in the traditional UF teaching show a general decrease in motivation to stay engaged in the learning process (21, 28).

The FT method is designed to allow students to visit topics repeatedly, once before class in the form of preparation and formative assessment, once during class in the review of lecture, and yet again in group work and its immediate feedback. The student survey from the FT class found this teaching method very helpful (Table 1). It is likely that graded assessments, in general, influence students to access the content and utilize the resources that, in turn, allows students to increase their learning, as demonstrated in their exam performance in this study. In course evaluations, students identified the repetition as helpful to their learning. A majority of students viewed the numerous exposures to material as a positive aspect of FT. Students indicated they did not have to study as much immediately before an exam.

Attendance in itself has been shown to increase student success (18, 28). The FT course had in-class group assessments in every class meeting. This built-in formative assessment in class could have contributed to student success. Interestingly, the UF study design also had built-in formative assessment in the form of daily quizzes. This suggests that attendance cannot be the only factor for success, since both study designs had strong attendance incentives. Other elements, such as repeated exposure to content through pre-class assignments and assessments, in-class review, and activities, may have played a role in the observed steady increase in student performance in the FT mode of teaching.

Since the textbooks were switched from the fourth semester onwards from a commercially available text to an instructor-created, in-house text, it is not known how the in-house textbook influenced the success with FT. However, improved student performance observed in this study cannot be correlated to the in-house digital textbook, since its introduction occurred in the fourth semester of the study when the teaching approach was still in the traditional UF style and student scores were quite different from *semester 4* to the semester using FT.

In conclusion, the study results suggest FT helps students engage in learning and improves their academic performance. The study also demonstrates that a majority of students view the FT method of teaching positively. Although students may require time to adjust to the FT style, replacing traditional lecture-based UF teaching with FT that utilizes student-centered strategies brings valuable differences to their performance and perception.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

C.G. performed experiments; analyzed data; interpreted results of experiments; prepared figures; drafted manuscript; edited and revised manuscript; approved final version of manuscript.

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