

HOW WE TEACH | *Generalizable Education Research*

The effect of flipped teaching combined with modified team-based learning on student performance in physiology

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Gopalan C, Klann MC. The effect of flipped teaching combined with modified team-based learning on student performance in physiology. *Adv Physiol Educ* 41: 363–367, 2017; doi:10.1152/advan.00179.2016.—Flipped classroom is a hybrid educational format that shifts guided teaching out of class, thus allowing class time for student-centered learning. Although this innovative teaching format is gaining attention, there is limited evidence on the effectiveness of flipped teaching on student performance. We compared student performance and student attitudes toward flipped teaching with that of traditional lectures using a partial flipped study design. Flipped teaching expected students to have completed preclass material, such as assigned reading, instructor-prepared lecture video(s), and PowerPoint slides. In-class activities included the review of difficult topics, a modified team-based learning (TBL) session, and an individual assessment. In the unflipped teaching format, students were given PowerPoint slides and reading assignment before their scheduled lectures. The class time consisted of podium-style lecture, which was captured in real time and was made available for students to use as needed. Comparison of student performance between flipped and unflipped teaching showed that flipped teaching improved student performance by 17.5%. This was true of students in both the upper and lower half of the class. A survey conducted during this study indicated that 65% of the students changed the way they normally studied, and 69% of the students believed that they were more prepared for class with flipped learning than in the unflipped class. These findings suggest that flipped teaching, combined with TBL, is more effective than the traditional lecture.

flipped classroom; modified team-based learning; unflipped; student performance; student preparedness

FLIPPED TEACHING is a student-centered reverse teaching approach, where the lecture is introduced outside the classroom, thus allowing more time during class to process the information and practice the content with a variety of active learning strategies, including teamwork and instant feedback. Flipped teaching has been adapted by many educators in recent years, perhaps due to two key reasons: 1) it replaces the passive didactic teaching, and 2) it allows self-paced preparation, where students can pause or replay recorded lectures to better understand key concepts (7).

The use of active learning strategies instead of didactic lecture has been shown to accelerate learning but limit the lecture time and thus decrease time on content coverage (4, 8). This concern has prompted alternate approaches that bridge

active learning and content coverage. The emergence of flipped teaching appears to be an effective solution, as it offers a mechanism of introducing lecture as homework and allowing the classroom to be used for active learning. This hybrid-teaching format provides enhanced time efficiency, student self-pacing, repetitiveness, and interactive learning (24). Moreover, it requires students to assume responsibility for important aspects of their own learning, mainly the basic knowledge and comprehension of content, which are often considered to be the foundational elements of the learning process (32).

Flipped teaching allows flexibility in the mode of lecture delivery. The homework content may include video lectures, readings, and/or study guides to help students become familiar with the topics. Advancement in recording software and hardware, emergence of platforms to host videos, and the ease with which they can be accessed using mobile and computer devices allow educators to utilize this technology to share lectures with students before class (20). If the instructors prefer to use lecture videos, but are reluctant to use recording technology due to limitation of time or resources, there are exceptional professional videos available online for free as alternate choices. Thus digital advances have brought boundless opportunities for students to take on a much more active role in the learning process. For example, students acknowledge that they access the internet to obtain new information related to course work, a shift in how information is acquired (19).

The availability of study material before the scheduled class time can help students be not only acquainted with the topics ahead of time, but also self-paced and self-disciplined in a more learner-oriented manner (13, 14). Assuming students have utilized the teacher-posted learning resources before in-class session, active learning strategies in the classroom offer opportunities for deeper understanding through application and analysis of the content. In fact, the flipped teaching model has been shown to improve student preparedness and increase students' level of engagement during class (26, 28). By providing study material that encompasses basic topics outside of the classroom, the class time can be dedicated to exploration of complex topics in detail through active learning strategies. Because flipped teaching allows students to move at their own pace while preparing for the in-class activity, the instructors can devote more class time to providing greater insight into difficult topics (16). A study by McLaughlin et. al. (25) in a pharmaceuticals classroom supports this notion: student attendance, learning, and the perception of the teaching model were all increased when flipped teaching was utilized. Some students, however, perceive the flipped approach as increased

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workload, as it demands regular study habits and upfront time commitment (6, 33).

Since flipped teaching is emerging rapidly, more evidence is needed to demonstrate the effectiveness of this teaching approach (1, 9, 10, 21, 34). Our study aims to examine the effect of flipped teaching combined with modified team-based learning (TBL) on student performance by comparing their performance on individual questions from the traditional and flipped teaching, as well as student preparedness. We anticipate students will have performed better in the flipped style compared with the unflipped lectures due to the repetitive nature of this teaching strategy (5, 12, 23–25).

MATERIALS AND METHODS

One hundred and eighty-seven Advanced Physiology students in their professional *year 1* at St. Louis College of Pharmacy, 109 women and 78 men, ages 20–45 yr, submitted their informed consents to participate in this study. Students were enrolled in the Advanced Physiology course for the first time after they had completed a preprofessional sophomore level anatomy and physiology course. This course was team taught by three instructors (20 lectures per instructor) and was held during a regular semester of 16 wk, where the class met for 50 min, 3 days/wk. This course utilized two graduate level textbooks; *Guyton and Hall Textbook of Medical Physiology*, 12th edition, by J. E. Hall, and *Basic Immunology*, 4th edition, by A. K. Abbas, A. H. Lichtman, and S. Pillai. The same instructor taught both flipped and unflipped sessions used in this study. In addition to three lectures per week, the course consisted of weekly 2-h case discussion sessions and weekly 2-h laboratory sessions.

Consent forms. On approval of the project by the Institutional Review Board, written consent forms were distributed to the class size of 242 students, among which 187 students participated in the study (77.3%). Students submitted their signed consent forms to the teaching assistants who then handed them to the department administrative assistant for storage in a locked office cabinet until the final grades were submitted to blind the teacher-researcher from knowing the student participants. Any identifiable details, such as the names, and the student identification numbers were removed and replaced immediately by numeric codes before data analysis.

Flipped classroom study design. Among the three faculty members teaching this course, only one instructor (C. Gopalan, the principal investigator or PI) used the flipped approach. The PI tested flipped teaching during the previous year. Since this approach was established for the first time during the previous year, no data were collected.

The first unit in this course was the physiology of the immune system. It was covered in 12 lectures. The first 10 of these lectures were flipped. Students in this class were learning immunology for the first time. An anonymous student survey conducted suggested that less than 2% of the students were exposed to immunology content before this course at the level of introductory anatomy and physiology. The second unit of this course consisted of neuro-, endocrine, and cardio-

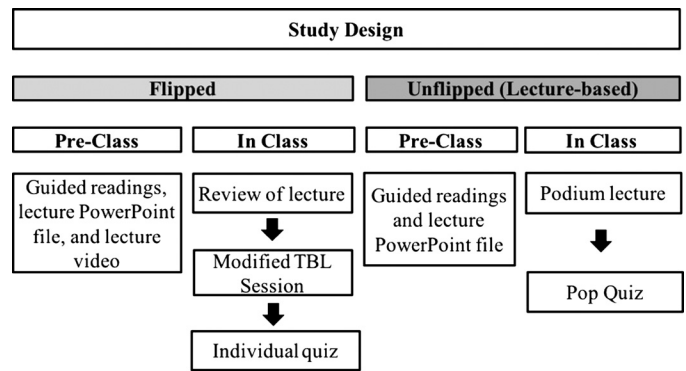


Fig. 1. Study design of flipped and unflipped teaching.

vascular physiology, which was taught by the other two faculty members (Table 1). The last unit included renal, respiratory, and exercise physiology. Renal and respiratory physiology topics were covered in unflipped format by the PI over eight lectures, whereas exercise physiology was covered by one of the other two instructors over two lectures in the traditional format.

Moodle, the course management system, was utilized to post course content as well as online assessments. Students were encouraged to post questions on the discussion board or through email concerning any of the lecture content that was assigned to them as pre-class work. The discussion board was used by <5% of the class.

The resources that were made available for the homework portion of the flipped classroom included reading assignment, the PowerPoint slides, and the instructor-recorded lectures. They were posted at least 48 h before the scheduled class. These lecture videos were ~30–35 min long. They were originally prepared using Camtasia and rerecorded using Panopto to acquire viewing analytics. During the class period, the instructor briefly reviewed the key concepts of the lecture and addressed any questions that were received before as well as during class. Interestingly, students rarely asked questions before or during class. A maximum of two questions per lecture was the pattern. Once the lecture review was completed in the first 15 min of the class, students were ready to begin a modified TBL session (Fig. 1).

TBL groups were constructed as described previously (11). Each group consisted of four to five students who remained as a group for the entire semester. The TBL activity typically included five application/analysis/interpretation questions. Once the class completed group work, the instructor discussed these questions and answers before allowing students to access an online quiz. Each student completed an online assessment related to the same content. The quiz questions, however, were at the level of factual detail or comprehension level based on Bloom’s taxonomy (2). The questions in this assessment were randomized and came from a pool of questions to minimize cheating. Students completed one peer evaluation of their team members for five points.

Table 1. Dispersion of questions into flipped and unflipped teaching

Teaching style	Unit 1 (Immunology)		Unit 2 (Endocrine, Cardiovascular, and Neurophysiology)	Unit 3 (Respiratory, Renal, and Exercise Physiology)
	Questions from flipped teaching (10 lectures; exam 1)	Questions from unflipped teaching (2 lectures; exam 1)	Taught by other faculty members (exam 2)	Questions from unflipped teaching (respiratory, 4 lectures; renal, 4 lectures; exam 3)
No. of questions used in the study	41	8	0	40
Correct answers, %	76.75	64.24	0	58.3

The percentage of answers correct in each group is shown.

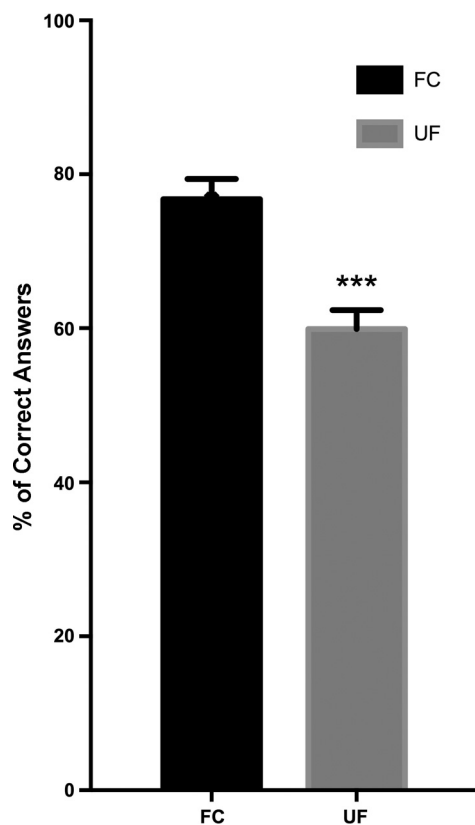


Fig. 2. Percentage of correct answers on the exam questions from the flipped teaching vs. the unflipped (UF) teaching. FC, flipped classroom. Values are means \pm SE. *** $P < 0.0001$.

Four teaching assistants, who had excelled in Advanced Physiology course in the previous year and were exposed to flipped teaching by the PI, were selected to assist in the classroom to distribute, collect, and grade paper copies of the group work. They also proctored the online unit exams along with faculty members. Each exam consisted of 50 multiple-choice questions to be completed in 50 min and were given online via Moodle.

The entire immunology content was taught by the PI over 12 lectures, 10 flipped, and 2 unflipped, and was tested on *exam 1*. The respiratory and renal physiology content was taught over four unflipped lectures each. Thus a total of 10 lectures were flipped, and the remaining 10 were unflipped, which included 2 lectures from immunology content, 4 from renal, and 4 from respiratory physiology content (Table 1). The PI taught all 20 lectures that were tested in this study.

Unflipped class study design. As mentioned before, the unflipped lectures included two immunology, four renal, and four respiratory physiology lectures (Table 1). Unlike the immunology content, students had been introduced to both renal and respiratory physiology content once at the introductory level in their sophomore year using the *Human Physiology* textbook by L. Sherwood. The unflipped lecture format provided reading assignments and PowerPoint files to students at least 48 h before each lecture. The 10 lectures in the unflipped study were given in the traditional lecture format. During these classes, students were not given a recorded lecture before the scheduled class period (Fig. 1). The lecture was given in the podium style, and an opportunity was given for students to ask questions. The in-class lectures were recorded in real time using Panopto and were made available to students immediately after lecture to access as needed. The availability of recorded live lecture did not affect student attendance, mostly because they did not want to miss pop quizzes. Practice questions were posted for students to work through at their

own pace outside of class. There was no grade assigned for completing these questions.

Questions used to compare the two modes of teaching were spread over *exams 1* and *3* and were noncumulative. *Exam 1* was given over the entire immunology section. However, the first 10 lectures were in the flipped style and were tested over 41 questions. The remainder of *exam 1* included immunology content from the two unflipped immunology lectures, which were tested over eight questions. *Exam 3* was given over the unflipped respiratory and renal physiology lectures and was tested over 40 questions (Table 1). Each exam question was analyzed to determine the number of students who answered correctly.

We also examined if flipped teaching would help the lower one-half of the class vs. students above the 50th percentile. This was achieved by determining the median of the final class grade and then separating the class into the upper 50th and the lower 50th percentile. Additionally, an anonymous online survey was given at the end of the semester to receive student feedback on flipped teaching. The survey was intended to learn about student perceptions regarding the two teaching strategies.

Statistical analysis. One-way ANOVA was used to compare student performance on the questions from flipped teaching vs. questions that came from unflipped lectures. 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

Results are summarized in Table 1 and Fig. 2. It was found that the performance on flipped questions was an average of 17.5% higher than on questions that came from unflipped lecture ($P < 0.0001$). On the immunology exam, there were eight questions that were unflipped, and students answered 64.24% correctly on these questions. In *exam 3*, the respiratory and renal physiology content was covered in the unflipped style, there were 40 questions, and students answered 58.3% of these questions correctly. Questions from the flipped teaching were part of the immunology exam (41 questions), and 76.75% of questions were answered correctly.

Figure 2 represents the percentage of questions students answered correctly for the unflipped questions compared with the flipped lecture.

To determine whether the flipped teaching was beneficial to higher achievers vs. the lower achievers, the class was separated into the upper 50th percentile and the lower 50th percentile using the mean of the final class grade. It was found that the

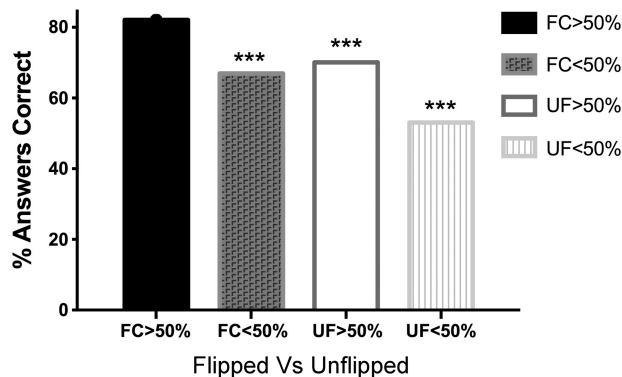


Fig. 3. Comparison of correct answers above and below 50% of the class. *** $P < 0.001$ when student performance from unflipped teaching was compared with flipped teaching in the >50 th percentile, and similarly between unflipped teaching to flipped teaching in the <50 th percentile.

lower 50th percentile of the class had a 13.91% higher correct answer response on the flipped classroom vs. unflipped classroom; the upper 50th percentile gained 12.02%. These numbers, however, were not significantly different (Fig. 3).

An anonymous student survey regarding student preparedness for flipped or unflipped class suggested that 69% of students felt more prepared with the flipped classroom approach, and 39% percent of students indicated that they felt more prepared when presented with a traditional lecture. Since the survey was anonymous, we were unable to compare individual performance to student preparedness.

DISCUSSION

The flipped classroom study design is a promising student-centered teaching approach. Advances in technology provide easy-to-use tools for recording lectures and sharing these with students rather than the traditional didactic lecture. Although there is eagerness to implement this new strategy in the classroom, there is limited evidence of its effectiveness. We conducted a partial flipped study combined with modified TBL to obtain initial evidence to support this teaching strategy.

Students performed better in the flipped teaching portion of our study compared with the unflipped section, even though the content for flipped teaching was introduced for the very first time, unlike that in the unflipped portion where the content was not totally new. Others have also reported similar positive results from the flipped study design (5, 12, 23, 24). Students in both the upper and lower half of the class benefited from the flipped study. Nouri (27) reported similar change, where the lower achievers benefited from the flipped teaching intervention more than the higher achievers. A study by Foldnes (7) showed no significant difference from flipped teaching compared with traditional teaching when students worked individually, but was able to demonstrate a positive result when students worked in cooperation with peer interaction (7). Our success in the flipped study, therefore, could be due to the incorporation of a TBL session as part of the in-class activity.

Although a well crafted and captivating lecture presentation seems like an efficient way for an instructor to cover course content, converging evidence implies that listening to a classroom lecture is not an effective way to promote deep and lasting student learning (15, 18, 22). The traditional lecture-based method of teaching has proven to be less engaging than inquiry-based education (3, 8, 29–31). Studies suggest that the lack of mechanisms to ensure intellectual engagement with the lecture material results in a decline of student concentration after 10–15 min (15). Moreover, the pace of the lectures is not adapted to all learner needs, and traditional lectures are not suited for teaching higher order skills, such as synthesis, application, and analysis (17, 35). By contrast, active learning strategies have been shown to promote student engagement and improve knowledge retention (4, 8, 26). The flipped strategy requiring repeated exposure to the lecture content before and during class, peer instruction, and interaction, and a variety of assessments, including immediate feedback, appear to provide greater benefit to students.

The positive feedback we received from students regarding flipped teaching correlated with the improved performance others have reported (5, 12, 14, 21). Whether testing flipped teaching in the beginning of the semester vs. the end of the

semester helped obtain better results is not clear at present. Students may be more excited to learn in the beginning of the semester compared with the end of the semester for a number of reasons (32). It is also uncertain whether some content is more suitable for flipped teaching than some other topics. In our study, flipped lectures included immunology content where the topics covered were in the soap opera style, starting with innate immunity to fight infection. If innate immunity failed to prevent the spread of infection, activation of specific immune response through the activation of B and T lymphocytes, antibody-mediated immunity, and cell-mediated immunity were building off of the previous lectures. Students perhaps were inquisitive to learn how the next set of events would be able to combat the infection. Respiratory physiology lectures were separated into pulmonary ventilation, gas exchange, gas transport, and neural regulation. Renal content was organized into glomerular filtration, tubular reabsorption, and the regulation of fluids and ions. It appears that the topics did not tie in as closely as the immune system topics did. Further studies are needed to learn those topics that are suitable for one teaching format over the other.

Although our study showed positive results favoring flipped teaching, the study design had limitations. The content covered in the two groups was dissimilar. Flipped teaching included most of the immunology lectures, whereas the unflipped portion included some immunology, but mainly respiratory and renal physiology content. Since the content covered was at the graduate level for both flipped and unflipped groups, we believe that the content was being compared at the same level of difficulty. However, since the respiratory and renal content was not new to the students, as they were exposed to basic details at the introductory level previously, it is difficult to explain the actual role the content played in our results.

Conclusion. Our findings suggest that flipped teaching is more effective than the traditional unflipped lectures. This success could be brought about by the nature of the teaching method that demands exposure to the topic in a repeated manner as well as due to the use of modified TBL as part of flipped teaching study design. Whether flipped teaching is effective in teaching certain topics is yet to be tested.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

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

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