Reclaiming face time: how an organic chemistry flipped classroom provided access to increased guided engagement

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Abstract

Affording adequate time for students in organic chemistry to engage with material is a constant struggle for those teaching the course. By using the flipped classroom model, students have more time in class to process information in the presence of the professor, while course content is not sacrificed. This paper will discuss what it means to 'flip a classroom,' how the classroom time can be restructured, and how it improves student success rates. In addition to presenting some alternative ways for flipping, this paper will also address the best means for implementation and how the flipped classroom ties into current research for cognitive theory.

Introduction

For many students, what makes organic chemistry difficult is that it is a physical science coupled with a hieroglyphic language. The study of a physical science involves applying a particular vocabulary of natural phenomena to its numeric representation. Organic students rely upon this physical science foundation, typically acquired from a pre-requisite course in general chemistry. The background, however, widely varies, with students scattered somewhere between the extremes of completely unprepared to entirely prepared. Added to the mix is the fact that organic chemistry is represented in an entirely new language: 2-D line structures of carbon atoms. Although students draw and interact with these 2-D hieroglyphs, they must hold the actual 3-D molecular visualizations within their minds in order to truly grasp the reactivity and functionality. With all of these new types of representations, the study of organic chemistry quickly becomes a study in foreign language.

Students perceive the subject matter of organic chemistry to be very difficult, and many enter the class with trepidation.[1] Although lectures typically serve as methods of first-exposure to the content and help students with a basic understanding of it, students must have further practice, typically by working textbook problems as homework. True learning requires both practice (by building new neural pathways) and emotion (by stimulating biochemical neurotransmitters),[2] and for students studying late at night by themselves, frustration accrues and inhibits the learning process.

The Purpose of the Flip

Just as any good foreign language program provides the learner with access to a fluent speaker, so should an organic chemistry classroom. Student misconceptions need to be quickly identified and addressed, and their accurate interpretations also need validation. In my own experience teaching organic chemistry for the past decade, I found that student understanding and success rates were highest when I could get students working on problems in front of me, typically as part of small teams.

Although this workshop-type of teaching is important in the classroom, there are two threats to its implementation. The first is the sheer amount of content that needs to be covered in an organic chemistry course. The second is that course sizes have been creeping up over the past few years to where it becomes increasingly difficult to give the students individual help during the lecture period.

In recent years, I have tried many interventions outside of class time, including: a.) creating a workshop hour where students would work problems in groups; b.) utilizing a supplemental instructor program; c.) referring students to the university-sponsored tutor; d.) standard office hours. All of these programs only reached a limited number of students, however, as the students are increasingly busy outside of class time with jobs, volunteering, campus activities, and various other commitments. Increased class time on problem solving seemed to be the most effective intervention to benefit student learning.

In order to recapture class time, one day per week was set aside as a dedicated problem solving session where students would work organic chemistry problems in small groups while I circulated to answer questions and coach correct strategies. In order to create time for this activity, one lecture per week was flipped outside of class time. The rationale is that when students attend lecture, they are mostly engaged in the passive activities of content-driven learning, so flipping pushes those activities of listening, viewing, and note taking outside of class time. The active learning of *doing* – solving problems, discussing strategy, asking for help – best belong not as homework, but as activities to be performed during class time.

In flipping the classroom, the pedagogical questions that I wanted to better understand were thus:

- Can flipped pedagogy be effectively applied in a larger-enrollment class?
- Does recovered class time help with gains on final course grade?
- How do the students perceive the teaching methodology?

Flipped Methodology: What Changed in the Classroom

There are many available resources to guide educators and help them share ideas on how to flip the classroom.[3,4] There is no single pervasive methodology to the flipped classroom, but those who flip share a common goal to reassess the roles of student and teacher in the classroom in order to better engage students in both subject matter and their own learning processes.[5] This was certainly my goal: to gain more face-time with my students to engage in guided problem solving activities.

Table 1 gives a description of how the flipped classroom was implemented. As shown in the table, the class schedule only allowed three 50-minute periods per week (plus lab time, not shown). It seemed unwise to throw the students entirely into an unfamiliar pedagogy, so a hybrid approach was established, whereby they would still have a traditional classroom experience during Monday and Friday sessions and the flipping would come in during the Wednesday session. The table describes the activities during the Monday and Friday periods. Although the majority (>50%) of the time was spent in

Table 1. Classroom Strategy for Flipped Class

Monday 50-minute class period	Monday afternoon	Wednesday 50-minute class period	Friday 50-minute class period
Introduce new material via lecture. Work examples with professor. Use i>Clickers for in-class feedback.	Content video goes up online. Students are expected to watch and take notes prior to Wednesday class period.	Group problem solving, working problems from workbook.	Introduce new material via lecture. Work examples with professor. Use i>Clickers for in-class feedback.

receiving new content via lecture, students were also able to work some examples at their seats, and they used i>Clickers for obtaining informal and instantaneous feedback on their understanding of the content.

After each Monday class, a video was provided that would substitute for the Wednesday lecture. These were only created after the completion of the Monday session so that the video could start right where Monday's class had ended, to provide a seamless transition to covering the new material. To create videos, I used Camtasia Studio[6] as screen capture software while I drew in the SMART Notebook program[7] using a Bamboo writing tablet.[8] (There are a myriad of programs available for creating content videos and multiple resources of pre-made videos. For those unfamiliar, the references below are a good place to start.[3,4]) When creating videos, I performed some basic editing, but did not worry about creating polished, perfect videos, just as I am not always polished and perfect in the classroom. I uploaded the videos to the educational hosting site Vimeo.[9] I would always provide my students with a pdf of the notes covered in the video and provide the video link on the course management system, Blackboard.

Although there was a small learning curve for me to learn to make videos and for the students to get used to watching them when assigned, it was the regained classroom time that was the major focus on the flipped pedagogy. Students had all purchased a required copy of *Organic Chemistry I Workbook for Dummies*,[10] which was used extensively during the Wednesday group problem solving sessions. This workbook was inexpensive, easily portable, and provided simple review information right next to the problems in case the students needed it. The use of a separate workbook also provided supplemental problems beyond those in the textbook, so that there was no redundancy for the high-achieving students who kept up regularly with their suggested textbook problems.

There were 58 students enrolled in the flipped organic chemistry 1 course. In that same semester, I also had an additional 27 students enrolled in a separate section of organic chemistry 1. Since a research goal was to see how flipped learning worked in a larger class, it was best to use the class of 58 as the experimental (flipped) class and the class of 27 as a traditional (not flipped) class. The smaller section met at a different time and did not have any of the flipped components as part of their teaching and learning structure; the class time in the smaller section was devoted more to the traditional activities seen in the Monday and Friday columns in Table 1. The content covered in the two sections was identical and the exams were virtually identical. Thus, the traditional class worked as a control group and allowed for the measure and comparison of any learning gains experienced with the flipped class.

Results of the Flipped Classroom

When compared with historical data collected over several years (Table 2), the flipped class students showed increased performance outcomes overall. As discussed below, the failure rate dropped to 26% and the course GPA jumped to 2.42.

Students in my fall organic chemistry 1 courses typically experience a failure rate ranging from 35 to 42%. The failure rate refers to the students who earned the grade of D or F, or those who withdrew by the midterm withdraw deadline because they were likely to fail. Since students earning the grade of D in organic chemistry 1 cannot move on to organic chemistry 2, the D grade is considered not successful. The success rate is thus the percentage of students who earned a C or above.

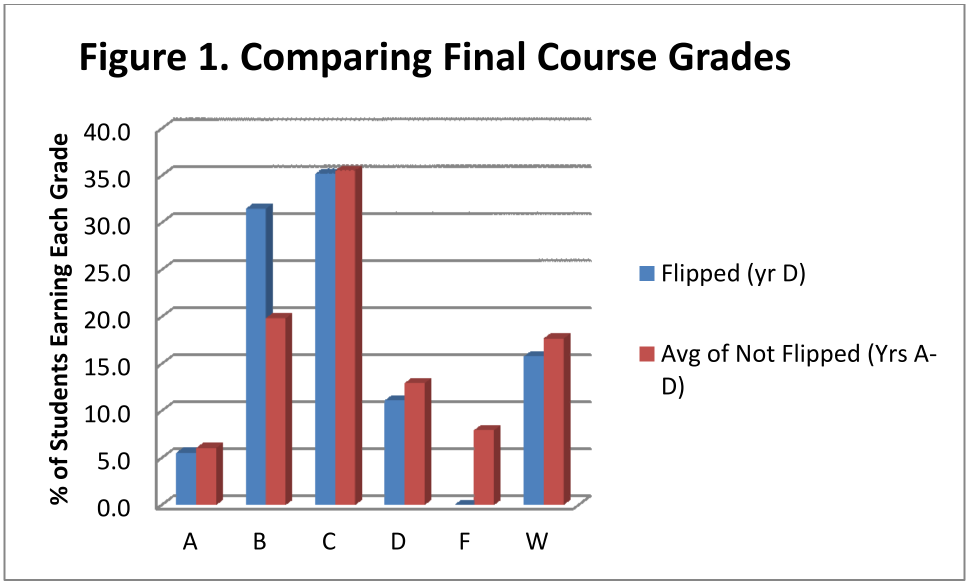
The average class GPAs were also calculated, using the university's standard point system (A=4.0, B+=3.5, B=3.0, C+=2.5, C=2.0, D=1.0, F=0.0). For the large-class enrollments seen in sample years A-C, the course GPA is just barely above passing (C average), showing that the students struggle with attaining high achievement.

Based upon these comparisons, the flipped class had a higher percentage of students who earned a passing grade (C or better) and the course had a higher average GPA overall. As passing organic chemistry 1 is difficult for many students, these results have a significant impact for organic chemistry professors looking to increase their students' success.

The comparisons between the year D flipped and not flipped (control) groups are also noteworthy. As aforementioned, the students had the same material, nearly identical exams, and the same teacher. The only difference was the course structure (see previous section). Prior to year D, I had never taught a small (<50 students enrolled) fall organic 1 course, so I cannot comment on any historical success rates of students in lower-enrolled courses. However, it is interesting that although the flipped course enrolled over twice as many students, they were more successful in terms of both average GPA and overall success rate. The flipped pedagogy seems to make more of a difference in student success than the student-faculty ratio does, which directly addresses the research question regarding how flipping can affect a larger-enrollment class.

Table 2. Data for Fall Organic Chemistry 1 Courses

Sample Year	Students Enrolled	Failure Rate	Success Rate	avg GPA
A	92	42	58	2.06
B	62	40	60	2.04
C	55	35	65	2.06
D (not flipped)	27	37	63	2.30
D (flipped)	58	26	74	2.42



In a further comparison, Figure 1 shows the grade distribution of students in the flipped class and the average grade distributions from the not flipped classes. There was not much change in the top-performing students (6.1% As in not flipped courses, 5.6% As in the flipped) or in students who withdrew (17.7% Ws in not flipped courses, 15.8% Ws in flipped), but there was a large shift in the middle.

No students in the flipped class earned the grade of F, which contributed to the increased average GPA of the flipped class students as discussed previously. The flipped class is the only organic chemistry 1 course I have ever taught in which no students earned an F. Typically, students who were likely to earn an F would stop attending and/or stop studying by the time that three-quarters of the semester have passed. In the flipped class, there was no such surrender. Because of the increased in-class coaching and problem-solving that results from the flipped pedagogy, all of the students who had not previously withdrawn maintained their efforts until the end of the semester and earned a D at minimum.

To further analyze Figure 1, the evidence suggests that the flipped pedagogy helped the students in the middle to move up their achievement nearly a letter grade overall. It seems as though the students who would have earned an F earned a D, those who would have earned a D earned a C, and those who would have earned a C earned a B. To look at the high end of this shift, the z-score of those earning a B in the flipped class is 2.43 (31.5% Bs in flipped course, 19.9% Bs in not flipped courses, with standard deviation of 4.8), which is statistically relevant. This seems to support another of the research goals, which was to determine how the flipped pedagogy could increase students' final course grades.

Student Feedback and Suggestions

To gain insight into the students' experiences, both flipped and not flipped students were asked to fill out an anonymous narrative survey about the experience at the end of the semester. By applying qualitative analysis to the information provided by the students, certain trends emerged in how they perceived the flipped pedagogy. This data can be seen in Table 3.

Table 3. Student Survey Responses

Responses of Flipped Classroom Students	
I.) Problem solving	Responses (n=42)
Dedicated problem solving day is useful to learning.	42 (100%)
Top trends from student comments:	
Problem solving day made it easy to ask questions of the professor.	8 (19%)
Working through problems with classmates is beneficial.	7 (17%)
Student schedules prohibit attending office hours, so these problem-solving days are a way to obtain assistance.	3 (7%)
II.) Content videos	
Preferred flipped classroom to traditional classroom.	42 (100%)
Should continue this flipped pedagogy for future classes.	42 (100%)
Top trends from student comments:	
Found videos useful to learning.	39 (93%)
Did not like videos.	3 (7%)
Liked being able to view at their own pace, pausing, rewinding, playing again.	20 (48%)
Need to keep the videos at a shorter length.	8 (19%)
Wanted videos over course content posted more frequently than once per week.	4 (8%)
Responses of Not Flipped Students	
I.) Problem-solving	Responses (n=20)
Working problems in class was the most useful in-class activity.	16 (80%)
Working with classmates in groups helps me to learn course material.	7 (35%)
Top trends from student comments:	
Professor should assign problems for a grade and/or extra credit.	12 (60%)
It is helpful when professor walks around the classroom to guide us when solving problems.	3 (15%)
II.) Lecture-based learning	
More in-class time should be allotted for problem solving.	8 (40%)
Top trends from student comments:	
Lectures are too long and have too much material.	3 (15%)

For the flipped students, 100% found the dedicated problem-solving day to be useful to their learning. Likewise, 100% of them preferred the flipped pedagogy to a traditional lecture-based classroom and thought that this teaching method should continue for future classes. They had adapted to the new expectations and recognized the benefits of the flipped pedagogy.

Although the main goal for using video lectures for content delivery was to make room for in-class problem solving, the videos themselves seemed to be a valuable addition to the students' learning practices. The survey results also showed that the students liked the videos, with 93% of the students indicating this response. A likely reason for the favorable view of videos is that nearly half of the students reported using the pause, rewind, and repeat features to go back over the material whereas in lecture time, they were often just copying down notes without complete comprehension. The 7% (three students) who did not like the videos indicated that the drawbacks were: they could not ask questions during the video, the videos were time consuming/they were too busy outside of class, and/or that they would zone out while watching. Since the flipped classroom should be inherently time-neutral, the student who is too busy to watch the videos would also likely be too busy to do homework problems. The student who zoned out while watching videos would also likely fail to pay attention during a traditional lecture as well.

When the not flipped students were surveyed (also in Table 3), it was clear that they also believed in-class problem solving was important (80%), but overall they did not emphasize its usefulness as much as the flipped students. They recognized that it was difficult to pay attention to long lectures (15%) and that more in-class problems would be useful to their learning (40%). Interestingly, when asked for suggestions on improving the course in the future, 60% of these students asked for homework problems or extra credit problems, stating that they were more likely to do problems if the professor required them to do so. This is noteworthy in that I do require students to do problems: I just expect that they police themselves on this activity. This type of comment was not apparent from the flipped students, further supporting the evidence that the flipped classroom helps students gain more competence in problem solving and reinforcing good study habits on their own.

Reflection on Best Practices and Other Ideas for Implementation

In the semester immediately following the flipped year D organic chemistry 1 class, I tried to use flipping for my organic chemistry 2 course. The course had smaller enrollment (25 students) and both the students and I quickly learned that the flipped pedagogy was more of a distraction than an aid in that particular course. I had learned during the previous semester that some course content lends itself to video lecture better than others. In the organic chemistry 2 course, I was trying to only create content videos for the easier material at the start of each chapter – naming of new functional groups, physical properties, etc. This meant that videos were not posted on the same day every week, and the students had a hard time remembering what was expected of them on which day. Additionally, since the teacher-to-student ratio was smaller and the students already had a solid foundation from organic chemistry 1, they did not seem to need the dedicated problem solving day as much as the organic chemistry 1 students had. By about 4 weeks into the semester, I abandoned trying to flip the classroom. Perhaps the Goldilocks principle[11] can be applied to the use of flipping in organic chemistry 1: all of the conditions (student level of anxiety and motivation, content as foreign language, need for additional professor guidance, etc.) are just right to make it an ideal fit.

Based upon the data gathered from the students and on the class performance, I identified ways in which I could better implement flipping in the future.

1. I determined to spend at least one class period early in the semester coaching the students on how to effectively learn from videos, in keeping with the best practices in this field.[1]
2. I believe that posting videos and scheduling problem solving sessions at regular, predictable intervals (such as seen in Table 1) provides the structure necessary for student buy-in.
3. I would typically make my videos like I teach: introduce a concept and then do several examples. In the future, I could cut back on the number of examples in order to shorten the videos without shortchanging the students, since the students have opportunities to do problems in the classroom.

4. Rather than making one long video of course content, I could make shorter (<10 minute) modules based upon each topic and/or subtopic that I want to cover.
5. To help students make connections between the concepts, I can also give a short (5 minute) overview of video content to introduce the start of each problem-solving day.

In the narrative survey that the students provided, they had also given some suggestions for ways to tweak the class in the future, allowing for the expansion of content-delivery in new ways. I typically give students paper keys of exams and problems worked in class, but students see the answers rather than the process. By making short videos where I work through the problems in real-time, I could provide the students with better models for problem solving on their own.

This change was implemented in a subsequent semester when giving students problem sets on spectroscopy. Working through a set of spectral data is not always straight-forward and the students need lots of guided practice. They always feel that they need more practice with combined problem sets on spectroscopy - IR, mass spec, ^{1}H NMR, and ^{13}C NMR all for one specific compound. Although some class time was allotted for working through the problem sets, creating a video key allowed the problem-solving strategy lessons to be expanded to out-of-class time (Figure 2).[12] Students could follow along with the methods for deciphering the spectra and check their own strategies.

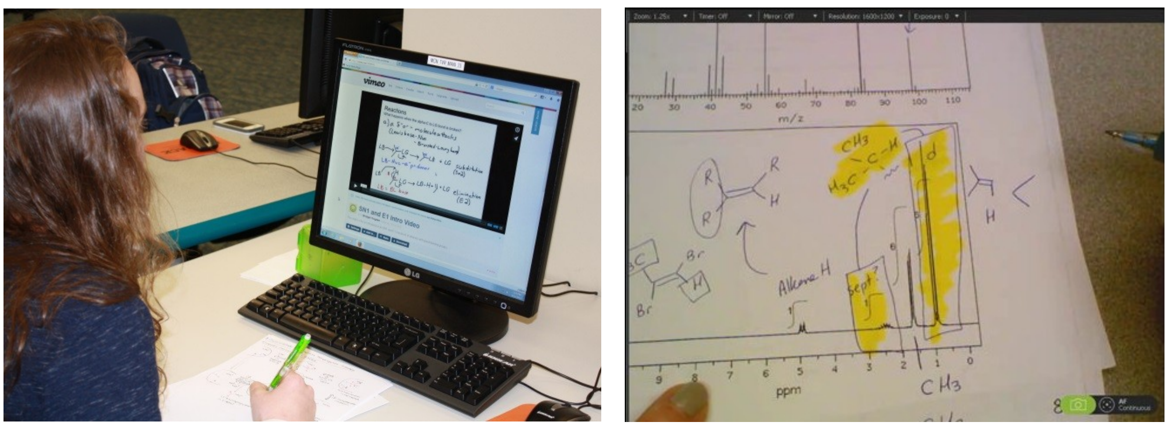


Figure 2. a.) Flipped class student watching a video lecture.[9] b.) Screenshot of a video key covering a spectroscopy problem.[12]

Another item that the students suggested was a video as exam review. Exam review is typically not conducted during class time because I need to focus on the content or problem solving at hand. However, students often ask for review notes or review sessions prior to exams. Review sessions are difficult to schedule given that class time cannot always be sacrificed, and students have a myriad of other activities scheduled during their time out of class. Posting a review video, however, would afford the students an additional learning tool. I look forward to utilizing this idea in future semesters.

Conclusion and Summary

A major duty of teaching is to continually observe students in the classroom environment and to make adjustments when necessary. It had become apparent that the previous lecture-based style of content delivery in organic chemistry 1 was not entirely giving students what they needed to succeed. By flipping the classroom, I was able to determine that yes, flipped pedagogy can be effective in a larger-enrollment class; yes, the extra time spent on engagement seemed to help the class a whole with earning higher course grades; and yes, the students' perception of the pedagogy supported that they found the methods worthwhile. Even flipping just one class period per week resulted in measured improvement. Based upon this preliminary data, I look forward to implementing flipped learning in my future organic chemistry 1 courses to help students succeed with less anxiety and deeper learning.

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9. Vimeo. www.vimeo.com. (accessed Apr 2014). (A sample video from my flipped class is available here: http://vimeo.com/trogden/sn1e1intro).

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11. I first heard the idea of the Goldilocks principle at a seminar in September 2013 by Dr. David Christian of Macquarie University in Sydney, Australia. Often used by astrophysicists and those who study "big history," the principle implies that new innovations are made and new things appear when conditions are just right. The term has been appropriated by many disciplines.

12. A sample link for a video key covering a spectroscopy problem is available here: http://vimeo.com/58554311. (accessed Apr 2014).