The Flipped Classroom:
Implementing Technology To Aid
In College Mathematics Student's Success

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ABSTRACT

August 2016 there was a call (Braun, Bremser, Duval, Lockwood & White, 2017) for post-secondary instructors to use active learning in their classrooms. Once such example of active learning is what is called the "flipped" classroom. This paper presents the need for, and the methodology of the flipped classroom, results of questionnaires on student perceptions, as well as quantitative data on student performance.

Keywords: Flipped; Classroom; Technology; Alternative; Learning

*A*ctive learning can now be found throughout the research as an effective means for student learning and engagement, and has "robust support from education researchers, funding agencies, public policy makers and institutions" (Braun et al., 2017). One such example of active learning is the "flipped" classroom.

In contemporary college and university courses, lecturing remains the dominant teaching technique used by mathematics faculty (Braun et al., 2017). During this time, the instructor typically reviews topics at the front of the room and occasionally answers student questions. Once the lectures have been completed, the students are then left on their own to complete homework that is associated with the lectures. Very little of this time is devoted to issues the students may encounter while performing the homework assignments. While the student is completing their homework, should they have difficulty, they would need to seek help outside of class.

In the flipped classroom, as the name implies, the lectures and homework are reversed. The student is given the task at home of watching pre-recorded videos of the lecture material. During this time, they may (or may not, depending on the lecture content) be given elementary problems to execute while at home. Then, within the classroom, the instructor can highlight the important topics of each section and allow for active learning while the students have access to each other, and the instructor. In addition, more challenging homework problems can be attempted and reviewed by the class as a whole.

While there were several books and papers published on the flipped, or inverted, classroom as far back as 1997 (Mazur, 1997), it wasn't until 2007 that the idea was first implemented. Chemistry instructors Jonathan Bergmann and Aaron Sams from Woodland Park High School in Colorado recorded their lectures and posted them online to allow students that were unable to attend class to be able to access the material (Bergmann & Sams, 2012). Since 2007, many secondary classrooms and even entire schools have implemented a flipped format successfully. However, despite their individual success, there were very few implementations at the college level. In addition, any examples found in leading education journals were for subjects other than mathematics. This led me to develop and implement a flipped classroom format while teaching as a Masters Degree candidate.

During the Fall term of 2015 at the University of Nevada, Las Vegas (UNLV) I taught two separate sections of Pre-calculus II (Math 127). Instructors are required to cover approximately 25 sections of the textbook in a fifteen week period. Assessments typically consist of homework (worth 10%), 3 in-class tests (worth a total of 60%) and a cumulative final exam (worth 30%). Classes meet twice per week for 75 minutes each class period.

In designing the out of class lecture videos, I chose to break each of the 25 sections into multiple videos, typically about three or four videos per section. I did this for two specific reasons. First, it allowed me to keep the average length of each video to approximately 15 minutes, which allowed students to watch the lesson videos even when their time was limited. And second, by breaking up each section, it allowed the students the opportunity to go back and re-watch videos on topics with which they struggled without having to watch the entire hour video or scrolling through to find the topic they needed. As I would later learn from the students, this has become a favorite feature of the flipped classroom.

For the purpose of this study, I combined the two different sections of students from Fall 2015 into one data set and will refer to them throughout the paper as the Flipped group. 62 students formed this data set, including 36 males (or 58%) and 26 females (or 42%). For the control group, I used one section of Math 127 that I had taught Fall of 2014, subsequently referred to throughout the paper as the Lecture group. 38 students formed this data set, including 24 males (or 63%) and 14 females (or 37%).

It should be noted there are performance differences between fall and spring offerings which is why I chose to compare fall classes only. It has been my experience that fall classes typically consist of students that tested into that class or are retaking the class after failing in the spring semester 3 months prior. The spring classes differ as they typically have students that failed only weeks earlier in the fall or have just passed the prerequisite class. As a result, generally speaking, I have found spring classes outperform fall classes.

In order to try and maintain symmetry with data sets, I focused on students that completed all of the course work. Some students officially withdraw from the class and others quit coming to class and did not take the final exam; all are considered withdraws. Of the original 44 students enrolled in the Lecture group, 38 students (or 86%) completed all of the coursework. Of the original 77 students enrolled in the Flipped group, 62 students (or 81%) completed all of the coursework. I would have hypothesized that the flipped classroom would have led to a higher retention rate. However, this could be the result of class standing identified in Table 1. The Lecture group consisted of 42% seniors while Flipped group consisted of only 10% seniors. Seniors likely had little choice but to stay enrolled and try to pass the class, and perhaps this is the reason there was a slightly higher retention rate for the Lecture group.

Table 1. Class Standing as a Percentage that Completed the Class

	Freshman	Sophomore	Junior	Senior	Graduate
Lecture Group	32%	13%	11%	42%	2%
Flipped Group	50%	16%	23%	10%	2%

The Flipped group students completed a survey the first day of class. I was specifically interested in three issues:

1. Did they qualify to be in the class through testing or through the prerequisite class?
2. Were they previously enrolled in Math 127?
3. Did they have previous experience with a flipped classroom?

Table 2. Initial Survey Results for Fall 2015

Question Asked	YES	NO
Did they qualify to be in the class through testing?	25 (42%)	35 (58%)
Were they previously enrolled in Math 127?	22 (37%)	38 (63%)
Did they have previous experience with a flipped classroom?	7 (12%)	53 (88%)

Table 2 outlines the results of the 60 students that completed the survey. It can be seen in Table 2 that 42% of students tested into Math 127 and did not need to take the prerequisite course to qualify. Depending on the method of placement (which can vary wildly across institutions) this may or may not be an accurate reflection of preparedness. The other 58% of students, per university policy, would have qualified for the course by taking the prerequisite course at any postsecondary institution. This, too, may or may not be an accurate reflection of preparedness.

Regarding previous enrollment, as indicated in Table 2, of particular note is the number of students (22 or 37%) that had been previously enrolled in Math 127. In my experience, the typical pass rate for all Math 127 sections at UNLV is approximately 50%. As such, it is not unexpected that 37% of the students had been previously enrolled in the course. Of the 22 students previously enrolled, they had taken the course an average of 1.5 times. In addition, 24% of those students were enrolled in the class for the third or fourth time. This might suggest that if a student does not pass the class the first time, it could take multiple attempts before they can expect to pass. Also, of the 22 students that were retaking the class, 16 had originally qualified by passing the prerequisite course with a C or higher.

Regarding previous experience with a flipped classroom, as indicated in Table 2, of the 60 students that completed the initial survey, only 12% had previous experience with a flipped classroom. I did not specify a flipped math classroom so it is possible students had experience with a different type of flipped classroom. This perhaps supports my conclusion from the research that there are currently limited post-secondary classrooms teaching in this format.

I conducted 4 additional surveys of the students. The purpose of the surveys was to solicit feedback on watching videos, completing homework and student disposition. While there is technology available to track student progress and completion of requirements, I did not have access at the time of implementation. I therefore had students self-report on progress. Because the flipped format places so much emphasis on students to be proactive with their studies, it was essential for the students to watch the videos and complete as much of the homework as possible.

Table 3. Results of Survey Two

	Highly Satisfied	Satisfied	Neither	Dissatisfied	Highly Dissatisfied
Assessment of Flipped Classroom	60%	35%	5%	0%	0%
Believe Flipped Classroom is Aiding Understanding	58%	33%	9%	0%	0%

Survey Two was administered at the end of the second week of class. To date, students had three classroom visits conducted in the flipped format. On this survey, I asked them about the percentage of videos they had watched prior to attending class, the percentage of homework completed prior to class, their feelings about the flipped classroom and their outlook for the remainder of the semester. 57 students completed the survey. The students reported watching, on average, 95% of the videos prior to attending the class and reported completing, on average, 84% of the homework prior to attending class. The most encouraging feature to me was that 81% of students reported they were excited about the outlook for the term. I did my best to explain the past results of other flipped classes to assure the students it had the potential to work for us. This, combined with the struggles that many had already encountered with this class could explain such a high percentage of student excitement. Granted, it was early in the term, but 95% of students were either Highly Satisfied or Satisfied with their progress and 91% believed the format was helping them understand the material. This could suggest the flipped classroom not only fosters student satisfaction, but possibly aids in understanding.

Table 4. Results of Survey Three

	Highly Agree	Agree	Neither	Disagree	Highly Disagree
Believe Flipped Classroom is Aiding Understanding	45%	49%	6%	0%	0%
Believe Flipped Classroom has Prepared them for Exam One	43%	43%	11%	2%	0%

Survey Three was administered to the students one month into the semester, the day prior to their first exam. It included similar questions to Survey Two, but contained additional questions on the amount of time spent outside of class and also assessed their feelings about the flipped classroom format. 53 students were present on the day of the survey. The students reported watching, on average, 87% of the videos prior to attending class. This is down

slightly from the 95% reported on the Survey Two. The students reported completing, on average, 71% of the homework prior to attending class. This is also down from the 84% reported on the Survey Two. This could be a cause for concern or it could simply be because of harder problems that they are no longer able to complete at home. Because the flipped classroom helps students solve the more challenging problems, students could be waiting for class time to complete the more difficult problems of their homework. An important consideration is how much of the homework is completed after students attended class. Those numbers will be discussed when I address the numerical analysis of the study.

In Survey Three, students reported spending an average of 5 hours on the material outside of class. This would imply that the average student was spending approximately 7.5 hours per week on the material, including class time. Past students informed me it would take approximately 8 to 10 hours a week struggling to do homework, so a decrease in time spent shows another possible benefit of the flipped classroom. Students can better manage their time and productively study.

Because Survey Three was administered the day prior to the first exam, it is a better indicator as to how the students felt it was helping them comprehend the material. As indicated in Table 4, 88% of students are Satisfied or Highly Satisfied with the flipped classroom format. And 84% of the students feel the flipped class aids in their understanding. Only one student indicated that the flipped classroom did not help them prepare for the exam.

Table 5. Results of Survey Four

	Highly Satisfied / Highly Agree	Satisfied / Agree	Neither	Dissatisfied / Disagree	Highly Dissatisfied / Highly Disagree
Assessment of Flipped Classroom	51%	37%	8%	2%	2%
Believe Flipped is Aiding Understanding	43%	41%	12%	2%	2%
Believe They are Giving Maximum Effort	33%	41%	12%	12%	2%
Believe Grades are Accurate Reflection of their Effort	35%	41%	16%	4%	4%

Survey Four was administered the day following the second exam. Another month had passed and they now could reflect on two exams. Potentially they could determine whether the flipped classroom was truly aiding in their understanding of the material. I included similar questions to Survey Three but added questions to determine if they felt they were giving the maximum effort and to determine if they felt their grades accurately reflected their effort. I will get into more detail and analysis with testing and scores later in the paper, but I wanted to point out that the average on Exam #2 was 77%. I make this note because many students were disappointed in their grades and this could potentially have had an impact on their self-reported feelings. 51 students were present to take the survey. Consistent with Survey Three, on average students reported watching 85% of the videos and completing 74% of the homework prior to attending class.

Despite expressing disappointment upon receiving their scores on Exam #2, as can be seen in Table 5, there is still strong support for the flipped format. 88% are Satisfied or Highly Satisfied with the format and 84% Agree or Highly Agree that the format is helping with their understanding. Perhaps with the flipped classroom the student is relied upon to fulfill their side of the burden. If they do not watch the videos or attempt the homework problems prior to coming to class, their chance of success is greatly diminished. They may report they are watching 85% of the videos and doing 74% of the homework, but 76% also stated that they Agree or Highly Agree that their grades are an accurate reflection of their efforts.

I received many freeform comments on Survey Four indicating students "have not been doing good keeping up and would do much better going forward." Perhaps that helps explain why there are still 59% of the students excited about the remainder of the semester. As mentioned in the analysis of Survey Three, there is still one student that is absolutely against the flipped format.

The final survey was administered at the very end of the term. All of the exams had been taken, graded and returned and all of the homework had been submitted; only the Final Exam remained. This is likely the most important survey because it was a chance for the students to provide an overall assessment of the flipped classroom format. The results rely heavily on the students being able to give an accurate account of their efforts. 50 students were present for this survey. On average, the students reported watching 73% of the videos and completing 60% of the homework prior to attending class. These numbers dropped significantly compared to prior surveys. Two freeform comments could help explain this. The comments are as follows:

"It works very well when the work is done consistently!"
"The whole idea is great, but it's up to the student to do well. I did well in the beginning but once my other classes got hard I fell behind and my grade dropped."

Table 6. Results of Survey Five

	Highly Satisfied / Highly Agree	Satisfied / Agree	Neither	Dissatisfied / Disagree	Highly Dissatisfied / Highly Disagree
Final Assessment of the Flipped Classroom	36%	52%	10%	2%	0%
Believe Flipped Classroom Aided Understanding	40%	40%	12%	6%	2%
Prefer Flipped Classroom to Traditional	52%	32%	8%	4%	4%
Would Recommend the Flipped Classroom to Others	60%	32%	6%	2%	0%

I am overjoyed that 92% of students said they would Agree or Highly Agree to recommending the flipped classroom to others as indicated in Table 6. In addition 88% of the students were Satisfied or Highly Satisfied with the flipped format.

Some of the student comments regarding their feelings about the flipped format were:

"As I have said on previous surveys, this has been my best experience with a math class thus far."
"Best format for a class. Made it a lot easier to comprehend concepts and helped a ton with studying."
"I am actually a little worried that Math 181 will be much harder because it will be a traditional classroom."
"More examples from book. Less focus on the online homework."

It should be noted that this final comment was from the student opposed to the flipped classroom. As one can see, their comment had nothing to do with the flipped classroom; rather, they were more focused on the requirement of online homework. Perhaps they were never opposed to the flipped format, but instead were upset by the requirement of online homework.

While survey results provide insight into how the students felt about the flipped classroom, these attitudes do not mean much for students if it doesn't translate into learning. The following details student performance measures to determine whether the flipped classroom may have impacted student learning as indicated by student assessments. In my class, practice of content objectives came in the form of online homework, as prescribed by departmental policy. The number of problems varied by section; it could be as few as 5 or as many as 20. All of the assignments would usually have several problems testing the basic concepts taught in the section and several problems that forced the students to take the concepts learned in the section and manipulate them to solve more challenging problems. The online problems were very similar to the ones found in the textbook and the students could always access the problem set at the end of each section of the book if additional practice was needed. The online homework problems assigned were common for both the Flipped and Lecture groups.

Percentages discussed for the homework comparison will be based on the percentage of homework completed correctly. The overall homework grade was 82% for the Lecture group and 84% for the Flipped group. I would actually have expected there to be a bigger difference as with the Flipped group we actually did homework problems in class. I broke down the homework scores by Final Class Grade to see if there was a difference within categories. Table 7 contains the homework averages for students who earned the same letter grade.

Table 7. Fall 2014 Final Grade vs Homework Grade

	A	B	C	D	F
Lecture Group	94%	96%	87%	78%	68%
		89%		74%	
Flipped Group	96%	92%	85%	79%	70%
		90%		75%	

For both groups, those that passed the class (A, B or C) had completed about 89-90% of the homework compared to those that did not pass, with about a 74-75% completion rate. One possible explanation for the consistency between groups could be the fact that homework is a required component of the student's grade as mandated by the department.

For both groups, three in-class exams were given during the term. To maintain consistency, I made the exams as similar as possible including the same number of questions and covering the same set of objectives. Table 8 details the exam averages for both groups.

Table 8. In-class exam averages

	Exam 1	Exam 2	Exam 3
Lecture Group	88%	64%	73%
Flipped Group	90%	77%	66%

The results were similar for both groups. While the Flipped class did 13% better on Exam #2, they did 7% worse on Exam #3.

While much analysis has been paid to the surveys, homework and in-class exams, I truly expected to see difference in scores for the final exam. Much of the research suggests that students in schools using the flipped format tended to score better on standardized exams compared to students in schools not using the flipped format.

The final exam given to Math 127 students is written and administered by the Department of Mathematical Sciences. The same exam is given to ALL Math 127 students during a two-hour period. As such, I expected to see better results from the Flipped group compared to the Lecture group, and other sections of Math 127. The final exam results are presented below in Table 9. The first two rows detail the averages obtained by the Lecture and Flipped groups. The remaining rows detail the averages obtained by all but two instructors for Fall 2015.

Table 10. Final Exam Averages

Group	Percentage
Lecture Group	37%
Flipped Group	49%
INSTRUCTOR 1	57%
INSTRUCTOR 2	53%
INSTRUCTOR 3	45%
INSTRUCTOR 4	38%
INSTRUCTOR 5	37%

There was dramatic improvement between the Lecture and Flipped groups. The exam questions were similar for each group, so to see such an improvement is encouraging. In addition, given concerns after poor results on Exam #3, I was pleased with the increased performance by the Flipped group on the final exam.

Despite scoring much better than my traditional class, my flipped class did not perform better as compared to some other instructors sections. Two of the traditional classes had higher final exam averages than my Flipped class. I considered not including this data, as it does not indicate a direct correlation about the flipped versus lecture formats. However, it begs the question – is possible that the instructor with 57% pass rates might also see an increase in performance, should they adopt this method of teaching?

Ultimately, the goal for students is to master the material and pass the class. For most degree tracts, that requires a grade of C or higher. For the Lecture group, only 53% percent of my students achieved a passing grade. However, for the Flipped group, 67% of my students achieved a passing grade. There was an attempt to keep the two groups as closely aligned as possible, with the biggest variance being classroom format; so one could make the argument that, perhaps, flipping the classroom had a positive impact on overall student performance as reflected in final grade in the course. While I did not survey student disposition for the Lecture group, I noted a sustained positive outlook for the students in the Flipped classroom. Perhaps this, too help students sustain a reasonable amount of effort, perform better on the final exam and secure the scores needed to pass.

The first day of class with the Flipped group, I told my students they would be part of something that I had hoped would revolutionize college math classes. I also told them there would be growing pains on both sides. For most of the students, they would be learning math in a manner they had never been exposed to. For me, I would be instructing in a manner I had only read about. While there were ups and downs throughout the semester, overall, I would certainly say it was a positive experience for both me and my students. I was so pleased with the results that I am repeating the flipped classroom format in all future classes. Every day our lives seem to be enriched by technology. However, in the math classroom the "advancements" have seemed to come in the way of smart boards and online homework. As instructors, we have a unique opportunity to implement this method of active learning, which could help our students succeed. With only one semester's worth of data, one would be naïve to declare the flipped class a success (or failure). However, my hope is with continued practice, I am able to implement this style in other math classrooms and see even more positive results. Then, perhaps my promise to my students to revolutionize the college math classroom may become a reality.

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