Title: Effects of the traditional and flipped classrooms on undergraduate student opinions and success

Order of Authors: Susan L. Hotle and Dr. Laurie A. Garrow

Susan L. Hotle, Ph.D. candidate in the School of Civil and Environmental Engineering, Georgia Institute of Technology, 790 Atlantic Drive, Atlanta, GA 30332-0355; shotle3@gatech.edu.

Laurie A. Garrow, Ph.D., associate professor in the School of Civil and Environmental Engineering, Georgia Institute of Technology, 790 Atlantic Drive, Atlanta, GA 30332-0355; laurie.garrow@ce.gatech.edu.

Abstract: The flipped classroom is becoming increasingly popular at universities due to its perceived benefits in promoting active learning and decreasing educational costs. Studies have found positive benefits associated with flipped classrooms; however, many have failed to control for confounding factors; examples of confounding factors include studies that compare courses taught by different instructors and/or across courses taught in different semesters using different quizzes). The objective of this paper is to compare the traditional and flipped classrooms in an undergraduate civil engineering course while controlling for potential confounding factors. The quasi-experimental study incorporates students' online behaviors, in-class performance, office hour attendance, and their responses to both attitudinal and behavioral questions to assess student opinions and learning outcomes. It was found that student performance on quizzes was not significantly different across the traditional and flipped classrooms. A key shortcoming noted with the flipped classroom was students' inability to ask questions during lectures. Students in flipped classrooms were more likely to attend office hours compared to traditional classroom students, but the difference was not statistically significant. Future research should explore whether students' inability to ask questions when the material is presented in flipped classrooms impacts learning outcomes.

Author keywords: traditional classroom, flipped classroom, online behavior, classroom attitudes

Introduction

For more than a decade, the educational system in the United States has been evolving and educators have been calling for the creation of new, innovative classroom techniques (e.g., see (Prensky 2010, Wilson 2004). The arrival of millennials into higher education, a generation unlike any of its predecessors, has left educators searching for tools on how to reach it (Prensky 2010, Wilson 2004). This unique generation, which has been labeled as "technologically savvy," will "expect faculty to incorporate technology into their teaching and to be proficient in using it" (Wilson 2004). Some argue that millennials' technological savviness has led to an inability to focus in the classroom whereas others believe "it is not our students' attention capabilities that have changed, but rather their tolerance and needs" (Prensky 2010). Regardless of the underlying changes in classroom attentiveness, educators need to rethink their approach on how to capture and keep the attention of their students.

One approach, the flipped classroom, also referred to as the inverted classroom (Strayer 2012; Mason et al. 2013), was introduced to promote the use of technology as well as active and collaborative learning in the classroom. In contrast to the traditional classroom (i.e., a method that includes an in-class lecture and out-of-class problem solving), the flipped classroom has students watch pre-recorded lecture videos before coming to class and then "class becomes the place to work through problems, advance concepts, and engage in collaborative learning" (Tucker 2012). The flipped classroom also switches the instructor's availability to students. Instead of being present during the lecture, the instructor walks around the classroom to answer questions during the practice problem sessions. It is argued that in the traditional classroom "the instructor's availability is at its maximum in class, but this is when the cognitive tasks for students are at their

lowest level and when students need the least help. It would almost seem that a reversal of the traditional setup would be an improvement: Have students acquire basic information through lectures, reading, and other sources outside of class, and put them to work on challenging, high-level cognitive tasks during class" (Talbert 2012).

The flipped classroom has become increasingly popular as the membership for the Flipped Learning Network more than tripled in one year alone, increasing from 2,500 teachers in 2011 to 9,000 in 2012 (Goodwin and Miller 2013). This increase is expected to continue at the university level. Specifically, higher education has seen a large fluctuation in enrollment, which is mainly attributed to the recent economic recession (Roach 2014). This has led to increased educational costs, prompting President Obama to announce a White House plan to make college more affordable; the plan includes flipped classrooms as part of the solution. This plan states, "A rising tide of innovation has the potential to shake up the higher education landscape. Promising approaches include three-year accelerated degrees, Massive Open Online Courses (MOOCs), and 'flipped' or 'hybrid' classrooms where students watch lectures at home and online and faculty challenge them to solve problems and deepen their knowledge in class. Some of these approaches are still being developed, and too few students are seeing their benefits" (The White House 2013). The flipped method is assumed to be more cost-effective than the traditional method. In part, this is because in a flipped environment, instructors who walk through the classroom are able to engage one-on-one with students. Thus, "more students can be added to the classroom without sacrificing the 'student to valuable-human-time' that is traditionally only gained with low student to teacher ratios" (Roach 2014). Although the flipped classroom allows a high degree of interaction with students, the benefits of this interaction likely decrease as the classroom size increases; however,

we are not aware of any studies that examine how the potential benefits of flipped classrooms diminish with increasing class sizes.

Although the flipped classroom appears promising in its ability to match the millennials' learning style and decrease educational costs, it is important to assess whether flipped methods are indeed better than traditional methods. Do flipped classrooms improve learning outcomes? Do students in flipped classrooms master course concepts better? Do students like flipped classrooms? Numerous studies have examined these and related questions at the high school and university levels. However, the delivery of flipped classrooms at the high school and university levels differs. It is typically easier to hold students accountable in high school settings; for example, high school teacher Jonathan Bergmann checks that each student took notes on the online lecture (Tucker 2012). This practice would not generally be feasible at the university level due to time constraints and could be negatively received by students. Similarly, high school students that finish the practice problems early are expected to start watching the next night's assigned video while in class (Fulton 2012). Most likely college students would leave class early instead, an option not available to high school students. Due to these differences, the remainder of this paper will focus solely on university-level studies, as they are most applicable to the research presented.

Several studies have found that students enjoy and are successful in the flipped classroom. In a study at Texas Tech University, a single semester of a microeconomics course was flipped. Not only did 76% of responding students indicate that the "flipped learning helped them learn," but also that the "students performed slightly better on average on midterm tests compared to previous semesters taught by the same instructor even though the tests were more difficult by the standards set forth by the Association to Advance Collegiate Schools of Business (AACSB)" (Roach 2014). Flipping a class at Villanova University's College of Engineering found that "the

bottom third of students' grades were more than 10 percent higher than in a traditional classroom (the difference between a D+ and a C) and more than 3 percent higher for the class as a whole (moving from a C+ to a B-)" (Bidwell 2014). Similarly, a study at Seattle University found, "1) the inverted classroom allowed the instructor to cover more material; 2) students participating in the inverted classroom performed as well or better on comparable quiz questions and on open-ended design problems; and, 3) while students initially struggled with the new format, they adapted quickly and found the inverted classroom format to be satisfactory and effective" (Mason et al. 2013). It is important to note that these findings could be due to differences in learning environments across these universities, e.g., the learning experience in a microeconomics course at Texas Tech, an engineering course at Villanova, and courses at Seattle University vs. Harvey Mudd are likely very different due to the types of students enrolled at these universities, typical class sizes, and other factors. These findings could also be due to different student levels, e.g., an introductory micro-economics course may be targeted to freshman whereas an introductory engineering course may be targeted to sophomores.

Although there are positive studies surrounding the flipped classroom issue, there are many studies that remain skeptical of this new classroom method. Sam Buemi, an instructor at Northcentral Technical College, reflects on his flipped classroom experiences stating, "...technology in the classroom is not a solution to age-old educational problems. Some students still come to class ill-prepared or unmotivated. Requiring work to be completed outside of class may not solve that problem" (Buemi 2014). Similarly, preliminary results in the first year of a three-year study found that "following the first year of implementation, the inverted classroom model at Harvey Mudd College showed equivalent results in comparison to the traditional classroom model in terms of student performance" (Lape et al. 2014). Urbaczewski's study of a

summer university-level course found that "overall, students were not pleased with [the flipped] format. Several students complained bitterly about the amount of work in the course, the frequency and difficulty of the quizzes, and some of the course policies. While many complained about not 'learning' anything in the basic spreadsheet course, they then also complained about having to 'learn on their own' or being behind because they did not really learn anything in the basic class" (Urbaczewski 2013).

The conflicting results reported in the literature may be due, in part, to confounding factors that are introduced through the study designs. The presence of two factors that change between study group A and study group B (e.g., traditional vs. flipped sections) makes it impossible to statistically attribute the impact of a result to the first (or second) factor. For example, one of the most common study designs compares traditional and flipped sections of a course that occur across different semesters. This means that student performance in each classroom is measured using different quizzes (Roach 2014; Mason et al. 2013). The difference in performance could be attributed to one quiz being harder than the other and not necessarily one classroom method being superior. Sometimes the sections are taught simultaneously, but with two different professors, leading to an instructor bias (Webster and Majerich 2014). The difference in performance could be attributed to one instructor being better than the other instructor. Another common form of bias in the literature is not having a traditional "control" group, which is very common as "most studies conducted [before June 2012] explored student perceptions and use single-group study designs" (Bishop and Verleger 2013). This study design can lead to incorrect conclusions specifically with student opinion surveys. For example, a majority of students can indicate that the flipped classroom helps them learn. However, if a concurrent traditional section had been held, it is possible that the majority of those students could have responded similarly regarding the traditional

method. It can also be hard to recognize the presence of selection bias in previous studies as the recruitment process is not well described. For example, there is the possibility of selection bias in flipped classroom studies if students are given the chance to drop the course after being notified the teaching style of their section.

The purpose of this Institutional Review Board (IRB) approved study is to compare student performance and opinions in the flipped and traditional classrooms while using advanced data collection techniques and avoiding many sources of bias that have been present in earlier studies. Specific research questions include the following: (1) Do students prefer a flipped or traditional classroom format? (2) Do students perform better in flipped or traditional formats? (3) Do students in flipped classrooms spend more or less time mastering material than students in traditional classrooms? (4) What do students perceive as benefits and disadvantages of flipped classrooms? This study uses information from student records, course grades, surveys, and online tracking systems to capture a wide range aspects of the classroom that could be impacted by the method used. Due to its careful design, this study is expected to meaningfully contribute to the comparison of the traditional and flipped classrooms at the university level.

Methodology

Design

Two sections of a required undergraduate course, civil engineering systems, were taught by the same instructor during the spring 2014 semester. This course is composed of three modules; the first module is qualitative and covers sustainability concepts whereas the last two modules are quantitative and cover engineering economy. One section used a traditional classroom approach to teach the two quantitative modules whereas the second section used a flipped classroom approach. In the traditional classroom format, all of the class time was spent lecturing to students,

with no active learning activities. All other factors between the two sections were identical, i.e., both sections had the same instructor, teaching assistant, graders, example problems, homework assignments, quizzes, due dates, and office hours. To control for possible time-of-day bias (e.g., differences in students who prefer morning versus afternoon courses), the two sections were taught back-to-back in the afternoon with a ten minute break in between the sections. The scheduling of the two sections also helped prevent students in the earlier section from sharing quiz information with students in the later section.

Students could register for – and switch between – course sections until the end of the first week of class. To ensure students did not self-select into the traditional or flipped section, students were not informed of the study nor told whether they were in the traditional or flipped section until after the registration period. Students from two majors typically register for the course: civil and environmental engineering (CEE) and industrial and systems engineering (ISyE). Students' prior exposure to engineering economics and the number of years they have spent in college differ by major. CEE majors typically take the course in their sophomore year and have had little to no prior exposure to engineering economics. In contrast, due to limited enrollment space during the during the spring semester, only ISyE majors who are in their last semester and need the course to fulfill graduation requirements are allowed to register. All ISyE students who registered in the civil engineering systems course during the spring 2014 semester had prior exposure to engineering economics as all ISyE students are required to take a course in engineering economics offered by their department. The amount of overlap between the engineering economics modules offered in the CEE and ISyE courses is approximately 50 percent. Given these differences, and the fact that more ISyE students registered for the flipped section, all ISyE students were excluded from the study for the spring 2014 semester.

Data Collection

This study incorporated information from online clickstream data, student records, grades obtained in the civil engineering systems course, teaching assistant and instructor observations, and surveys. Table 1 defines the variables used in the study and the source of each variable. Given the variables are self-explanatory, this section describes relevant details of the data collection process.

The course used two websites. The first website is the primary website that the Georgia Institute of Technology uses for its courses; however, it was not possible to post videos and track behavior from this website, thus a second website was used for this purpose. Clickstream data was collected from both websites. Students accessed the majority of course materials from the main course site, e.g., the syllabus, old practice quizzes, homework assignments, answer keys, and lecture slides. Whenever a link was clicked on the main course website, the clickstream data would note the student's name and computer's IP address, the link the student clicked on, and when the student clicked on the link. A second website was used to host the video lectures. On the video website, the clickstream data would note how many times a student clicked to watch a video. Since each of the websites required students to sign in using their student identification numbers, each action could be linked to the individual student.

Information about how far in advance students downloaded course material was also collected. Due to technological limitations, it was not possible to collect information about the total duration that a student watched a video and how far in advance it was watched for Study 1. The average number of days before starting the homework was determined using the course's clickstream data. The average number of days before a homework was due was calculated from the three homework assignments given during the study, each posted about two weeks before its due date. If the student never opened the homework or viewed it for the first time after the due

date, this variable was set to zero. For example, if a student viewed the Homework 1 assignment for the first time 6 days before it was due, Homework 2 assignment 1 day after it was due, and never opened the Homework 3 assignment, then their "Average Number of Days Before Homework Due" would be 2 (the average of 6, 0, and 0). Days before the Homework 2 assignment would be recoded to zero because it was negative. The same logic was used to compute how many days before the quiz the student looked at the old practice quizzes provided on the course website. These old quizzes were posted at the beginning of the semester.

In addition to the clickstream information, background information on each student was obtained from the Institute's records. This includes the student's age, gender, major as of December 2013, number of course credits earned at the Georgia Institute of Technology, and the student's overall GPA associated with courses taken at the Institute.

Student performance was measured via quiz grades. Each section had two quiz scores that were averaged. That is, in the traditional section, the quiz scores from the second and third modules were averaged to provide an indication of student performance in the traditional classroom setting. The same was done in the flipped section.

Student behavior outside of class was also noted. Office hours were held the day before each homework assignment was due and the day before each quiz. The teaching assistant kept records of which students attended each office hour session.

Finally, students completed three surveys throughout the semester, each designed with insights based on several online blogs and articles from teachers that had been using flipped classrooms (Kirch, unpublished blog, 2014; Camel, unpublished blog; Roshan 2012a; and Roshan 2012b). Insights from these online resources stressed the importance of asking students about their behavior outside of class that the online tracking could not capture (e.g. what they do while

watching the videos, whether they rewind or fast-forward the videos, the reasons they do not watch the videos, etc). The first survey collected background information and assessed students' familiarity with flipped classroom and online courses. All three surveys collected information about students' opinions and preferences regarding the different instruction methods. By having students complete the surveys at the beginning of the semester, after the first technical module, and after the second technical module, it was possible to assess how opinions and preferences changed in the flipped section relative to the traditional classroom control group. Limited information was collected from the traditional section in the last survey as they could not answer questions about their flipped experience in this course. That is, their opinion on the traditional method would likely not change throughout the study as they had not experienced the flipped method. However, the time commitment between the two modules could change, so they were asked to indicate the time commitment of the class again in the third survey.

[Insert Table 1 about here]

Data Analysis

An analysis database was compiled from the sources described in the previous section. STATA, a statistical software program, was used to analyze the data. The statistical analysis of data included descriptive statistics (e.g., means, standard deviations, and frequencies), correlations, pairwise t-tests, and Chi-square tests.

Subjects

Participation in the study was voluntary and had no impact on grades. The instructor and graders had no knowledge of which students were participating in the study until after course grades were submitted. Table 2 provides descriptive statistics for students who participated in the summary

and compares these statistics to the total class enrollment. This comparison allows us to determine if there was a selection bias, i.e., if the population of students who participated in the study differs from the population of students who enrolled in the course. Overall, those students who participated in the study are similar to the general population of students who registered for the course. Those who participated are slightly more likely to be female and slightly more likely to have higher overall GPAs; however, these differences were not statistically significant when using Welch's one-sided t-test, which is used to compare samples that possibly have unequal variances (excluding ISyE students, non-participants – participants <0, p=0.3514).

Students in the traditional and flipped sections are also similar. A comparison of the students' overall GPAs on their transcripts shows that the traditional class had a 3.09 average and the flipped was a 3.24 average. In both classes, the study participants had a higher average GPA than the total class enrollment. The difference in GPAs between the two study groups was 0.07. Both study samples were about 60% male, 40% female.

Students were surveyed for additional background information that their transcripts could not provide. The number of respondents per question is in parentheses. For example, of the 36 study participants in the traditional section, 35 of them answered the question on internet access. Of the 35 students who responded to this question, 97.1% had internet access at home. It was found that a very high percent of each study group had internet access at home, which meant they had a location in addition to the university's campus where they could access course materials and online lecture videos. Although the majority of students in each section had previously heard about a flipped classroom, at most a third had actually experienced a flipped classroom. Students were also asked about their experiences with online courses since, like flipped courses, they rely

heavily on the internet and have a more flexible schedule. Similar to prior flipped classroom experience, at most a third of each section had taken an online course in the past.

[Insert Table 2 about here]

Results

The graded course materials during the study were the homework assignments and quizzes. Since students were encouraged to work together on the homework assignments, the quizzes were used as the main indicator of individual student success. Specifically, two quizzes were given during the study period, each given at the end of a module. Table 3 provides descriptive statistics associated with the average of these two scores for each learning method. For example, the average overall score on the two quizzes in the traditional section's study sample was a 75.1%.

The average test score for the traditional section was slightly higher than the flipped. However, this difference was not significant at the 0.05 level when using Welch's t-test. This insignificant difference when comparing the outcomes of the traditional and flipped classrooms agrees with the preliminary findings of a three-year study by Lape, et al. (2014). The test scores based on gender are directionally interesting in that, on average, females performed better than males in the flipped classroom, whereas the opposite is true in the traditional classroom. It is a coincidence that these two groups switch the exact same average grades of 76.1% and 73.9% between the two classes. However, these differences were not significant when using a one-sided Welch's t-test (female-male<0, p=0.2376 for traditional format and female-male>0, p=0.2942 for flipped format). On average, students who preferred to work alone scored slightly higher in the flipped format than those who preferred to work in groups, whereas the opposite is true for the traditional format. There are multiple explanations that could explain this result. First, the lecture time is moved outside of class, which promotes individual learning. Conversely, it can be beneficial for those working alone to be forced to collaborate during class. Regardless of the

reason, the difference in test scores between those who preferred to work alone versus in groups was not significant when using a one-sided t-test (group-alone>0, p=0.2418 in the traditional section and group-alone<0, p=0.4586 in the flipped section).

[Insert Table 3 about here]

Tables 4 and 5 present the correlations and their corresponding p-values among study variables for the traditional and flipped sections, respectively. Correlations reveal patterns for the class as a whole. The student's transcript GPA was a better predictor than earned credit hours of quiz performance (and positively correlated) in the traditional section. Both of these variables were also good predictors of quiz performance in the flipped section; in fact, the student's transcript GPA was more highly correlated in the flipped section than in the traditional section. A student's overall GPA may be more indicative of the student's ability to perform well in a variety of subjects and situations. To the extent that the flipped classroom represents an unfamiliar learning environment (and one with an adjustment period), students with higher overall GPAs would be expected to perform better than students with lower overall GPAs. Therefore, this means that students' grades would remain relative to one another (i.e., high GPA means more likely to get a higher grade in the course and vice versa), not necessarily that the flipped helps one group more than the other.

Student behavior in the class itself was found to be correlated with success. The average number of days in advance of a due date that students downloaded a homework assignment was positively correlated with success on quizzes in the traditional section. The average number of days in advance of a quiz that students downloaded old quizzes was also positively correlated with success on quizzes in the traditional section. Interestingly, these relationships did not appear in the flipped classroom. That is, it was not as important to prepare in advance to achieve success in

the flipped classroom as compared with the traditional classroom. One explanation is that access to online lectures and the ability to watch and rewatch videos provides students with the resources they need to complete homeworks or study for quizzes; examples of old quizzes become less important for success. An alternate explanation is that the assurance of last-minute resource availability is promoting procrastination, which does not appear to be significantly impeding success as the grades between the two sections are not significantly different.

Student behavior was also measured via the number of materials students viewed on the course website (e.g., syllabus, lecture notes, practice quizzes, etc.). The more materials students viewed, the more likely they were to be successful on the quizzes. Two variables were used to quantify student presence on the website. As defined in Table 1, the "total number of non-video views" counts how many times students viewed the materials. However, it was possible for students to print out the resources, which could make the "total number of non-video materials viewed" at least once just as important as the number of resource views. For each class, both the total number of non-video views and total number of non-video materials viewed were positively correlated with quiz performance. The correlation between quiz grade and the total number of materials viewed at least once on the course website was stronger for the flipped classroom (0.3198 versus 0.1073). This makes sense, as the flipped classroom is designed to be more dependent on online resources. However, total times "videos viewed," i.e., the total number of videos a student opened up at least once, was not correlated with success on the quizzes. This could be due to not being able to track how long students watched the videos (e.g., the data did not distinguish between view times of two seconds versus 15 minutes). Also, it was not known how attentive the students were when watching each of the videos. The absence of correlation between videos viewed and student success is further supported by Table 8. This table shows for example the material on Quiz

3 was contained in four videos. Three of the students did not watch any of the four videos and on average made an 81.67% on the quiz.

Some subtle differences in student behavior between the traditional and flipped sections were related to the number of office hour sessions students attended that merits discussion. The more office hour sessions that the students attended, the more likely they were to do well on quizzes. This is true of both sections. Although the attendance of office hours shown in Table 7 is not significantly different between the two sections using Chi-Square tests, increased attendance from the flipped section is noticeable. The increase in attendance from the flipped section was somewhat surprising, given that the flipped classroom allows students, the instructor and/or other teaching assistants to interact directly with groups of students as they work problems. However, the questions students are asking the instructor and/or teaching assistants during class are focused more on the problems they are being asked to work through. Very few students asked questions about general concepts during the flipped class (nor in office hours). The higher attendance in office hour sessions by students in the flipped classroom, as shown by Table 7, could potentially be attributed to students not mastering fundamental concepts when watching the online videos, thereby experiencing more difficulty in applying concepts to homework problems. There are opportunities in several classes for students to use "cookbook" problem solving techniques, but miss important overall concepts. For example, in queueing theory, students may be able to calculate the number of cars in the queue and service time for both determinant and stochastic models, but fail to understand why these numbers are different for each model. Also, in fluid mechanics, students can solve for drag using the coefficient of drag. However, students who simply look up the number in a table would miss the overall dynamics of how drag works (e.g., the presence of the boundary layer) and how this coefficient is derived.

These correlation matrices provide additional insight into relationships among other variables. In both sections, males tended to view fewer (non-video) resources on the course website than females. Older students in the traditional class tended to start studying earlier than their classmates. However, this action was less noticeable in the flipped classroom. Students with higher GPAs procrastinated less in both sections with regard to the homework assignments and the quizzes. In the traditional section, the students who started the homework assignments earlier viewed more online resources, but those in the flipped viewed fewer online resources at least once. However, in both sections, the students who started studying sooner viewed more online resources.

[Insert Tables 4, 5, 6, and 7 about here]

Typically, instructors of flipped classrooms do not know if students are watching the videos. Based on the in-class problem-solving sessions, instructors cannot differentiate between students that did not understand the material versus those who did not watch the video. However, due to the technology used in this study, student video viewing behavior was analyzed. On the course website, there were a total of 11 lecture videos for flipped students to watch. Figure 1 shows how many of the 11 videos each of the study participants watched. For the flipped section, 8 out of the 23 participants viewed all 11 videos at least once and 7 watched 10 videos. All of the students watched at least 1 video. It should be pointed out that Figure 1 simply counts the number of video links that were clicked. That is, the tracking system could not differentiate between students that watched the entire video versus only two seconds of the video.

[Insert Figure 1 about here]

Table 8 shows how many times the students viewed each of the videos. For example, 21 students opened the first video (1A Video), whereas two students never opened the video. Each of these 21 students opened up the video an average of 2.9 times with a standard deviation of 2.0.

One student even clicked on the video eight times. Again, it is unlikely this student watched the video in completion each time, but rather may have opened it up accidentally and quickly closed the video. Although the majority of students watched each video, it is important to note that viewership decreased as the semester proceeded.

[Insert Table 8 about here]

Survey Results

Throughout the semester, both sections were surveyed about their opinions on the classroom method used. The surveys allowed us to compare the opinions between the two sections and to assess how students' opinions evolved as the class progressed. Students in the traditional classroom were only asked about the traditional method, as the majority of them had never experienced a flipped classroom and therefore could not answer questions about it. The flipped students were asked to compare their experiences in the flipped classroom with that in traditional classrooms. Table 9 shows the survey results.

The traditional section was treated as the control group and was asked only during the second survey how they felt about the traditional classroom. On average, the students had a positive experience in the traditional section, with 33.3% of respondents indicating they loved it and 63.0% liking it most of the time. Many students noted that they felt most comfortable in the traditional classroom setting since they had so much experience with it in the past. For example, one student said, "Traditional is what I am used to, so I like it now just as always." Another student believed that the traditional method had a higher educational value by suggesting, "I love traditional classes. I pay tuition to be taught by a teacher, not teach myself." A few students expressed concern that the traditional format did not always agree with their learning speed, causing them to "feel rushed" or the "need a chance to catch up." Halfway through the class,

students were asked how much more time they spent per week on this class compared to similar classes with the same credit hours. The results showed that 0% said much more than average, 32.2% said somewhat more than average, 35.7% said average, 25.0% said somewhat less than average, and 7.1% said much less than average. The same question was asked at the end of the semester and received a very similar response distribution. Therefore when this class was taught in the traditional style, the time commitment was on par with other the other courses the students had taken.

Before starting the flipped classroom, the survey administrator described what a flipped classroom was and then a survey asked them to give their initial opinion based on the description. The surveys provided students' opinions on the flipped method before they experienced it. In response, 23.8% would rather have the instructor lecture during the class (reasons cited included the ability to ask questions to the instructor at the time the material was presented and the perception that in-class lectures were more interesting and helped students retain information better). Conversely, 33.3% indicated they would rather watch the videos (reasons cited included the ability to learn at their own pace, supervised problem-solving sessions, and shorter in-class lecture times). A total of 38.1% were indifferent (could not give a good answer without experiencing the flipped method first, liked the videos but also want to ask questions during lecture), and 4.8% stated they had an opinion other than the options given (e.g., like the idea of videos but question motivation to watch them without a scheduled lecture time).

Midway through the semester, the flipped section was surveyed again for their opinions now that they had experienced the flipped classroom. Overall the students had a positive experience with the flipped classroom, where 26.3% loved it and 68.4% liked it. Very similar results were given to the same question at the end of the semester, although the final opinion

distribution was somewhat less favorable than that of the traditional classroom students, with fewer flipped than traditional students loving their format (29.4% versus 33.3%) and more hating it (5.9% versus 3.7%). The less favorable opinions may be confounded with the fact that the survey was administered late in the semester and at a time when many courses have final projects due; that is, there could be more out-of-class activities competing for students' time later in the semester, making it more difficult for students to find time to watch videos outside of class.

When comparing their flipped learning to that of traditional learning, midway through the semester 21.1% said flipped helped them learn much better than traditional, 57.9% better than traditional, 21.0% the same as traditional, 0% less than traditional. By the end of the semester, their opinions shifted to being more critical of the flipped than when compared to the traditional. Positive feedback regarding the flipped classroom included the following statements: (1) "I feel like I am learning in class instead of pretending to listen;" (2) the flipped classroom provided "great practice and a good opportunity to ask questions;" and, (3) "I like it because it is a more efficient learning process, but it takes some time to get used to the new method of learning." Conversely, negative responses included: (1) a student perceiving inconsistencies in the video material versus practice problem material; (2) a few students forgetting to watch the videos before class; and, (3) one student stating "I'd rather be in class so I pay attention." It is important to note that the flipped student survey responses did not indicate problems with the pacing of the class (e.g., too fast or too slow). Students in the flipped section felt the time commitment was basically the same as their other classes with the same credit hours. Midway through the semester, the flipped student opinions included 5.3% saying the time commitment was much more than average, 10.5% somewhat more than average, 52.6% average, 21.1% somewhat less than average, and 10.5% much less than average. At the end of the semester, this changed to 0%, 35.3%, 35.3%, 23.5%,

and 5.9% respectively. Overall, it could be said that both the traditional and flipped were on average enjoyable to students, but most students in the flipped classroom felt that they learned the material better than they would have in the traditional classroom. Also, the surveys show a learning curve with the flipped classroom, where there was more variation in the time commitment midway through the semester than at the very end. This learning curve is important as it implies that students are adapting to the new classroom environment during the first weeks of the course. Although some students catch on quickly, others can take several weeks to get into the habit of watching the videos on their own. This segmentation of the classroom could result in a bimodal grade distribution at the beginning of the semester. This presence of a learning curve suggests that universities that are using flipped classrooms should phase in the use of this teaching method across courses and closely monitor student progress during the initial transition period, e.g., through the addition of additional homeworks on the flipped material.

Next, the flipped students were asked about their interactions with the online course material. Although it was rare for students to do something else while watching the lecture videos, the majority of students stated that they did not take notes while watching the videos. Students were more likely to perform actions that lengthened the amount of time they watched the videos (pause, rewind, and rewatch) than decreased it (fast forward). Also, over time all of the resources provided to them (video lectures, homework, etc.) became more helpful to their understanding of the material and success in the class. However, students consistently found the homework assignments and in-class activities to be the most supportive of their learning.

[Insert Table 9 about here]

Study Limitations

Although this study was able to record students' actual online actions, it was difficult to find clear relationships between online actions and student success. Intuitively, this may be because the same online action, such as how many times a student clicked on each resource, can represent different behaviors. On one hand, a student with few clicks can be less engaged in the course and therefore less likely to succeed. On the other hand, this same action could represent students that are printing out each resource so they can take notes, therefore only needing to view each resource once on the website. Printing of resources would potentially lead to a higher success rate. As a second example, consider office hour attendance. Students who attend office hours can have several motives for showing up, including to check their approaches after completing the assignment or to get hints from others before attempting the assignment. Future studies may be able to overcome this limitation by recording the length of time online activities, such as video viewing, and/or identifying when students print materials.

Also, a number of students failed to view some or all of the online lectures and/or never looked at old practice quizzes. Either the students never took advantage of these resources or they could have viewed them during a joint study session where several students use a single computer with one student's username. We hypothesize that this limitation can be overcome simply by changing the classroom setting, specifically to an online course or MOOC where distance between students would minimize the ability of students to work together in person.

There were design elements of these studies that could be improved. Specifically, it would be best in the surveys to continue asking the traditional students about their feelings on the traditional classroom instead of assuming that it stays constant throughout the semester. Lastly, if flipped classrooms continue to become more popular, future flipped classroom studies will be able

to minimize potential reactive effects of experimental arrangements (Campbell and Stanley, 1963), which may have impacted this study. That is, once flipped classrooms become more mainstream, students will be less motivated to act abnormally (e.g., try harder in the class) due to being heavily scrutinized in an educational study.

Finally, it is important to note that our study is based on a moderate class size of approximately 50 students. A traditional learning environment will differ across class sizes, and the results or our student may not be transferrable to large classes with hundreds of students.

Conclusion

One of the key findings from the study is that regardless of classroom type, good study habits are essential to student success. The correlations suggest that students who were successful on the quizzes generally had higher GPAs, started the homework assignments earlier, began studying for the quizzes earlier, and attended office hours. None of the classrooms promoted or inhibited good study habits. Simply stated, students who have been successful in the past are likely to continue being successful whether in a traditional or flipped classroom.

Consistent with the findings of Mason and colleagues (2013), we found that students initially struggled with the flipped classroom format. Survey questions related to time commitment and enjoyment level received much more polarized answers from the students during the flipped classroom than compared to the traditional classroom. This result suggests that students must learn to adapt to this new classroom environment in the initial weeks of the course. The adaptation period varies for each student, where some catch on to the new idea quickly whereas others need additional time to get in the habit of watching the videos and being self-motivated. According to Roehl and colleagues (2013), in a flipped classroom the "... students may require more than a semester to adapt to the new method of instruction and to recognize its value." The adaptation

period could be problematic, as a typical college course is only a single semester and can lead to a bimodal distribution in grades. This research cautions flipped classroom instructors that the method can possibly increase the frustration of weaker students at the beginning of the course. On the other hand, the adaptation period can also be viewed positively. Learning a new technology can be seen as an element of one's educational experience, where "one's adaptability to new technologies is crucial for graduating students to succeed in the workplace" (Roehl et. al 2013).

The inability to ask questions at the time new concepts are introduced appears to be a critical issue in flipped classrooms. Students want to ask questions during the online video, but cannot. Importantly, these students appear less likely to ever ask the instructor or teaching assistant about questions they had about the lecture. Although many students asked questions during the in-class practice problem sessions, the majority of these questions were focused on the in-class problems, not lecture material. The focus on soving in-class problems may make it more difficult for student to apply concepts to homework assignments and can greatly increase the amount of time these students need to spend out-of-class to master the material, i.e., out of class time now includes both watching the lecture videos and going to office hours to ask their questions. This raises another important question: namely, whether the lack of interaction with the instructor at the time material is first presented is impacting fundamental understanding of the course concepts. By viewing lectures ahead of time, students lose the ability to ask questions at the time material is presented. The lack of immediate feedback may prevent deeper understanding of the material, as there is no opportunity for the instructor to dynamically address questions in different contexts. Further, the problem sessions provide more opportunities for students to apply the concepts in a problem context, but students may lose the benefit of struggling with the material and trying different approaches on their own. For future research, we recommended that instructors track

concept inventories across the sections, through pre- and post- testing questions included on quizzes, to detect significant differences between the classrooms in understanding core concepts, not just solving problems.

Based on the results of our study, the next time we taught the civil engineering systems course, we used a "modified flipped" format. Specifically, we shortened the in-class lectures by using PowerPoints to present key concepts (versus writing the material on the board) and used the extra class time to have students work problems together. We also posted the videos previously used in the flipped section for students so that they could review key concepts after class (or before major quizzes). Feedback from students in the modified flipped class was positive, and we plan to use this classroom format moving forward for the civil engineering systems course.

Acknowledgments

We thank Gautam Saha for leading the online data collection effort, Stacey Mumbower for helping with the survey design, and Hunter Stroud for transcribing the handwritten surveys.

References

Beichner, R. (2008). "The SCALE-UP Project: a student-centered active learning environment for undergraduate programs." *Invited paper for the National Academy of Sciences*,(http://physics.ucf.edu/~bindell/PHY%202049%20Fall%202012/Beichner_Comm CommissionedP.pdf) (Feb. 4, 2015).

Bidwell, A. (2014). "Flipped classroom may help weaker STEM students." *US News*, (http://www.usnews.com/news/stem-solutions/articles/2014/08/05/taking-a-page-from-humanities-college-engineering-gets-flipped) (Feb. 4, 2015).

Bishop, J. L., and Verleger, M. A. (2013). "The flipped classroom: A survey of the research." *Proc., 120th ASEE National Conference & Exposition*, Atlanta, GA.

Buemi, S. (2014). "Microflipping: A modest twist on the 'flipped' classroom." *The Chronicle of Higher Education*, (http://chronicle.com/article/Microflipping-a-Modest-Twist/145951/) (Feb. 4, 2015).

Campbell, D. T., and Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research*, Rand McNally, Chicago, IL.

Fulton, K. (2012). "Upside down and inside out: Flip your classroom to improve student learning." *Learning & Leading with Technology*, 39(8), 12-17.

Goodwin, B. and Miller, K. (2013). "Research says evidence on flipped classrooms is still coming in." *Technology-Rich Learning*, 70(6), 78-80.

Lape, N. K. et al. (2014). "Probing the inverted classroom: A controlled study of teaching and learning outcomes in undergraduate engineering and mathematics." *Proc., 121st ASEE Annual Conference & Exposition*, Indianapolis, IN.

Mason, G. S., Shuman, T. R., and Cook, K. E. (2013). "Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course." *IEEE Transactions on Education*, *56*(4), 430-435.

Noonoo, S. (2012). "Flipped learning founders set the record straight." *THE Journal*, (http://thejournal.com/articles/2012/06/20/flipped-learning-founders-q-and-a.aspx) (Feb. 4, 2015).

Prensky, M. R. (2010). *Teaching digital natives: Partnering for real learning*. Corwin Press.

Roach, T. (2014). "Student perceptions toward flipped learning: New methods to increase interaction and active learning in cconomics." *International Review of Economics Education*, 17, 74-84.

Roshan, S. (2012a) "Reflecting on the Flipped Classroom Through Student Feedback." *The Daily Riff*, (http://www.thedailyriff.com/articles/reflecting-on-the-flipped-class-932.php) (Feb. 4, 2015).

Roshan, S. (2012b). "The Flipped Class: Students Talk." *The Daily Riff*, (http://www.thedailyriff.com/articles/students-talk-about-the-flipped-class-survey-results-933.php) (Feb. 4, 2015).

Strayer, J. F. (2012). "How learning in an inverted classroom influences cooperation, innovation and task orientation." *Learning Environments Research*, 15(2), 171-193.

Talbert, R. (2012). "Inverted classroom." *Colleagues, 9*(1), 7.

The White House (2013). "Fact sheet on the president's plan to make college more affordable." (http://www.whitehouse.gov/the-press-office/2013/08/22/fact-sheet-president-s-plan-make-college-more-affordable-better-bargain-) (Feb. 4, 2015).

Tucker, B. (2012). "The flipped classroom." *Education Next*, 12(1), 82-83.

Urbaczewski, A. (2013). "Flipping the classroom and problem solving techniques – Observations and lessons learned." *Proc., AIS SIG-ED IAIM Conference.*

Webster, D. R. and Majerich, D. M. (February 2014). "Flippin' Fluid Mechanics-Improved Student Engagement and Learning via Web-based Applications." *Proc, Ocean Sciences Meeting*, Honolulu, HI.

Wilson, M. E. (2004). "Teaching, learning, and millennial students." *New Directions for Student Services*, 106, 59-71.

LIST OF TABLES AND FIGURES

682 **Table 1.** Definition of variables

Source	Variable	Description
Main Course Website	Total Number of Non-Video Views	Total number of times the student viewed all materials posted on the website (e.g., if a student viewed the first lecture slides twice and an old quiz three times, the total number of views would be five). Excludes video viewing.
	Total Number of Non-Video Materials Viewed	Total number of materials viewed at least once on the course website (e.g., if a student viewed the first lecture slides twice and an old quiz three times, the total number of materials viewed would be two). Excludes video viewing.
	Average Number of Days Before Homework Due	The number of days between the first viewing of the homework assignment and the day it was due. Three assignments were given during the study period; the average from these assignments was used in the study.
	Average Number of Days before Quiz	The number of days between the first viewing of an old quiz and the day of the quiz. Two quizzes were given during the study period; the average from these quizzes was used in the study.
Video Course Website	Total Number of Videos Viewed	The number of videos a student viewed at least once.
Student Academic Records	Male	Indicator variable equal to 1 if the student is male, 0 if the student is female.
	Age	Age of student in years as of December 31, 2013.
	Earned Credits	Number of hours earned at the Georgia Institute of Technology (excludes advanced placement and transfer credits).
	Transcript GPA	Overall grade point average on a 4.0 scale (includes only courses taken at the Georgia Institute of Technology).
Course Grades	Quiz Grade	The average grade the student made on the two quizzes. This variable is used to measure student performance associated with a particular classroom method.
	Course GPA	The grade the student received in the civil engineering systems course on a 4.0 scale.
Teaching Assistant Observations	Office Hour Sessions	The number of office hour sessions the student attended during the study period.
Surveys	Alone	Indicator variable equal to 1 if the student prefers to work alone, 0 otherwise.
	Student Background and Attitude Information	Used to capture the student's attitudes about each classroom type and to obtain additional background information, such as whether the student had access to internet at home.

683
684

685 **Table 2.** Summary statistics of non-ISyE students in the traditional and flipped sections

	Traditional		**Flipped**	
	Total Class Enrollment	Study Participants	Total Class Enrollment	Study Participants
Number of students	45	36	24	23
Number of transfer students	7	6	4	4
Average transcript GPA (non-transfer students only)	3.09	3.18	3.24	3.25
% male	57.8%	55.6%	62.5%	60.9%
% female	42.2%	44.4%	37.5%	39.1%
Average course GPA	3.16	3.31	3.29	3.30
% (number who responded) with internet access at home	N/A	97.1% (35)	N/A	95.2% (21)
% (number who responded) who had previously heard of flipped classrooms	N/A	74.3% (35)	N/A	85.7% (21)
% (number who responded) who had previously taken flipped course	N/A	28.6% (35)	N/A	33.3% (21)
% (number who responded) who had previously taken online course	N/A	20.0% (35)	N/A	33.3% (21)

686

Table 3. Average scores on the two quizzes

	Traditional			Flipped		
	N	Mean	Std. Dev.	N	Mean	Std. Dev.
Study Sample	36	75.1	8.9	23	74.8	10.5
Male	20	76.1	7.4	14	73.9	12.3
Female	16	73.9	10.6	9	76.1	7.3
Alone	19	74.5	9.7	12	77.6	8.0
Group	12	76.8	8.6	6	77.1	7.7

691 **Table 4.** Correlations in traditional section

	Quiz Grade	Alone	Male	Age	Earned Credits	Transcript GPA	Office Hours	Avg Days Before Hwk	Avg Days Before Quiz	Non-Vid Views	Non-Vid Mat Viewed
Quiz Grade	1										
Alone	-0.1271	1									
	0.4955										
Male	0.1281	-0.0877	1								
	0.4564	0.6389									
Age	0.2017	0.0308	0.2893	1							
	0.2382	0.8692	0.0871								
Earned Credits	0.1837	-0.1159	-0.3461	-0.3241	1						
	0.2834	0.5346	0.0386	0.0538							
Transcript GPA	0.3301	0.1809	-0.1179	-0.1333	0.0827	1					
	0.0748	0.3869	0.5351	0.4824	0.6639						
Office Hours	0.0526	-0.1419	-0.1721	-0.2703	0.0077	0.2458	1				
	0.7608	0.4464	0.3154	0.1108	0.9644	0.1905					
Avg Days Before Hwk	0.2217	0.1137	-0.1572	-0.0244	-0.1068	0.2129	0.1547	1			
	0.1939	0.5424	0.3599	0.8876	0.5354	0.2587	0.3676				
Avg Days Before Quiz	0.2285	0.1191	-0.0122	0.2638	-0.2791	0.3044	0.1467	0.5083	1		
	0.1801	0.5233	0.9439	0.12	0.0993	0.1019	0.3933	0.0015			
Non-Vid Views	0.2012	-0.0818	-0.2677	0.0615	0.0583	-0.0697	-0.0105	0.4191	0.355	1	
	0.2465	0.6674	0.12	0.7255	0.7392	0.7195	0.9522	0.0122	0.0364		
Non-Vid Mat Viewed	0.1073	0.0229	-0.0759	0.0627	0.0676	0.1552	0.049	0.2208	0.188	0.7184	1
	0.5335	0.9026	0.6601	0.7164	0.6953	0.413	0.7767	0.1957	0.2721	0	

692

Table 5. Correlations in flipped section

	Quiz Grade	Alone	Male	Age	Earned Credits	Transcript GPA	Office Hours	Avg Days Before Hwk	Avg Days Before Quiz	Non-Vid Views	Non-Vid Mat Viewed	Videos Viewed
Quiz Grade	1											
Alone	0.0262 0.9177	1										
Male	-0.1066 0.6282	0.1612 0.5229	1									
Age	-0.3071 0.1541	0.1265 0.617	0.3107 0.149	1								
Earned Credits	-0.2826 0.1914	0.2402 0.3371	0.0943 0.6686	0.0883 0.6886	1							
Transcript GPA	0.6792 0.0014	-0.1034 0.7249	0.0773 0.753	-0.2574 0.2873	-0.5484 0.0151	1						
Office Hours	0.0616 0.7803	0.0317 0.9006	0.0031 0.9888	-0.1958 0.3706	-0.2111 0.3335	0.2787 0.248	1					
Avg Days Before Hwk	0.1462 0.5057	-0.2938 0.2366	0.285 0.1875	-0.0482 0.827	-0.2772 0.2004	0.378 0.1105	-0.0882 0.6889	1				
Avg Days Before Quiz	0.0398 0.8569	-0.4642 0.0523	-0.1612 0.4625	0.2048 0.3486	-0.2622 0.2268	0.1174 0.6321	0.0081 0.9707	0.3503 0.1013	1			
Non-Vid Views	0.1145 0.6028	-0.496 0.0363	-0.3105 0.1493	-0.082 0.71	0.1354 0.538	0.0354 0.8857	0.0015 0.9946	0.1358 0.5366	0.5357 0.0084	1		
Non-Vid Mat Viewed	0.3198 0.1368	-0.0994 0.6946	-0.5115 0.0126	-0.0525 0.812	0.0035 0.9875	0.1217 0.6197	-0.0099 0.9643	-0.0133 0.9519	0.4911 0.0173	0.639 0.001	1	
Videos Viewed	-0.065 0.7682	0.057 2 0.821 7	0.195 9 0.370 3	0.214 0.326 8	-0.17 0.438	0.1412 0.5641	0.0944 0.6682	0.3356 0.1174	0.2485 0.2528	0.1031 0.6396	-0.2095 0.3374	1

Table 6. Relationship between number of videos watched with homework and quiz grades

	Videos Viewed								
	0	1	2	3	4	5	6	7	Correlation
Homework 3	(0)	88.7% (1)	(0)	58.5% (1)	(0)	94.3% (2)	86.8% (4)	86.2% (15)	0.1085
Quiz 2	(0)	74.3% (1)	(0)	68.6% (1)	(0)	81.4% (2)	80.7% (4)	75.2% (15)	0.0166
Homework 4	63.1% (3)	91.6% (20)	---	---	---	---	---	---	0.4599
Homework 5	75.0% (4)	36.7% (2)	92.0% (5)	88.3% (12)	---	---	---	---	0.3031
Quiz 3	81.7% (3)	83.3% (1)	61.7% (2)	70.0% (5)	73.3% (12)	---	---	---	-0.1785

Table 7. Percent of study participants per section attending office hours

	Traditional	Flipped
Homework 1	11.1%	17.4%
Homework 2	16.7%	21.7%
Quiz 1	8.3%	17.4%
Homework 3	27.8%	39.1%
Quiz 2	5.6%	8.7%
Homework 4	13.9%	21.7%
Homework 5	22.2%	21.7%
Quiz 3	5.6%	4.3%

Table 8. Number of student views per video

Flipped	Video Length (Mins)	Observations (%)	Mean	Std. Dev.	Min	Max
1A Video	7:25	21 (91%)	2.9	2.0	1	8
1B Video	8:09	21 (91%)	1.5	0.7	1	3
2A Video	8:37	23 (100%)	2.4	1.3	1	6
2B Video	10:35	22 (96%)	1.7	0.9	1	4
3 Video	19:13	21 (91%)	2.6	1.6	1	6
4A Video	4:33	20 (87%)	2.1	1.4	1	7
4B Video	3:59	16 (70%)	1.9	2.0	1	9
5 Video	12:26	20 (87%)	2.6	1.2	1	5
6 Video	9:40	18 (78%)	2.3	0.97	1	4
7 Video	8:58	15 (65%)	2.6	1.7	1	6
8 Video	9:05	15 (65%)	2.3	1.9	1	8

Table 9. Survey results from spring semester

What are your initial thoughts about the flipped classroom?					
	Prefer instructor lecture	Prefer watching lecture videos	Indifferent	Other	
1st Flipped (21)	23.8%	33.3%	38.1%	4.8%	
How are you feeling about the traditional/flipped classroom?					
	Love it	Like it	Dislike it	Hate it	
2nd Traditional (27)	33.3%	63.0%	3.7%	0%	
2nd Flipped (19)	26.3%	68.4%	5.3%	0%	
3rd Flipped (17)	29.4%	64.7%	5.9%	0%	
How much time do you spend on this class compared to others with the same credit hours?					
	Much more than average	Somewhat more than average	Average	Somewhat less than average	Much less than average
2nd Traditional (28)	0%	32.2%	35.7%	25.0%	7.1%
3rd Traditional (21)	0%	33.3%	38.1%	23.8%	4.8%
2nd Flipped (19)	5.3%	10.5%	52.6%	21.1%	10.5%
3rd Flipped (17)	0%	35.3%	35.3%	23.5%	5.9%
How does the flipped classroom help you learn the materials compared to the traditional?					
	Much better	Better	Same	Worse than	Much worse
2nd Flipped (19)	21.1%	57.8%	21.1%	0%	0%
3rd Flipped (17)	17.7%	58.8%	17.6%	5.9%	0%
What are you doing when you watch the videos?					
	Listening but doing something else	Listening and watching	Listening, watching and taking notes		
2nd Flipped (19)	0%	57.9%	42.1%		
3rd Flipped (17)	11.8%	58.8%	29.4%		
How often do you do each of the following activities when watching the videos?					
		Always	Sometimes	Never	
2nd Flipped	Pause (19)	36.8%	63.2%	0%	
	Rewind (18)	16.7%	61.1%	22.2%	
	Rewatch (18)	11.1%	61.1%	27.8%	
	Fast Forward (18)	5.6%	33.35	61.1%	
3rd Flipped	Pause (17)	35.3%	52.9%	11.8%	
	Rewind (17)	17.7%	52.9%	29.4%	
	Rewatch (17)	17.7%	64.7%	17.6%	
	Fast Forward (17)	5.9%	35.3%	58.8%	
How did the following materials help your understanding?					
			Helpful	Not Sure	Waste of Time
2nd Flipped	Video Lectures (19)		84.2%	15.8%	0%
	Homework (19)		89.5%	10.5%	0%
	In-class discussion (19)		73.7%	21.0%	15.3%
	In-class activities (19)		89.5%	10.5%	0%
3rd Flipped	Video Lectures (17)		82.4%	17.6%	0%
	Homework (17)		100%	0%	0%
	In-class discussion (17)		76.5%	23.5%	0%
	In-class activities (17)		94.1%	5.9%	0%

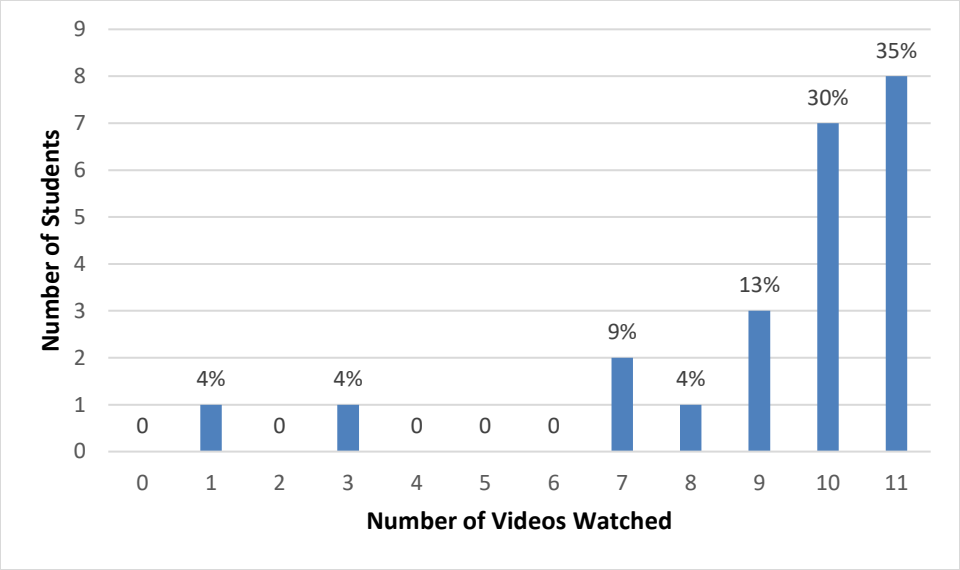

Fig. 1. Frequency of the number of videos watched by students