Comparing the Efficacy of Flipped vs. Alternative Active Learning in a College Genetics Course

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ABSTRACT

Active learning is known to be a key component of student engagement and content mastery. Flipped learning is a pedagogical approach that moves passive, initial instruction out of the classroom (usually as recorded videos) and reserves class time for active-learning exercises that fortify learning. Reports have demonstrated the success of flipped learning, but it is unclear whether that success is due to students watching videos at home (i.e., the "flipped" structure of the flipped classroom) or to the active learning that takes place in class. I sought to answer that question by comparing two sections of sophomore-level college genetics. One section was flipped and the other taught traditionally, but with extensive active learning included as homework. Student satisfaction, performance on quizzes and exams, and overall achievement of course learning goals were compared. Interestingly, after taking into account the diversity of academic strength in both sections, there was no difference between the sections for any of the measured parameters. Although flipped learning may offer no additional benefit over other forms of active learning, it is far easier and more efficient to embed and integrate active learning into a flipped classroom.

Key Words: Flipped learning, active learning, genetics, higher education.

Introduction

Passive lecturing without an active, student-centered component is largely ineffective for deep comprehension and long-term knowledge retention (Halloun & Hestenes, 1985; Seymour & Hewitt, 1997). With passive lecturing, students’ attention waxes and wanes, instructors become complacent, and learning often becomes focused on rote memorization of details and terms rather than on comprehension. Traditional lecturing does not promote higher levels of thinking about course content and impedes one-on-one teacher–student interactions (Sams & Bergmann, 2013). Also, millennials, in particular, have a lower tolerance for lecture-based learning and a strong preference for more active, student-centered teaching and learning approaches (Prensky, 2010; Roehl et al., 2013). Despite our knowing that lecture-based instruction is deeply flawed, however, we continue to offer this approach to our students, especially those in secondary and higher educational institutions. Why?

Part of the reason is that the acquisition of any new knowledge is a two-step process. First, there is the initial passive exposure to the material, with the learner observing or listening to the teacher. The second step involves the learner assimilating this new knowledge through purposeful practice (i.e., practicing the material with the intent of mastering it). Indeed, Ericsson et al. (1993) state that students must engage in such purposeful practice, with the intention and explicit goal of learning, in order to reach mastery of the content. However, having only a finite amount of time with students, instructors lecture in an effort to achieve the initial exposure to content and then rely on homework assignments to achieve purposeful practice. This approach, though logical, wastes valuable class time on passive, unidirectional instruction instead of allowing students and teacher to be engaged in a bidirectional give-and-take of knowledge. Arguably, the flipped-learning approach offers the best of both worlds: a means for initial exposure while preserving class time for purposeful practice.

Flipped Learning

Flipped learning is a pedagogical approach to teaching and learning in which the initial exposure to course content occurs at home before the students come to class.
Advantages of Flipped Learning

Instructors report that flipped-learning approaches have allowed them to get to know their students better and more individually, increased two-way communication in class (between instructors and students, and among students), and provided time and flexibility for instructors to help struggling students (Bergmann & Sams, 2008; Clark, 2015). This additional time and flexibility in the classroom also freed instructors to set up advanced students with more challenging activities, thus truly achieving a personalized learning environment (Sams & Bergmann, 2013). In addition, since flipped classrooms provide background course content through online videos, students who are absent do not fall behind as readily (Bergmann & Sams, 2008).

There is sometimes a misconception among instructors considering flipped learning that students will not like this approach. However, the existing literature suggests the opposite. Most studies of flipped learning that include an analysis of student perceptions report positive student feedback on this approach. In general, college students appear to prefer flipped learning (Bergmann & Sams, 2008). Specifically, college students experiencing flipped learning have reported an increase in comprehension and comfort with the material being learned (Fautch, 2015), increased comfort in sharing questions and answers with one another in class (Fautch, 2015), increased engagement, better instruction and better use of in-class time (Clark, 2015), a feeling that there is more time for the instructor to answer their questions (McGivney-Burelle & Xue, 2013), enjoying the group work that flipped learning allows (Clark, 2015), and even enjoying the online videos they are required to watch before class (McGivney-Burelle & Xue, 2013). In one meta-analysis of studies comparing flipped and unflipped instruction, reports of student satisfaction between the two formats were largely consistent and similar, with students taught through flipped learning being equally satisfied with the course (Bishop & Verleger, 2013). However, the same meta-analysis did note that there were invariably a few students in each study who strongly disliked the change to flipped learning. Another study reported a significant decrease in student satisfaction due to flipped learning (Strayer, 2007, 2012). Interestingly, though, even in that study the flipped students reported increases in cooperation and innovation in their flipped classroom. More important than student perception of flipped learning, though, is the impact of this approach on student performance.

In one study a single unit of mathematics was flipped, resulting in an increase of 5% on exam and homework performance, despite the disruption of flipping instruction midway through the course (McGivney-Burelle & Xue, 2013). In another study, flipped learning had a positive impact on student attitudes toward the class and instructor, as well as on student performance (Wilson, 2013). But, as more commonly observed, the effects of flipped learning on student performance are questionable. Numerous studies have reported no change in student performance when comparing flipped and unflipped sections/cohorts (Bergmann & Sams, 2008; Clark, 2015; DeSantis et al., 2015; Fautch, 2015). One such report suggested improvement of the grades and assessment results of lower-performing students, more student persistence with course content in flipped sections, and somewhat increased exam performance (Fautch, 2015), but none of these findings were statistically significant.

Measuring the Role of “Flipped” in Flipped Learning

Active learning is superior to passive learning – this is clear. Also, flipped learning facilitates a more active-learning environment by freeing in-class time. Therefore, flipped learning should be superior to passive, lecture-based instruction as long as class time is reserved for active learning and fortification of course content. The better question then becomes “Is there any ‘magic’ to flipped learning itself?” Or, in other words, “Is flipped learning superior to other active-learning approaches?” This question has, thus far, been explicitly addressed in only one study. Jensen et al. (2015) sought to determine where an instructor’s time is best spent: on content delivery or content application? To address this, both comparison groups had the same course experience, with the exception that what one cohort was doing in class, the other was doing at home and vice versa. Critical-thinking components were intentionally woven throughout both sections – flipped and unflipped – and, in both sections, active learning was the predominant mode of content delivery. The researchers found that student performance was equivalent in all sections, and from this concluded that active learning was the key component for successful teaching and learning. Most interestingly, perhaps, in student surveys, students in both cohorts reported that the in-class time was the most helpful for their success in the course. In other words, face-to-face interaction with the instructor was seen as most beneficial, regardless of what students were doing in class.

The study presented here compares the delivery of college-level genetics in (1) the flipped-learning format with active learning in the classroom and (2) lecture-based instruction with active-learning elements assigned as homework. Because flipped learning requires the creation of learning resources (most notably, online lectures that are available to the students throughout the duration of the course), all such resources were made available to all students, regardless of their learning format, to ensure that no student in either section – flipped or unflipped – would be at any foreseeable disadvantage.

Realizing that background content is most commonly delivered passively, and that active learning is needed to fortify that knowledge, the question directly tested here was “Does it matter where active and passive learning occur?” In other words, “Is there a distinct advantage to passive learning occurring outside of class, as it does in flipped classrooms?”

Study Design

Students & Course Enrollment

This study was conducted during the fall 2014 semester at Bay Path University, using two parallel sections of a single-semester undergraduate course in genetics. Bay Path is a private, four-year women’s institution where genetics is required as part of all life sciences curricula (i.e., biology, biology secondary education, biotechnology, biochemistry, medical sciences, forensic science, and neuroscience programs). There were 15 students enrolled in the flipped section and 25 in the unflipped section. To avoid scheduling conflicts with other courses, students were free to choose their section and were
Flipped vs. Unflipped Sections

An explicit and intentional effort was made to keep the two sections as equal as possible, with the exception of the flipped nature of the instruction. In general, for the unflipped section all passive learning occurred in class and all active learning occurred at home. For the flipped section, passive instruction was completed at home and active learning occurred in class.

Flipped section. Each week, two full-length lectures became available to students directly through the Tegrity web portal and through Bay Path University’s learning management system, Canvas. Prior to the next week’s first class meeting, student reflections for each lecture were due. In their reflections, students needed only to report the concept(s) from the lecture that was/were clearest and state what made it so clear and report the concept(s) from lecture that was/were most confusing and state where that confusion lay. Specific feedback was provided to each student for each of their reflections.

During the first class meeting, the concept(s) reported as most confusing by the majority of the class were reviewed informally. Material was presented in a different way than in the lecture to promote clarification. During the second class meeting of the week, students engaged in more challenging activities. These typically were problem sets that utilized information from that week’s lectures but required deeper manipulation of that material (i.e., these were critical-thinking activities on the higher end of Bloom’s taxonomy; Bloom, 1956). Students spent approximately 60–75% of class time working through these challenges in groups. The remaining class time at the end of the session was spent, as a class, discussing ideal answers to each challenge question. Student group work on these challenge activities was submitted through Canvas and graded for effort, not accuracy. Following the second class meeting of the week, two more lectures became available to students to watch for the following week. Finally, each first class of the week began with a very brief (5–10 minutes) quiz on the previous week’s material. Figure 1 shows a typical week in the flipped section.

Unflipped section. Students received two full-length lectures in class each week. Within 24 hours of each lecture, students were required to submit brief reflections following the same guidelines and format as described above for the flipped cohort. Since review of confusing concepts was not possible in class, specific, individual, and often extensive feedback on these reflections was given to each student. After the second lecture session of each week, students were also assigned, as homework, challenge activities that were due just prior to our next class meeting. There were approximately five days allotted to complete these challenge activities, and the questions were identical to those completed by the flipped cohort in class. The unflipped students were strongly encouraged to work through these challenge activities in groups, but group work was optional. Extensive feedback was given to each student regarding their solutions to the challenges. Finally, at the start of each first class of the week, a very brief (5–10 minutes) quiz on the previous week’s material was administered that was similar to the flipped cohort’s quiz (with only minor changes made to specific details of the quiz to deter cheating).

Table 1 summarizes the in-class and at-home activities in both sections of the class. All recorded lectures were made available to all students in both cohorts, and those recorded lectures were identical, both in content and delivery, to the live lectures given in class to the unflipped students. It should be noted, however, that students in the unflipped section rarely accessed the recorded lectures, with the majority of students never once logging in to the Tegrity website.

Considerable effort was made to keep the flipped and unflipped sections as equal as possible, but two differences are worth noting. First, the flipped cohort received in-class review each week, while the same was not true for the unflipped students. Second, the unflipped students received more individualized feedback on their challenge activities than did the flipped section. While the specific effects of these differences cannot be measured, because the weekly reviews benefited the flipped cohort while the individualized feedback benefited the unflipped students, the impact of these differences was very likely mitigated.

Table 1. Summary of in-class and at-home activities of flipped and unflipped sections.

<table>
<thead>
<tr>
<th></th>
<th>Flipped Cohort</th>
<th>Unflipped Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In Class</strong></td>
<td>• Review of confusing concept(s)</td>
<td>• Lectures</td>
</tr>
<tr>
<td></td>
<td>• Challenge activities in groups</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Quiz</td>
<td></td>
</tr>
<tr>
<td><strong>At Home</strong></td>
<td>• Lectures</td>
<td>• Reflections</td>
</tr>
<tr>
<td></td>
<td>• Reflections</td>
<td>• Challenge activities (working in groups was optional and encouraged)</td>
</tr>
</tbody>
</table>

Figure 1. The weekly schedule of the flipped cohort.
Assessment

Students in the flipped and unflipped cohorts were compared across three broad areas. The first was performance on weekly quizzes, essay-based unit exams, and the cumulative, essay-based final exam. The content and format of the unit exams and final exam were identical between the two sections.

The second area of comparison was the assessment of course learning gains, measured via a pretest/posttest approach. At the start of the course, each student completed an online quiz in which each question mapped to a course learning objective. This measured the amount of prior genetics knowledge in each cohort. Students then completed the same quiz at the conclusion of the course. Student performance on each question was tabulated independently. This provided a quantitative measure of how much background knowledge of genetics students had when starting this course, and how much was learned from the course.

Finally, the third area of comparison was student satisfaction. Every three weeks, students participated in an anonymous online poll (administered via PollEverywhere.com) asking about their overall satisfaction with the course as a whole, their satisfaction with their particular section of the course, and their perceptions of the other section. This poll/survey was not formally validated, but instead was based on generic student-satisfaction polls found online.

Results

Student Satisfaction

Student satisfaction remained high in both sections throughout the semester, with no students reporting dissatisfaction at any point (Figure 2A). Interestingly, student satisfaction decreased appreciably in both sections during unit 2, as the course moved out of review material and into Mendelian genetics. This trend rebounded back to overall satisfaction as the course progressed further (and moved away from more mathematical aspects of genetics). There was no decrease in overall student satisfaction in the flipped cohort compared with the unflipped cohort. Interestingly, for all surveys, the vast majority of students would recommend the course to a friend, if taught in the same format they themselves were experiencing (Table 2), and the vast majority of students did not wish they had taken the course in the other format (Table 2). These data, taken together, demonstrate strong overall student satisfaction with the course, irrespective of which section they were in.

Finally, student responses on the overall course evaluations administered by Bay Path University are shown in Figure 2B. While they are nearly identical for all prompts, students in the flipped section gave slightly higher marks for the integration of supplemental resources, whereas students in the unflipped section gave slightly higher marks for feeling the freedom to disagree/express ideas and for instructor availability. Overall, for both sections and for all prompts, student satisfaction was high and equal to, or greater than, the overall average for all instructors rated at the host institution (data not shown).

Student Exam & Quiz Performance

Performance on mastery-based assessments (i.e., exams and quizzes) was compared between the flipped and unflipped sections. Figure 3A shows the class averages on each of the 10 weekly quizzes for both the flipped section (in black) and the unflipped section (in gray). The 15 students in the flipped cohort outperformed the 25 unflipped students on all quizzes. Figure 3B shows the cumulative quiz average for both the flipped and unflipped sections. A Student’s t-test revealed that the flipped cohort performed significantly better than their unflipped counterparts (t = 2.6, P = 0.019).

A similar trend was observed when comparing exam performance, as illustrated in Figure 3C. On all three unit exams, as well as on the cumulative final exam, the flipped section outperformed the unflipped section. Student’s t-tests revealed a significant difference between the two cohorts on exam 1 (t = 2.09, P = 0.043) and the cumulative final (t = 2.9, P = 0.006), but not on exams 2 (t = 298.0, P = 0.699) and 3 (t = 2.03, P = 0.051).

Finally, to illustrate that the differences in section performance were not due to a small handful of high-performing students in the flipped section skewing the averages upward, the overall distribution of final-exam scores are shown in Figure 3D. The unflipped section shows a normal distribution of final-exam scores, with ~20% of students scoring in the 70–79% range. The flipped section had an asymmetric distribution, but still ~40% of students scored in the 80–89% range. Therefore, exam averages reflect true class performance, with the highest percentages of students in the ranges that include the class averages. The higher exam and quiz performance in the flipped cohort is not due to a small minority of high-scoring students.

Assessment of Student Learning Gains & Overall Differences in Cohort Academic Strength

Summative assessment, for measuring student attainment of course learning objectives, was conducted between the flipped and unflipped sections using a pretest/posttest approach as described above. The flipped section had a class average of 37.1% on the pretest and 69.1% on the posttest, yielding a 1.86-fold improvement (Figure 4A). The unflipped section had a class average of 30% on the pretest and 57.8% on the posttest, yielding a 1.93-fold improvement. Based on their performance on the pretest, it appears that students in the flipped cohort began the course with more prior knowledge in genetics (Figure 4A), given that they performed 20% better on the pretest than the unflipped cohort. From that point, however, both sections gained a similar amount of knowledge in genetics from the course (~1.9-fold), regardless of which format they learned from, as shown in Figure 4A.

To address the possible confounding factor that students in the flipped section were simply better-performing students than those in the unflipped section, the average of the students’ overall grade point averages (GPAs) at the end of the previous semester were collected for each section (Figure 4B). Students in the flipped section had a significantly higher overall average GPA than those in the unflipped section (t = 3.355, P = 0.002); GPAs of 3.58 vs. 3.06, respectively. To better understand the relationship between overall GPA and course performance, eight students were identified in each section for grade matching (i.e., 16 students). Pairs of students (with one student from each section) were identified with nearly identical GPAs that were within 0.03 points of each other (on the typical 4.0 GPA scale). The exam averages in the genetics class were then compared for each of the eight student pairs. The average exam score for the eight grade-matched students in the flipped
Starting at the end of the third week of the semester, and repeated every three weeks until the twelfth week of the course, student satisfaction was polled as described in the study design. (A) Students were asked to rank their overall satisfaction with the course on a five-point scale, with the third option being neutral. The “flipped” (n = 15 students) and “unflipped” (n = 25 students) cohorts are labeled as such, with the week the survey was administered indicated under the relevant datasets. (B) Results from student course evaluations are shown for the two sections, labeled “flipped” and “unflipped.” Students were asked to rank their instructor on a four-point scale, with four being the highest mark. The corresponding questions/prompts are shown in the table adjacent to the histogram.

Table 2. Student satisfaction data.

<table>
<thead>
<tr>
<th>Week</th>
<th>Would you recommend this course, taught in this format, to a friend?</th>
<th>Do you wish you could switch into the other section and take this course in the other offered format?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flipped (n = 15)</td>
<td>Unflipped (n = 25)</td>
</tr>
<tr>
<td>Week 3</td>
<td>100% / 0%</td>
<td>100% / 0%</td>
</tr>
<tr>
<td>Week 6</td>
<td>100% / 0%</td>
<td>100% / 0%</td>
</tr>
<tr>
<td>Week 9</td>
<td>100% / 0%</td>
<td>94.4% / 5.6%</td>
</tr>
<tr>
<td>Week 12</td>
<td>92.3% / 7.7%</td>
<td>95.2% / 4.8%</td>
</tr>
</tbody>
</table>

Note: “Flipped” and “unflipped” refer to the teaching methods used in the course.
section was 78.8, and the average exam score for the eight grade-matched students in the unflipped section was 77.4. This difference is not statistically significant (P = 0.26 as measured by a Student’s t-test). In other words, when grade-matched students with near-equal academic success are compared between flipped and unflipped formats, there is no difference in student performance in genetics.

**Discussion**

The aim of this study was to determine whether there is a distinct advantage to passive learning occurring outside of class, as it does in flipped classrooms. This was done with the intention of not putting the unflipped students at any academic disadvantage; all learning resources were equally afforded to both groups. The primary
Figure 4. (A) Summative assessment of student learning gains was achieved by a pretest/posttest approach. At the start of the semester, all students were given a comprehensive quiz testing their overall, but superficial, knowledge of core concepts associated with genetics. This same quiz was re-administered at the end of the semester, and student achievements were compared. Shown are the flipped cohort’s percent accuracy on the pretest at the start of the semester, the flipped cohort’s percent accuracy on the posttest at the conclusion of the semester, the unflipped cohort’s percent accuracy on the pretest, and the unflipped cohort’s percent accuracy on the posttest. (B) The class average of overall grade point averages (GPAs) for all students in the flipped and unflipped sections, prior to the start of the fall 2014 semester. There were 15 students in the flipped section and 25 students in the unflipped group. Error bars represent standard deviations of the mean.
difference between the two comparison groups was where passive lecturing occurred: at home for the flipped cohort and in class for the unflipped section.

Student satisfaction was nearly equal between the two sections. While overall student satisfaction did ebb and flow over the course of the semester, changes in student perceptions and satisfaction remained equal between comparison groups. From this it can be inferred that differences in student satisfaction were due to changes in the course material and not the format in which the sections were taught. Students were largely satisfied with the section they were in and would recommend it to other students.

Student performance in the class initially appeared to show a difference between cohorts. Throughout the semester, students in the flipped section outperformed their unflipped counterparts on exams and quizzes, and many of these differences in performance were statistically significant. This initially suggested that the flipped students were learning more effectively than those in the unflipped section. However, although both sections included very bright and high-performing students, as the semester progressed it appeared increasingly likely that the students in the flipped section were academically stronger, as a single cohort, than those in the unflipped section. This suspicion was supported by a close analysis of student learning gains. Results from summative assessments show that, on average, both sections nearly doubled their knowledge of genetics by taking this course (a 1.86-fold improvement from pretest to posttest in the flipped section and a 1.93-fold improvement from pretest to posttest in the unflipped section; Figure 4A). In other words, both sections experienced nearly identical gains in knowledge of course content, regardless of which section they were in. This apparent contradiction of the flipped cohort outperforming the unflipped group on exams and quizzes, while simultaneously not demonstrating higher learning gains is explained by the students in the flipped section entering the course with more background knowledge in genetics. Additionally, the students in the flipped section had demonstrated more previous academic success, measured by their cumulative GPAs (perhaps explaining their greater retention of previous coursework involving genetics), than those students in the unflipped section. Therefore, the outperformance of the unflipped section by the flipped cohort is likely due more to a greater initial overall knowledge of genetics, and greater experience in achieving academic success, than to the flipped-learning format itself.

It is important to note that students in both formats achieved a near doubling of knowledge in genetics by taking their respective courses. And both sections achieved largely impressive marks on exams comprised entirely of free-response essay questions. Focusing on the cumulative final-exam averages (Figure 3C), the flipped and unflipped students achieved averages of 84.3 and 72.8, respectively. It could be argued that both final-exam averages are quite impressive for a cumulative, essay-based, two-hour exam in undergraduate genetics (with no curving or grade adjustments). Taken together, significant learning gains and content mastery were demonstrated in both sections. However, in the final consideration, the data presented here show that there is no difference in student learning gains or student performance when cohorts are compared from flipped active-learning and unflipped active-learning classrooms. This interpretation agrees wholly with that of Jensen et al. (2015), described above. So, what is to be made of this?

○ Conclusions

As summarized in the Introduction, the inclusion of active learning is a critically important ingredient for student mastery in the classroom (Halloun & Hestenes, 1985; Ericsson et al., 1993; Seymour & Hewitt, 1997; Prensky, 2010). Both sections of the genetics class in the present study featured active-learning components, and both cohorts were exposed to three critical ingredients required for learning: (1) the initial exposure to background knowledge and content (which is typically passive and unidirectional, from teacher to student); (2) the student’s own reflection on what was clear and what was not (to promote and direct reiteration of complex concepts); and (3) student-centered active practice with, review of, and manipulation using course content and material. It appears that as long as these three ingredients are achieved in a course, as they were in both sections of this study, successful learning should occur. However, successfully incorporating these ingredients is far easier and more efficient in a flipped classroom than in a traditional one. The effort required by instructors teaching an active unflipped course, as described here, is quite high. Also, perhaps more importantly, unflipped students are required to complete the most challenging aspects of the course on their own, away from their instructor. In the flipped format, students are engaged in passive and less-demanding activities at home, to their potential benefit, and instructors limit the need for personalized feedback because content and student comprehension can be addressed and clarified in class.

In the final analysis, this study sought to determine whether flipped learning offered any measurable benefit above and beyond active learning alone. In other words, is there a benefit to completing more passive instruction outside of class, leaving class time for active learning? The results presented here suggest that where active learning takes place (in class vs. outside of class) is not a differentiator in learning outcomes. Flipped learning offers no measurable benefits over other active-learning formats. Therefore, instructors who are already successfully implementing active-learning components in their courses should likely continue teaching in those formats. However, for more traditional instructors who are practicing less active pedagogies, and who seek more student engagement and increased learning outcomes, a flipped-learning approach could likely give them the time and flexibility they need in the classroom to easily integrate active learning into their courses. I, for one, have personally experienced the incredible benefit of teaching through a flipped-learning format, and I will never teach another way again.

○ Acknowledgments

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