

Chapter 11

Evaluation of a Peer-Led Team Learning-Flipped Classroom Reform in Large Enrollment Organic Chemistry Courses

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Organic Chemistry is an essential course for students in STEM disciplines and for those interested in pursuing professional degrees such as medicine and dentistry. It also has the reputation of being a “gate-keeper” course that has high DWF rates. At Georgia State University, the enrolled students have been split into one small honors class (of about 70 students) and two large sections of 212 students, in each section. The course presents conceptual challenges for many students in these large sections resulting in a high DWF rate (approximately a 30% DWF rate). There are an increasing number of studies in the literature that show the benefits of active learning strategies, including lowering of failure rates and higher performance on examinations. In order to reduce the DWF rates and increase student motivation, persistence, and completion of their degrees, we implemented a flipped classroom in conjunction with Peer-led Team Learning (PLTL) in Organic Chemistry. Herein, we present the details of this implementation, the assessment of student outcomes and lessons learned.

Introduction

Across the United States, Organic Chemistry is one of the most challenging science courses. Many STEM majors require this course to continue in their intended path and to continue in STEM pathways beyond the undergraduate degree. For many students, this course has become a barrier to success (1, 2). Nationally, the failure and withdrawal rates for Organic Chemistry have been known to be as much as 50% (3).

Georgia State University (GSU, Atlanta Campus) is a large urban research university. As of Spring 2019, we currently have 25,653 undergraduates and 34,484 students enrolled. GSU is a diverse institution - we are a mix of African American (40%), White (33%), Asian (16%), and other (11%) students; 40% of our students are men and 60% are women. Typically, our Organic Chemistry II courses consists of three sections - one honors/chemistry major section (~70 students) and two non-major sections of approximately 212 students per section.

In 2015, we collected baseline data on the DWF and ABC rates of students taking Organic Chemistry courses. At that time, the failure/withdrawal rate (C- or lower and withdrawals) averaged 20-30% for the first- and second-semester Organic Chemistry courses. High failure rates can lead to more students repeating the course, thereby delaying graduation and increasing their chances of leaving the STEM pathway. Over 2000 students enroll in Organic Chemistry courses each year at GSU. As a result, it is possible that 400-500 students each year were either repeating the course or considering a non-STEM major. From this data set, we also observed that underrepresented minorities earned disproportionately lower grades in these courses. For instance, the average grade in the course for Black or African American students was 2.51, while the average of other student-groups ranged from 2.80 to 3.03. Another indicator of student success in Organic Chemistry is the American Chemical Society (ACS) National Examinations. The ACS National Examination is a standardized exam that assesses students' conceptual understanding of course material. This exam can be used to compare our students to a national sample. The average score on the ACS Exam for Organic Chemistry courses at GSU was in the 40th percentile. As a chemistry department, our goal was to raise this to at least the 50th percentile.

Given the current state of student success and retention in Organic Chemistry, we began to investigate high impact, evidence-based practices in the education literature that had potential to increase student success and retention in our high enrollment Organic Chemistry courses. In 2014, we planned to pilot Peer-led Team Learning (PLTL) in our courses. PLTL is a nationally recognized practice that provides an environment in which students can engage in problem solving and discussion among themselves (4, 5). PLTL utilizes undergraduate students who have successfully completed the course to facilitate group problem-solving sessions. Typically, the problems used in the PLTL workshops are designed to be sufficiently challenging to encourage group discussion and build conceptual understanding of topics. There was already strong evidence that PLTL helped elevate exam scores and final grades and increase student retention in chemistry courses (6, 7, 8, 9, 10, 11, 12, 13). For example, in a study involving an Organic Chemistry course, students in PLTL had an 85% pass rate compared to 69% for students who did not attend the optional PLTL (10). Also, students participating in the PLTL workshops outperformed those who did not take workshops on course GPA (2.90 versus 2.51), and on the standardized American Chemical Society (ACS) Examination scores (77th versus 69th percentile).

PLTL has been implemented as an optional or as a mandatory component of a course. In our case, we decided that the mandatory implementation, in which one day per week of the course is used for PLTL, would be ideal for the student body at Georgia State for the following reasons: 1) Our Organic Chemistry courses were more than 200 students in enrollment and PLTL will provide a way to increase classroom community among students and make a larger class seem smaller, 2) unlike other peer reform practices such as Supplemental Instruction (SI), the PLTL would be an integral part of the course and will occur during regular class hours. Many of our students are commuters and also work off campus so they do not always have time to attend SI, and 3) it will give students an opportunity to work together on problem solving which fosters learning through social constructivism (14, 15).

Although we were hopeful that PLTL could be effective, the instructors were concerned that replacement of one class period with PLTL may reduce the time available to present the necessary course content. One solution was to use a flipped or blended classroom approach to address the loss of class time. In general, the flipped classroom involves moving instruction outside of the classroom so that face-to-face class time can be used for active learning. There are now many examples of

implementation of flipped courses in general and organic chemistry. At the time of our implementation, there were few reports of the flipped or blended learning in large enrollment courses. For further reading, a comprehensive review of the use of the flipped method in chemistry courses have been published by Seery (16). Since our implementation of this model, a recent publication in the *Journal of Chemical Education* discussed a similar approach at another institution (17). With the use of the flipped classroom approach, we were comfortable introducing PLTL without losing valuable class content. The instructor (Mutanyatta-Comar) was primarily assigned to the Organic Chemistry II which is offered in both Fall and Spring semesters. Therefore, the PLTL-flipped course was implemented in Organic Chemistry II over five semesters during Spring 2014 to Fall 2017.

PLTL-Flipped Classroom Setting

The PLTL-flipped course consisted of three lectures per week (70 minutes/lecture). In a PLTL-flipped course, students participated in lecture twice per week. The classroom had typical theatre-style seating for around 200 students.

The third lecture was replaced by PLTL (Figure 1). The class was divided into groups of about 16 students per peer leader. The missed lecture was supplemented by online YouTube videos that we prepared using the “Explain Everything” app for iPad. 18 Students accessed the videos through the GSU Learning Management System (Desire2Learn format).

As indicated previously, we implemented PLTL-flipped five times in Organic Chemistry II: Spring 2014, 2015, 2016, Fall 2015, 2017. Dr. Mutanyatta-Comar was the only instructor in Organic Chemistry willing to implement PLTL-flipped. Dr. Mooring is a chemistry education researcher, and she assisted Dr. Mutanyatta-Comar with training peer leaders, and planning appropriate assessments.

For Spring 2014, 2015, 2016 and Fall 2015, PLTL sessions were held on Fridays. But for Fall 2017, PLTL was on Mondays. We found the latter model to be more reasonable for students allowing them to have enough time to write notes from the assigned videos. The activities listed for Fridays (Figure 1) took place outside the classroom to compensate for the missed lecture on Mondays (PLTL sessions). Class time (Fridays and Wednesdays) was used for lecture (~50 minutes) and group activities (20 minutes). The post lecture activities are equivalent to homework. Homework assignments had specific deadlines. Students were expected to do textbook questions and questions from the ACS study guide for additional practice. These were ungraded and there was no deadline.

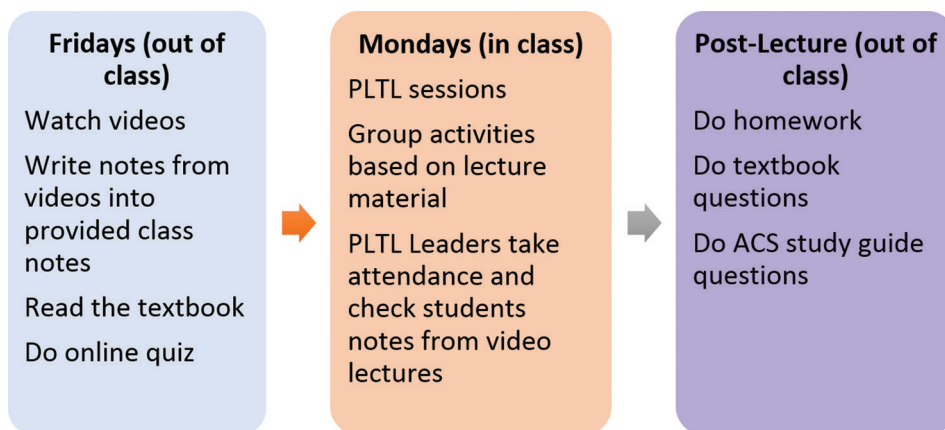


Figure 1. PLTL-Flipped Classroom Structure.

Components of Implementation of Our PLTL-Flipped Model

There are five components to the implementation of our model that we will discuss in detail below:

1. Recruiting and hiring peer leaders
2. Weekly training of peer leaders
3. Preparation of videos
4. Room reservations for PLTL sessions
5. Assessment

Recruiting and Hiring Peer Leaders

Peer leaders are students who have recently and successfully completed Organic Chemistry I/II courses. We asked Organic Chemistry instructors to recommend students with excellent grades and final ACS exam scores. We interviewed the pool of students and selected leaders based on additional qualities such as leadership and communication skills, confidence, and a passion for teaching. In addition, they had to be available for weekly training and for the PLTL sessions. We also hired one student to assist with administrative tasks such as preparing copies of PLTL worksheets and distributing them to the PLTL classrooms. This administrative leader was also available as back up in case one peer leader was absent.

We applied for internal grants provided by the University System of Georgia to give a small stipend to the peer leaders. The leaders were paid \$10 per hour for 3 hours/week: one hour for each of the following – preparation and review of workshop material, training session, and facilitation of the PLTL session. Fostering leadership, resume building and solidifying concepts in preparation for entrance exams such as the MCAT seemed to be the motivation for the majority of students who became Peer Leaders, since the monetary compensation was minimal.

Weekly Training of Peer Leaders

Peer leaders met with us for one-hour weekly training on how to facilitate the PLTL sessions. Dr. Mooring designed a course (CHEM 3600) to train new peer leaders. This course was also cross-listed with Biology, so students could receive credit in their appropriate area of study. However, only a few leaders needed the credit for graduation.

During the weekly training, peer leaders discussed various topics related to facilitation of group discussions. Examples of topics covered included group dynamics, problem-solving strategies, student learning styles, leadership, communication skills and strategies to trouble-shoot common issues between peer leaders and students. The topics were covered using weekly readings, discussion, and group activities. We also went over the workshop material before the actual PLTL sessions. The peer leaders worked in groups and approached the material as though they were the students in the course. We also encouraged them to think about any challenges that the students would have with the content. During training sessions, the leaders also reflected and discussed their weekly challenges and triumphs as leaders based on the PLTL sessions they facilitated the previous week.

Each peer leader met with about 10-19 students (depending on the number of peer leaders that semester) in an assigned room to facilitate PLTL sessions. The PLTL leader further divided the students in groups of threes or fours to enable effective group discussions among students. Leaders were required to facilitate the workshop and take attendance each week.

Preparation of Videos

We prepared YouTube videos using “Explain Everything™” app for iPad. Dr. Mooring received a grant from the GSU Center for Instructional Innovation in 2013 to purchase 20 iPad tablets to support chemistry learning. Therefore, the iPads were readily available to faculty. The app is easy to use, is intuitive, and does not require any additional software. The app records over uploaded PowerPoint presentations or PDF documents. In addition, free-hand drawing and writing could be done on the tablet using a stylus. The video is directly uploaded from the app to YouTube. Students accessed the YouTube video as a link embedded into our course learning management system, Desire2Learn. Only those who have access to the link can view the videos.

As a best practice, each video was no more than 15 minutes long (19, 20). Students were strongly advised to take notes and write down questions they had as they watched the video material. After watching the video, students were asked to either answer simple quiz questions (online or in-class) related to the videos. This step was to ensure that students were watching the videos and were prepared for the face-to-face discussion in PLTL.

When we first implemented PLTL (Spring 2014), we prepared videos on relatively simple topics such as naming organic compounds. We gradually increased the number of videos prepared, some of which included reaction mechanisms. By Fall 2016, we had prepared a total of 105 videos for organic chemistry II. Although preparation of the videos is tedious (due to editing) and time consuming, once the videos are prepared, they can be reused for the following semesters. It is noteworthy to mention that, we did not prepare videos for all content material covered in organic chemistry II. We strongly feel that some topics need to be taught face-to-face so that students can grasp the concepts.

Room Reservations for PLTL Sessions

Georgia State University is located in the heart of downtown Atlanta. The University is therefore constantly faced with challenges related to space availability. For PLTL sessions, a class of 212 students was divided into small groups of approximately 16 students per group; hence, we needed about 13 rooms per semester. Therefore, room reservation had to be done way ahead, prior to the semester of PLTL implementation to ensure that rooms were available for PLTL sessions. We coordinated with the chemistry department staff member who is in charge of class scheduling to enable us to reserve these rooms.

Assessment

We assessed the impact of the PLTL-flipped course in three ways. First, we used self-reported surveys to assess students’ perceptions of various course components, such as PLTL, peer leaders and videos. Second, we assessed the impact of the course on the DWF and ABC rates. And third, we looked at the impact of the PLTL-flipped course on students’ performance on the American Chemical Society (ACS) compared to non-PLTL-flipped courses.

The survey questions were designed using a web-based survey software, Qualtrics. Students were given a maximum of three extra credit points for completing the surveys. Historical and current DWF and ABC rates were collected from GSU Institutional Research Office for comparison. This study was approved as “exempt” by the IRB board of GSU and the collection of Organic Chemistry student data from the Institutional Research Office was approved as non-human subject research.

Results and Discussion

Student Perception of PLTL-Flipped Model

In general, students' comments regarding the videos were positive (more than 80%). Student comments were coded and categorized into themes (Table 1). Positive comments about the video material included the ability to re-watch videos, being able to see the material prior to class. Negative comments were few, but commonly referred to issues with time management. Furthermore, students preferred the use of videos for concepts such as naming as opposed to challenging material such as mechanisms. A few students also commented that the PLTL-flipped model just did not fit their perceived learning style.

Table 1. Students' comments regarding the video material

| <i>Positive Comments</i> | |
|---|--|
| The ability to re-watch videos | "... I find the videos far more helpful than the actual class session. They are often more detailed and it gives me time to take notes." "That I could pause the video and go back if I miss something or needed to hear/see something again." |
| Usefulness of seeing the course material prior to class | "Being able to grasp concepts BEFORE coming to class. Being able to review concepts AFTER class." "I really like the videos because it allows me to preview the material in an easy way so that when I come to class, I already have an understanding of some of the material. Also, the videos help teach most of the material so that we can spend class time focusing on the harder material." |
| <i>Negative Comments</i> | |
| Not preferred learning style | "I rather have all the material presented in class. I feel like it's unfair to have the same amount of hours of class if there is online learning as well." "I like the more one on one interaction in class and how if I didn't understand I could ask friends or you right away." |
| Not good for more challenging material | "Video lectures are not the optimal way for me to learn more material, but I understand that they are necessary to create time for PLTL. As long as easier concepts, such as naming, are covered in the videos, I see no problem with using them." |
| Time management | "Work and weekend CNA classes often caused me to be behind, but I would've loved extra time to watch them beforehand. I'm often playing 'catch up'. "Between balancing my other classes and two jobs it was hard to find time." |

Students also enjoyed going to the PLTL sessions as indicated by the following comments:

"I really enjoy the PLTL because it is an interactive way to practice more problems and since the groups are so small, the group can go at its own pace instead of trying to rush and catch up with everybody else. My peer leader is very nice and really knows her information so she can answer any questions that we have."

"I love my PLTL sessions because he makes you do problems on the board which is nice. He makes you do the problems first then we all do it together. This can make it easier for you to understand and learn the material."

Many students also commented that they enjoyed PLTL but will like it to be more than one hour. In addition, a small number of students had mixed comments regarding PLTL:

“My PLTL Leader is good for supplemental instruction, but I truly hate the fact that the PLTL sessions take place of lecture time. I would highly prefer to be taught in class that have the PLTL sessions because sometimes there can be discrepancies in the way the PLTL leader understands the material which can impact my overall understanding and hinder my progress...”

Results of DWF and ABC Rates

There was a general trend indicating that our PLTL-flipped model lowered DWF rates and increased ABC rates (Figures 2 and 3). In the Spring semesters 2014, 2015 and 2016, the average ABC rate was 79.8% for the reformed courses and 74.5% for the traditional courses. The differences in the ABC and DWF rates between the reform and the traditional courses were determined using a Z-test of proportions and found to be statistically significant at $p < 0.05$ (See Table 2). However, in the Fall semesters, there were no statistical difference between the reformed courses and the traditional courses in DWF or ABC rate. It is important to note that in the Fall 2015 and Fall 2017 semesters, the reformed course moved to an 8 am start time; whereas, the Spring courses began at 1:30 pm. Also significant, is that in Fall 2015, the traditional course was at 3 pm and saw a slightly better (but not statistically significant) ABC and DWF rate than the reformed course (72.8% vs 70.4%). There is some evidence in the literature that early morning classes at 8 am or 9 am have negative impacts on college students grades and learning (21). In Fall 2017, when both the reform and traditional courses were at 8 am, both courses showed very similar DWF and ABC rates. These results point to the possible impact of course time on student outcomes in a course.

Table 2. Comparison of combined semesters: Mutanyatta-Comar with PLTL vs NPLT (other instructors)

| | <i>Spring</i> | | <i>Fall</i> | | <i>Fall & Spring</i> | |
|----------------|---------------|-----------------|-------------|-----------------|--------------------------|-----------------|
| | %ABC | %DWF | %ABC | %DWF | %ABC | %DWF |
| <i>PLTL</i> | 79.8 | 18.9 (N=541) | 71.9 | 25.2 (N=267) | 76.6 | 21.4 (N=808) |
| <i>NPLTL</i> | 74.5 | 24.3 (N=562) | 73.2 | 25.8 (N=253) | 74 | 24.9 (N=815) |
| <i>Z-Score</i> | 2.0941 | 2.1768 | 0.332 | 0.1569 | 1.2143 | 1.6713 |
| <i>P value</i> | 0.01831 | 0.01463 | 0.3707 | 0.43644 | 0.11314 | 0.04746 |

N = Total number of students. * Significant at $p < 0.05$.

In order to determine if our initial results were due to the PLTL-flipped model or an instructor effect, we compared %ABC and %DWF for Dr. Mutanyatta-Comar when she taught the course using the PLTL-flipped model versus five prior semesters when she did not use any active learning. In Spring 2010, 2011, 2013 and Fall 2011 and 2012 she taught the course before introducing this reform in her Organic Chemistry II course (Table 3).

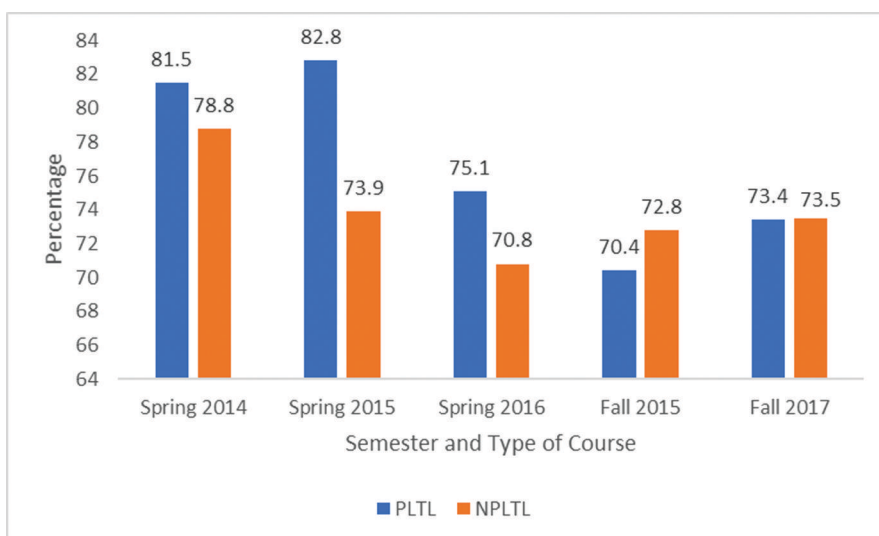


Figure 2. Comparison of %ABC for PLTL vs NPLTL in Organic Chemistry II. * *PLTL: PLTL-flipped/reformed course; NPLTL: Traditional course.

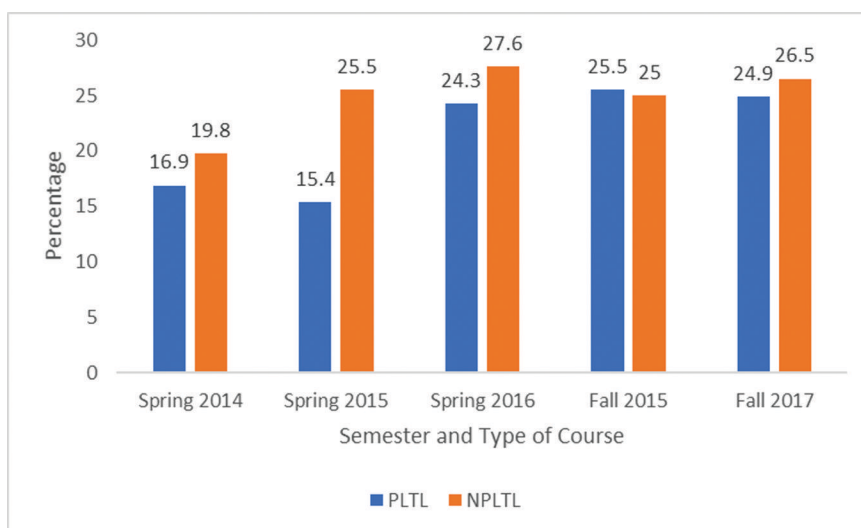


Figure 3. The impact of PLTL on %DWF in comparison to NPLTL in Organic Chemistry II. * *PLTL: PLTL-flipped/reformed course; NPLTL: Traditional course.

Data analysis indicate that the PLTL-flipped model results are still statistically significant in lowering %DWF and increasing %ABC, except for Fall semesters (possibly because of the impact of the semesters with the 8 am course time). However, the overall combined Fall and Spring semesters show a significant difference in both the %ABC and %DWF, see last two columns of Table 3.

Table 3. Comparison of combined semesters Mutanyatta-Comar taught with PLTL (Spring 2014, Spring 2015, Spring 2016, Fall 2015 & Fall 2017) and without PLTL (NPLT; Spring 2010, 2011, 2013 and Fall 2011 & 2012)

| | Spring | | Fall | | Fall & Spring | |
|---------|--------|-----------------|---------|-----------------|---------------|-----------------|
| | %DWF | %ABC | %DWF | %ABC | %DWF | |
| PLTL | 79.8 | 18.9 (N=541) | 71.9 | 25.2 (N=267) | 76.6 | 21.4 (N=808) |
| NPLTL | 64.8 | 31.4 (N=359) | 80.3 | 16.3 (N=412) | 71 | 25.3 (N=780) |
| Z-Score | 5.0122 | -4.3066 | 2.5405 | 2.8428 | 2.5386 | 1.8374 |
| P value | 0 | 0 | 0.00554 | 0.00226 | 0.00554 | 0.03288 |

N = Total number of students. * Significant at $p < 0.05$.

ACS Scores

In all semesters of the implementation there was no statistical difference (Z-test of proportions) in ACS scores between traditional (NPLTL) and the PLTL-flipped course (see Table 4). The ACS scores of students in the Honors section of the course were not included in the statistical analysis to afford a fair comparison between courses.

Table 4. The median ACS scores out of 70 in Organic Chemistry II Courses

| Semester/ Year | PLTL-Flipped Course | Traditional Course | Z-test statistic ($p=0.05$) |
|-------------------|--|--|----------------------------------|
| Spring 2014 | 33 (N=174) | 38 (N=190) | -1.3725 |
| Spring 2015 | 33 (N=149) | 36 (N=150) | -0.7436 |
| Spring 2016 | 33 (N=146) | 32 (N=160) | 0.00 |
| Fall 2015* | 30 (N=79, non-honors) 46 (N=3, honors) | 30 (N=111, non-honors) 43.5 (N=4, honors) | 0.00 |
| Fall 2017* | 32 (N=145, non-honors) 52 (N=3, honors) | 33 (N=93, non-honors) No honors section | -0.2114 |

N = Total number of students who took the ACS exam. * Organic Chemistry II was only cross listed with the honors section in Fall 2015 and 2017.

Results of Student Performance by Race

Given the high proportion of Black students at GSU (40%), we felt that it was important to comment on the outcomes of Black students in the traditional and the reformed courses. We preferred to use the term “Black”, because many of our students are international students from Africa and the Caribbean. Our Institutional Research Office also uses the term “Black” in data reports for the same reason. As mentioned previously, before implementing the PLTL-flipped reform, we observed that there was a performance gap between the final grades of Black students and students of other races in Organic Chemistry courses. Therefore, it was important that we

investigated what impact the reformed course had on these students when the data was disaggregated by race.

We obtained data on student performance in Organic Chemistry II course at GSU from Fall 2012 through Spring 2018. This data included information on student race and grade in the Organic Chemistry course. We used this data to compare the performance of students by race in the PLTL-flipped courses (Spring 2014, Spring 2015, Spring 2016, Fall 2015 & Fall 2017) to students in all previous traditional courses (Fall 2012, Spring 2013, Fall 2013).

A chi-squared (χ^2) test of independence was used to compare the proportion of Black and non-Black students receiving A, B, C, D, or F/W grades for the traditional courses and for the reformed Organic Chemistry II course. Our results indicate that for the traditional course the proportions of these grades were significantly different between Black students and students of other races ($\chi^2 = 95.0244$. The p-value is < 0.00001 ; $p < 0.05$). However, for the reformed course this difference was not significant ($\chi^2 = 9.0414$; $p = 0.060072$; $p < 0.05$). Table 2 shows the rates of A, B, C, D and F/W grades by student race. It is clear, that the performance gap between Black students and students of other races became smaller in the PLTL-flipped courses compared to the traditional courses. The difference in the ABC rate between Black students and non-Black students was around seven percentage points (80% vs. 73%) in the traditional course, while in the reformed course, the gap was mostly closed with approximately one percent difference in the ABC rate between Black students and other students (77% vs 76%).

Looking into this more closely, we also observed that the ten percent gap in 'A' grades between Black and non-Black students were reduced to a six percent gap in the PLTL-flipped course. Moreover, Black students earned more 'B' and 'C' grades than non-Black students in the reformed course. Whereas, in the traditional course the situation was reversed (Table 5). This was a significant and important finding of this implementation that requires even further investigation.

Table 5. Grade distribution in Organic Chemistry II Courses by Race

| | <i>PLTL-Flipped Course</i> | | | | <i>Traditional Course</i> | | |
|--------------|----------------------------|------------------|--------------------------------|--------------|---------------------------|--------------|--------------------------------|
| <i>Grade</i> | <i>Black</i> | <i>Non-Black</i> | <i>Gap (Black – non-Black)</i> | <i>Grade</i> | <i>Black</i> | <i>Other</i> | <i>Gap (Black – non-Black)</i> |
| A | 11.90% | 17.90% | -6.00% | A | 10.50% | 20.90% | -10.40% |
| B | 21.60% | 19.60% | 2.00% | B | 23.10% | 27.70% | -4.60% |
| C | 43.70% | 38.80% | 4.90% | C | 39.60% | 31.50% | 8.10% |
| D | 2.40% | 1.30% | 1.10% | D | 2.60% | 2.10% | 0.50% |
| F/W | 20.40% | 22.30% | -1.90% | F/W | 24.20% | 17.70% | 6.50% |

Limitations of the Study

There are a few limitations to the results and conclusion drawn in this study. We recognize that the results we obtained may be unique to our institutional characteristics and demographics. However, it is the diversity of our institution that also makes the results of this study more widely applicable. Below we describe other characteristics of this study that may affect how the results are interpreted.

For sequenced courses, for example Organic Chemistry I and II, the majority of students tend to adjust better to pedagogical changes if they maintain the same instructor. For example, the positive

results (increased %ABC, lower %DWF) observed for organic chemistry II in Spring 2014 and 2015 (Figures 1 & 2) may be attributed to the fact that 42% of the students in Spring 2014 and 55% of those in Spring 2015 took Dr. Mutanyatta-Comar's Organic Chemistry I in Fall 2013 and Fall 2014, respectively.

In the case of off-sequence courses, when Organic Chemistry II is taught in the Fall semester, instead of the Spring semester, one should keep in mind that this is usually the most challenging group of students for the following reasons: i) some of the students may have taken Organic Chemistry I in the spring semester. Given the vast amount of information in this course, it is easy to forget the material. ii) the course may consist of a number of transfer students. The coverage of material may differ in different institutions. iii) we have also encountered students that have stated that they took Organic Chemistry I approximately 3-4 semesters ago or even 1-2 years ago. All these factors may help explain the data observed in Figures 2 and 3, Fall semesters.

Peer leaders are generally recruited from students who have successfully completed the course. Our first group of peer leaders were selected from students who had taken organic chemistry with various instructors. However, for subsequent semesters, leaders were recruited only from Dr. Mutanyatta-Comar's course, particularly those that had taken a course with PLTL, for consistency of the teaching style. We noticed that students who took the course from other instructors had a different perspective of PLTL and approached course content differently which sometimes confused students.

Finally, the study showed preliminary evidence that the use of the flipped-PLTL reform positively impacted Black students. However, we believe that considering other variables and additional qualitative studies can help to further analyze these results.

Lessons Learned

Implementation of pedagogical changes in any course can be overwhelming both for the instructor and students. When the instructor is open to student feedback and changes are introduced gradually, students generally buy-in. When we first implemented PLTL, we did not completely flip all of the course at once. Rather, we began by assigning one video per week for the first semester. This gave us time to prepare more videos to be used in the following semesters. We assigned about two videos per week and gradually added more videos each semester. However, instructors do not necessarily need to prepare their own videos due to readily available videos from sites such as YouTube, MIT open courseware, and Khan academy. Some instructors have also flipped the classroom by having assigned textbook readings instead of watching a video.¹⁶

Formative and summative assessment are critical. In order to alleviate work overload, it is a good idea to collaborate with other faculty members with expertise in chemistry education research, educational research or statistics to assist with data collection and statistical analysis.

Another important component is that the material used in the PLTL-flipped course needs to be well structured. That is, students need to know when assignments are due, which videos to watch or which reading should take place before class. Learning management systems are a convenient way to do this. In addition, students should be guided on how to manage their time so that they stay on track.

Another aspect to consider includes which day of the week one plans to do PLTL sessions and when to assign the videos to substitute for the missed lecture. In four of the five semesters we implemented the PLTL-flipped model, videos were assigned at the beginning of the week. Students were expected to have watched the video(s) prior to the PLTL sessions held on Fridays. We noticed increased unpreparedness during PLTL sessions in which students were not participating in group discussions. Several students did not have time to watch the videos due to lack of time management

skills resulting from hectic work schedules and commitment to other courses. During the last semester of PLTL-flipped model implementation, PLTL sessions were held on Mondays. Videos were assigned the weekend prior to PLTL but did not constitute material covered in the PLTL sessions. Students were expected to have watched the videos by Wednesday in preparation for class activities. This change allowed students ample time to watch videos and there was improved preparedness.

Conclusions

Instructional modifications can be costly and external funding is generally limited. We were fortunate to have access to NSF and internal grant funding to help implement our project. These grant funds were used to pilot our effort by paying for peer leaders and providing summer salary for instructors to work on course material. If such funding is available at your institution, we encourage others to put them to use.

In summary, the PLTL-flipped reform had a significant impact on students' performance and the majority of students had a positive attitude towards the course components. The positive value on students' performance may be primarily due to the fact that the format allows for an increase in active-learning activities (PLTL and in-class group activities). The flipped course format may reduce students' cognitive load because they have the ability to absorb some of the course material at their own pace outside of class.

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