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Effectiveness of Flipped Classroom for Mechanics of Materials

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Effectiveness of Flipped Classroom for Mechanics of Materials

Abstract

The flipped classroom is a teaching method that *flips* the activities done in and out of class, i.e., concepts are learned out of class and problems are worked in class under the supervision of the instructor. Studies have indicated several benefits of the Flipped Classroom (FC), including improved performance and engagement. In the past years, further studies have investigated the benefits of FC in statics, dynamics, and mechanics of materials courses and indicate similar performance benefits. However, these studies address a need for additional studies to validate their results due to the short length of their research or small classroom size. In addition, many of these studies do not measure student attitudes, such as self-efficacy, or the difference in time spent out of class on coursework.

The objective of this research is to determine the effectiveness of the flipped classroom system in comparison to the traditional classroom system (TC) in a large mechanics of materials course. Specifically, it aims to measure student performance, student self-efficacy, student attitudes on lecture quality, motivation, attendance, hours spent out of class, practice, and support, and difference in impact between high, middle, and low achieving students. In order to accomplish this, three undergraduate mechanics of materials courses taught during the spring 2015 semester at Arizona State University were analyzed. One FC section served as the experimental group (92 students), while the two TC sections served as the control group (125 students). To analyze student self-efficacy and attitudes, a survey instrument was designed to measure 18 variables and was administered at the end of the semester. Standardized core outcomes were compared between groups to analyze performance.

This paper presents the specific course framework used in this FC, detailed results of the quantitative and qualitative analysis, and discussion of strengths and weaknesses. Overall, an overwhelming majority of students were satisfied with FC and would like more of their classes taught using FC. Strengths of this teaching method include greater confidence, better focus, higher satisfaction with practice in class and assistance received from instructors and peers, more freedom to express ideas and questions in class, and less time required outside of class for coursework. Results also suggest that this method has a greater positive impact on high and low achieving students and leads to higher performance. The criticisms made by students focused on lecture videos to have more worked examples. Overall, results suggest that FC is more effective than TC in a large mechanics of materials course.

Introduction and Background

The Flipped Classroom is a teaching method in which students learn class concepts at home, typically through online videos, and work on assignments in class with the guidance of the instructor. The use of this methodology has become well established and has numerous benefits which include: increased active learning[1], ability to learn material at one's convenience[2], potentially less time spent outside of class on coursework, performance improvements[3-6], and increased student-teacher interaction[1].

Although there is large support for the use of FC, there are relatively few research papers that focus on Mechanics of Materials. Three of the studies are fairly inconclusive and are limited by their small sample size. Vogt[7] is conducting an on-going survey study which has included 16 student responses so far and does not include a performance study. Lee et al.[8] conducted performance analysis that indicates improvement, but the significant variability in data and small sample size of 11 and 15 students makes the study inconclusive. Swartz et al.[9] conducted a survey study, which involved 22 students. The only results mentioned in the study state that 15 of the 22 students voted to maintain FC for the second half of the semester.

Two strong studies incorporated over 100 students and focused primarily on performance. Ryan et al.[10] found a small performance improvement, but was only able to compare data from the first exam, as the later exams varied greatly between 2013 and 2014. Notably, the percentage of students who scored less than 60% decreased by 7%, hinting that FC benefitted lower achieving students. Last, the study states that the instructor received the highest student course evaluations for overall course quality and instructor effectiveness during the year of the study, but does not mention the previous scores or number of student responses. Thomas et al.[11] conducted an extremely detailed performance analysis on a large sample size, but there was no statistical difference.

In summary, there are two performance studies that are promising and one that is inconclusive. In addition, there are no complete studies that measure the other benefits of FC, such as student-teacher interaction, in a Mechanics of Materials course. This study serves to fill in those blanks by measuring student performance, student self-efficacy, student attitudes on lecture quality, motivation, attendance, hours spent out of class, practice, and support, and difference in impact between high, middle, and low achieving students, in a flipped and traditional classroom.

Implementation of the Flipped Classroom

Three Mechanics of Materials courses taught during the spring 2015 semester at Arizona State University were utilized with 3 different professors, with a total of 217 students. One course was taught using the FC method and served as the experimental group, with 92 students. The two other courses were taught traditionally, with 125 total students. All three courses were taught with two 75-min lectures and a 50-min recitation each week. In this specific FC, students learned the material at home primarily using lecture videos created using Livescribe Pencast™ PDF. This lecture video was supplemented with PDF lecture notes. Over the course of the semester, 23 sets of Livescribe Pencast™ PDF and PDF lecture notes were created.

In class, students were sorted into groups of four at the beginning of the year. Groups would complete a pre-lecture quiz and group worksheet together. Each worksheet included an average of 4 problems with an extra challenge problem. Quizzes had only 1-2 questions. In order to properly address the questions of the large class size, four teaching aides were present during lecture in addition to the instructor. Over the course of the semester, 24 worksheets and quizzes were assigned.

Last, three extra things were done. Five short homework assignments were assigned to provide extra practice and another method to measure performance. Second, a truss project was assigned

to each group, in which a 2D truss was to be designed, built, and tested to failure to provide a hands-on application of course concepts. Third, an optional timed practice final exam was made available for students from all three courses to directly compare student performance between the three classes.

Research Methodology

In order to measure student performance between three distinct classes, standardized course core outcomes were used. This is the accepted concept inventory for Mechanics of Materials at this university and is the only feasible method to compare student performance between three different classes. The five assigned homework assignments, various exam problems, and the problems of the practice final exam align with different core outcomes and were used to measure the performance of each student. Table 1 details how each core outcome was measured.

Table 1. Evaluation of Core Outcomes

Course Core Outcomes	Achievement Level	Corresponding Assignments
Students will understand the definitions of stress and strain, and basic mechanical properties of materials such as elasticity, yielding stress, Young's modulus and Poisson's ratio.	Knowledge	Homework 1 Exam 1
Students will apply concepts of strain and stress to the analysis of statically-determinate and indeterminate bars under axial loading.	Comprehension	Homework 2 Exam 2, problem 1
Students will apply concepts of strain and stress to the analysis of statically-determinate and indeterminate shafts in torsion.	Comprehension	Homework 3 Exam 2, problems 2 & 3
Students will analyze the shear, moment distribution, and calculate stress in beams under bending.	Comprehension	Homework 4 Exam 3, problem 1
Students will predict deflection in beams under bending and analyze statically indeterminate beams.	Comprehension	Homework 5 Exam 3, problems 2 & 3

In order to analyze self-efficacy, student attitudes on lecture quality, motivation, attendance, hours spent out of class, practice, and support, and difference in impact between high, middle, and low achieving students, an online survey instrument was designed and administered at the end of the semester to all voluntary students.

To determine if the student was high (A), middle (B), or low (C) achieving, the students' grade from the prerequisite course, engineering mechanics (statics and dynamics), was utilized. An A+, A, or A- in engineering mechanics would categorize a student as a high achieving (A) student for the purposes of this study, as shown in Table 2. Grade point average was considered, but the responses did not allow for an even distribution into three distinct groups.

Table 2. Method for Categorizing Students into Achievement Groups

Engineering Mechanics Grade								
High Achieving (A)			Middle Achieving (B)			Low Achieving (C)		
A+	A	A-	B+	B	B-	C+	C	C-

The survey instrument is based off of various different studies which measured motivation[12] and self-efficacy[13]. The instrument measures variables of interest using 18 questions and utilizes a 7-point Likert scale for each question, except questions 11 and 14. Question 11 deals with lecture attendance and is measured on a scale of 1 to 4, with 1 being lowest attendance. Question 14

deals with time spent on coursework outside of class and is measured in number of hours, ranging from 1 to 10+ hours per week. For organizational purposes, the 18 questions were sorted into 4 different categories, including: self-efficacy, lecture quality, practice, and support. The questions and categories are detailed in Table 3.

Table 3. Survey Instrument Questions and Categories

	Survey Instrument Questions
Self-Efficacy	
1.	I can get the grades I want in MAE 213.
2.	I can do well on exams in MAE 213.
3.	I can do well on assignments in MAE 213.
4.	I can explain class concepts well to others in MAE 213.
5.	I have a strong understanding of class concepts.
Lecture Quality	
6.	I generally feel prepared for each class session.
7.	I am focused and engaged in lecture.
8.	During class time I often miss important points because I'm thinking of other things.
9.	Lecture helps me to learn the material.
10.	Going to lecture motivates me to do well/be engaged.
11.	Lecture attendance: (1-4)
Practice	
12.	OUTSIDE of class, I am satisfied with number of problems worked/amount of practice worked.
13.	INSIDE of class, I am satisfied with number of problems worked/amount of practice worked.
14.	Hours Spent Outside of Class for MAE 213 (lecture videos, homework, study, test prep, etc.) per week.
Support	
15.	I have a sense of community with other students.
16.	I receive the assistance I need from the instructor/teaching aides.
17.	I receive the assistance I need from peers.
18.	I feel free to express ideas and questions in class.

Another section of the survey was accessible by students in the FC section which included FC specific questions and is shown in Table 4. These questions deal with satisfaction and various course tools. A general comments section is provided for qualitative analysis and to capture any special points that the survey instrument may have overlooked.

Table 4. Flipped Classroom Section Questions

Flipped Classroom Section Questions	
Flipped Classroom Satisfaction	
1.	My preference of classroom style:
2.	I am satisfied with the flipped classroom system.
3.	I would like more of my classes to be taught in a flipped classroom style.
Effectiveness of Course Tools	
4.	I would not attend lecture if I did not receive any in-class grades (lecture quizzes, attendance points, etc.).
5.	Audio lectures are useful (Pencast).
6.	Instructor-provided lecture notes are useful (PDF).
7.	Lecture quizzes are useful.
8.	Lecture worksheets are useful.
9.	Discussion during lecture is useful.
Qualitative Feedback	
10.	General Comments

Results

Performance

Overall, 95% of students in the FC passed the core outcomes, while only 80% of the TC passed. This indicates that the FC leads to higher performance than TC by nearly 19%. However, due to the Family Educational Rights and Privacy Act (FERPA), detailed student performance data from the TC sections was unobtainable. Therefore, the original goal to compare each core outcome and assess whether differences were significant was made impossible. Instead, a chi-squared test of independence was conducted using a 95% confidence level and is shown in Table 5. The chi square value was calculated to be 9.4, giving a P-value of 0.002127, which is much less than the significance level of 0.05. As a result, the null hypothesis, that classroom style is independent of whether or not a student meets (passes) the core outcomes, is false. This indicates that there is significant difference between classroom style and performance.

Table 5. X^2 Test of Independence

	Pass	Fail	Row total
Flipped Classroom	87	5	92
Traditional Classroom	100	25	125
Column Total	187	30	217
χ^2	9.4369		
Significance Level	0.05		
P-value	0.002127		

With respect to the optional practice final exam, there was large attendance from the FC section, but only two TC students were in attendance and had left the exam early. This removed the usefulness of the practice final exam as a strong performance comparison.

Quantitative Survey Results

Of the 217 students enrolled in the three courses, 105 students (48.4%) participated in the online

survey, with 63 FC students (68.5%) and 42 TC students (33.6%). Scores from the 7-point Likert scale were averaged and compared. At an initial glance, FC had better averages than TC for 16 of the 18 variables, as seen in Figure 1.

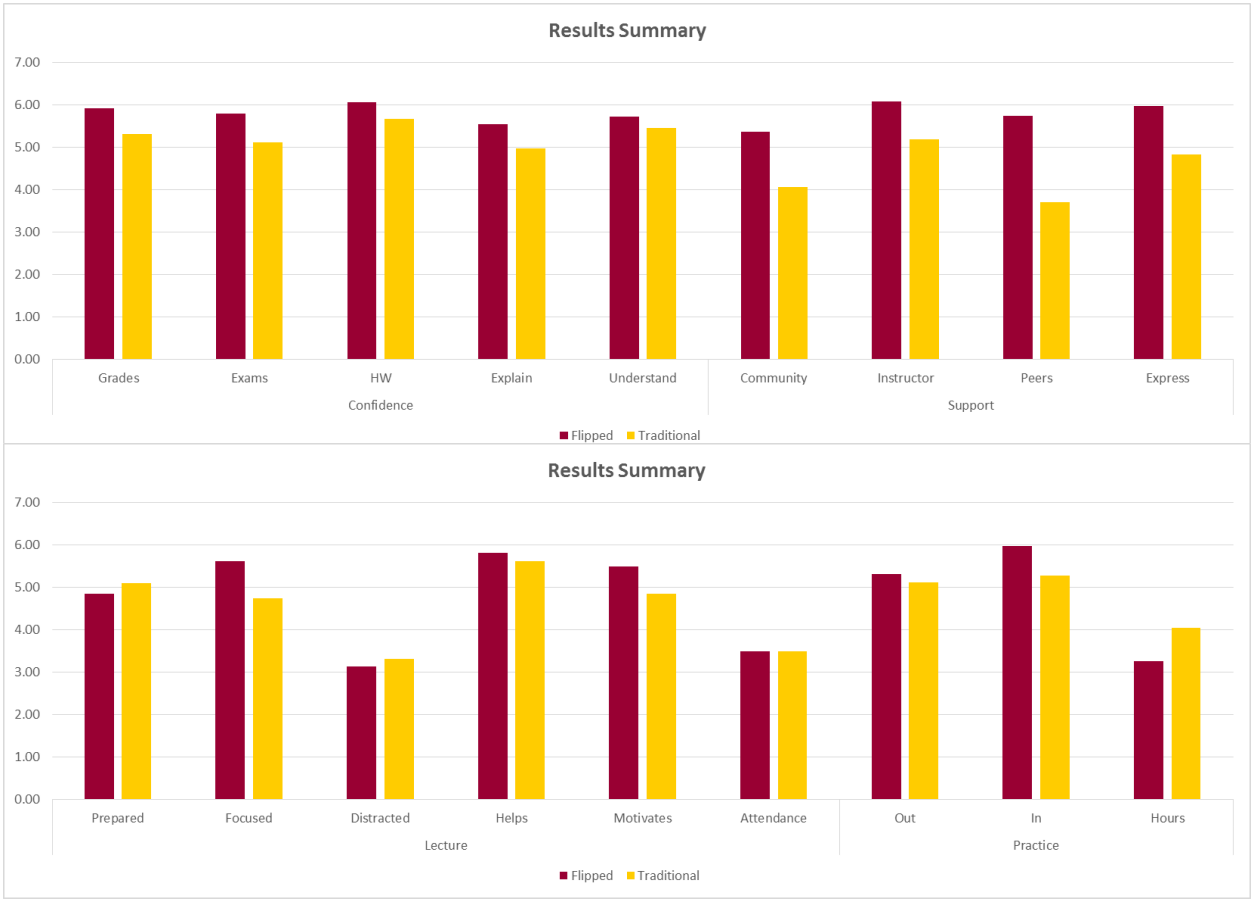

Figure 1. Mean Scores from Online Survey Instrument

To determine which variables were statistically significant, a two-tailed, two sample t-test, assuming unequal variances with a 90% confidence level was utilized. Table 6 highlights the significant p-values calculated from the t-test. This analysis determined that 12 variables were significant, each in favor of the FC. The mean scores, differences in scores, and percent differences were calculated to determine how large the difference was for each variable. The effect size was calculated to analyze approximately how many students were affected from FC. These numbers are detailed in Table 7. In this study, effect size was calculated using Cohen's D given in Equation 1, where x is the mean and s is the pooled standard deviation given in Equation 2, where n is the sample size and s_1 and s_2 are the variances. For Cohen's d, 0.2 signifies small, 0.5 medium, 0.8 large, and 1.3 very large effect sizes, as offered by Cohen.

$$d = \frac{x_1 - x_2}{s} \tag{1}$$

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}} \quad (2)$$

Table 6. T-Test Analysis of 18 Variables

		Confidence					**Support**			
		Grades	Exams	HW	Explain	Understand	Community	Instructor	Peers	Express
Total	F.C.	5.92	5.79	6.06	5.54	5.73	5.37	6.08	5.75	5.97
	Traditional	5.31	5.12	5.67	4.98	5.45	4.07	5.19	3.71	4.83
	Two-Tail P	0.03	0.02	0.06	0.02	0.21	0.00	0.00	0.00	0.00
	% Difference	**11.51%**	**13.18%**	**7.00%**	**11.32%**	5.09%	**31.77%**	**17.13%**	**54.70%**	**23.48%**
A	F.C.	6.23	6.27	6.14	6.09	6.27	6.00	6.48	5.86	6.33
	Traditional	5.92	5.58	5.75	5.25	5.58	3.75	5.50	3.92	5.25
	Two-Tail P	0.41	0.07	0.36	0.03	0.04	0.00	0.04	0.00	0.06
	% Difference	5.25%	**12.35%**	6.72%	**16.02%**	**12.35%**	**60.00%**	**17.75%**	**49.54%**	**20.63%**
B	F.C.	5.73	5.50	5.81	5.04	5.23	4.92	5.80	5.72	5.80
	Traditional	5.25	5.19	5.75	5.19	5.81	3.69	4.88	3.63	4.88
	Two-Tail P	0.31	0.48	0.85	0.70	0.08	0.04	0.05	0.00	0.11
	% Difference	9.16%	6.02%	1.00%	-2.87%	**-10.01%**	**33.42%**	**18.97%**	**57.79%**	18.97%
C	F.C.	5.80	5.60	6.40	5.60	5.80	5.40	5.93	5.73	6.07
	Traditional	4.86	4.64	5.50	4.50	4.93	4.79	5.29	3.64	4.43
	Two-Tail P	0.10	0.11	0.03	0.03	0.05	0.29	0.13	0.00	0.01
	% Difference	**19.41%**	20.62%	**16.36%**	**24.44%**	**17.68%**	12.84%	12.25%	**57.39%**	**36.99%**
	Full Question	I can get the grades I want in MAE 213.	I can do well on exams in MAE 213.	I can do well on assignments in MAE 213.	I can explain class concepts well to others in MAE 213.	I have a strong understanding of class concepts.	I have a sense of community with other students.	I receive the assistance I need from the instructor/teaching aides.	I receive the assistance I need from peers.	I feel free to express ideas and questions in class.

		Lecture						**Practice**		
		Prepared	Focused	Distracted	Helps	Motivates	Attendance	Out	In	Hours
Total	F.C.	4.86	5.62	3.14	5.81	5.49	3.49	5.32	5.98	3.25
	Traditional	5.10	4.74	3.31	5.62	4.86	3.50	5.12	5.29	4.05
	Two-Tail P	0.40	0.00	0.64	0.51	0.06	0.95	0.50	0.01	0.04
	% Difference	-4.67%	**18.59%**	-5.04%	3.39%	**13.07%**	-0.23%	3.88%	**13.21%**	**-19.61%**
A	F.C.	5.29	6.33	2.52	6.14	6.24	3.57	5.38	6.33	2.43
	Traditional	5.17	5.33	2.58	6.25	5.58	3.50	5.50	5.33	3.67
	Two-Tail P	0.81	0.01	0.92	0.77	0.17	0.81	0.82	0.06	0.12
	% Difference	2.30%	**18.75%**	-2.30%	-1.71%	11.73%	2.04%	-2.16%	**18.75%**	-33.77%
B	F.C.	4.44	5.04	3.44	5.44	4.92	3.32	5.16	5.64	3.60
	Traditional	5.19	5.00	3.69	5.44	4.88	3.38	5.19	5.31	4.31
	Two-Tail P	0.15	0.94	0.71	1.00	0.94	0.79	0.95	0.47	0.26
	% Difference	-14.41%	0.80%	-6.71%	0.05%	0.92%	-1.63%	-0.53%	6.16%	-16.52%
C	F.C.	5.20	5.60	3.40	6.07	5.33	3.67	5.87	6.27	3.67
	Traditional	4.93	3.93	3.50	5.29	4.21	3.64	4.71	5.21	4.07
	Two-Tail P	0.50	0.00	0.87	0.12	0.04	0.92	0.06	0.01	0.51
	% Difference	5.51%	**42.55%**	-2.86%	14.77%	**26.55%**	0.65%	**24.44%**	**20.18%**	-9.94%
	Full Question	I generally feel prepared for each class session.	I am focused and engaged in lecture.	During class time I often miss important points because I'm thinking of other things.	Lecture helps me to learn the material.	Going to lecture motivates me to do well/be engaged.	Lecture attendance (1-4):	OUTSIDE of class, I am satisfied with number of problems worked/amount of practice worked.	INSIDE of class, I am satisfied with number of problems worked/amount of practice worked.	Hours Spent Outside of Class for MAE 213 (lecture videos, homework, study, test prep, etc.) per week.

Table 7. Significant Variables

Survey Instrument Questions		FC Average	FC Std. Dev.	TC Average	TC Std. Dev.	FC-TC	Pooled Std. Dev.	Effect Size	Performance Difference
Self-Efficacy									
1.	I can get the grades I want in MAE 213.	5.92	1.22	5.31	1.44	0.61	1.31	0.46	11.51%
2.	I can do well on exams in MAE 213.	5.79	1.18	5.12	1.47	0.67	1.30	0.51	13.18%
3.	I can do well on assignments in MAE 213.	6.06	1.12	5.67	1.03	0.39	1.09	0.36	7.00%
4.	I can explain class concepts well to others in MAE 213.	5.54	1.26	4.98	1.18	0.56	1.23	0.46	11.32%
Lecture Quality									
7.	I am focused and engaged in lecture.	5.62	1.42	4.74	1.43	0.88	1.42	0.62	18.59%
10.	Going to lecture motivates me to do well/be engaged.	5.49	1.64	4.86	1.65	0.63	1.64	0.38	13.07%
Practice									
13.	INSIDE of class, I am satisfied with number of problems worked/amount of practice worked.	5.98	1.13	5.29	1.35	0.69	1.22	0.56	13.21%
14.	Hours Spent Outside of Class for MAE 213 (lecture videos, homework, study, test prep, etc.) per week.	3.25	1.91	4.05	1.85	-0.8	1.89	0.42	19.61%
Support									
15.	I have a sense of community with other students.	5.37	1.75	4.07	1.58	1.3	1.68	0.77	31.77%
16.	I receive the assistance I need from the instructor/teaching aides.	6.08	1.1	5.19	1.33	0.89	1.20	0.74	17.13%
17.	I receive the assistance I need from peers.	5.75	1.31	3.71	1.53	2.04	1.40	1.46	54.70%
18.	I feel free to express ideas and questions in class.	5.97	1.15	4.83	1.82	1.14	1.45	0.78	23.48%

These results indicate the FC students show higher self-efficacy by an average of about 11% with a medium effect size. Flipped classroom students felt 11.5% more confident in their ability to earn the grades they desired, 13.2% more confident on their ability to do well on exams, 7.0% more confident in their ability to do well on assignments, and 11.3% more confident in their ability to explain class concepts well to others. The effect size indicates that the FC creates a more significant change in self-efficacy for overall grades, exam scores, and the ability to explain class concepts.

In addition, the structure of the FC system is beneficial in making students more focused, engaged, and motivated by about 16% with a medium effect size. Students in the FC were 18.6% more focused and engaged in lecture and were 13.1% more motivated by FC to do well. The FC has a more significant effect size, 0.62, in focusing and engaging students in lecture.

Remarkably, FC students spend approximately 20% less time outside of class on coursework than TC students, while performing better or at least equally. This time reduction might be increased even further without the use of homework assignments to measure core outcomes. FC students were also more satisfied with the number of problems worked in-class by 13.2%.

Last, the satisfaction with amount of support received by FC students is overwhelming, indicated by large effect sizes from 0.74 to 1.46. The 17.1% increase in satisfaction from the assistance received from the instructor/teaching aides supports the benefit of increased student-teacher interaction. However, it might be important to note the additional 4 teaching aides available.

Notably, FC students felt 23.5% more free to express ideas and questions in class, further supporting the increase student-teacher interaction benefit. The last benefit seems to greatly support the increase in active learning benefit. There is a remarkable 55% increase in student-student interaction and 31.8% increase in students having a sense of community with their peers.

This indicates an increased amount of discussion and support from peers, which may not occur in

a TC setting. Students may not have an easy way to communicate or develop strong relationships with their peers if they live off campus. Typically, there is minimal interaction during a lecture. However, in this specific FC method, students are encouraged to interact and discuss concepts.

With respect to the 90% confidence level chosen, 10% of the significant variables may be subject to a Type 1 error. In this study, 10% is approximately 2 of the 18 variables. In this case, 16 variables would still be significant, which does not detract highly from the significance of this study.

Qualitative Survey Results

These quantitative results are further supported by the qualitative results. Of the 63 responses from FC students, 34 comments were received. General themes were found and are described in Table 8. Four students felt that FC really increased their understanding of Mechanics of Materials, supporting improved self-efficacy. Nine students described how FC really engaged them in a "*manner [that no other class] has before*," supporting the engaging and motivating aspect of FC in Mechanics of Materials. Five students focused on the benefits and convenience of having "*assistance readily available*," supporting the student-teacher interaction benefit.

The bulk of the criticism stemmed from a lack of quality examples, especially during more difficult parts of the course. Approximately 12 students mentioned this. One student stated that they "*learn by watching an instructor work out problems… and teach… tips or tricks*." This is an important point, and fortunately, this can be addressed by revising lecture videos to include more detailed examples and tricks to various problems.

In addition, notable single comments were highlighted. One student mentioned a team building aspect that the course had helped to develop and emphasized the important role that discussion played in their learning. Another student wrote about being able to learn at their own pace. This is an extremely important note as low achieving students may be low achieving because they learn at a different rate. Because of this, the traditional lecture may cause the student to fall behind. A large benefit to the flipped classroom is the ability to watch the lecture video at one's convenience and be able to pause or rewind if needed. This might also benefit nontraditional students who may miss class often due to many responsibilities at home.

Last, a large theme was that the FC may not be feasible in more complex courses such as "*Thermofluids or Numerical Methods"* where the "*topics [are] harder and problems [are] longer*." This is an important point because it provides student insight on what type of courses in which the FC might be applied in. Due to the nature of these comments, it seems that Mechanics of Materials is highly appropriate course in which to apply the FC in. Not only did the qualitative analysis support the quantitative analysis, but it provided insight on additional, important benefits that were not intended to be studied.

Table 8. Qualitative Results from General Comments

Theme	Frequency	Sample Comment
Satisfaction with FC	20	*"I can honestly say that I have learned more in this class than I have learned in any other engineering/MAE course I have taken so far in college."*
Dissatisfaction with FC	4	*"I am not a fan of this at all. I learn by watching an instructor work out problems and teach me concepts behind these problems… Group work? I don't want someone attempting to teach me something the wrong way... If I had known this before enrolling, I would have sought after another instructor."*
Support (Instructor, TA, Peer)	5	*"It is really nice to do most of the work in class where there is assistance readily available if/when I get stuck."*
More Examples in Videos	8	*"The biggest issue I have with the flipped classroom concept is the lack of good examples. For each lecture, I think the instructor could work out a much more difficult example (i.e. the hardest problem of that type that we will see in the course) and that would provide a great understanding of concepts, as the examples given in lectures are very simple most of the time."*
FC is Engaging	9	*"This style of teaching has allowed me to interact with the material in a much more direct manner than I have in any class before."*
FC increased Understanding	4	*"I feel like I have a better understanding of the concepts in this class than I do in the tradtional classes I have."*
FC Infeasible in Complex Courses	4	*"I could see this working in MAE 212… but I don't know if it would be as effective in a class like MAE 240 (Thermo I) since I personally find the topics to be harder and the problems longer."*
Team Skills	1	*"I feel that working through problems with fellow classmates really helped my understanding of the core material in ways that I normally would not have. An additional bonus of this system is that it builds team skills, and that is a valuable experience from a class."*
Learning at Own Pace	1	*"This has really helped me solidify concepts inside of class with the help of the TA's and [instructor] as well as allow me to spend time outside of class learning more at my own pace."*

Satisfaction

From the Flipped Classroom Section Questions, general satisfaction with FC was analyzed. The result was in favor of FC, where 79% of students were satisfied with the FC. 70% of students preferred the FC, 71% would like more of their classes to be taught in the FC style, and 44% of students were extremely satisfied with the FC. The general satisfaction with FC is shown in Figure 2, which also details the frequency of scores for each question.

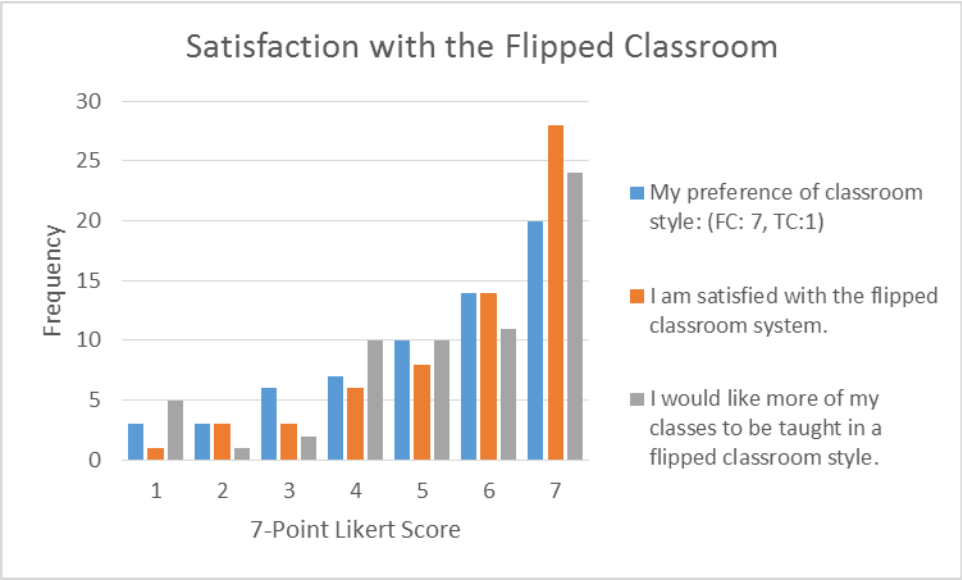

Figure 2. Satisfaction with the Flipped Classroom

Differences between Achievement Groups

With respect to the different achievement groups, results indicated that the high and low achieving students benefitted the most. The t-test analysis determined that 9 variables were significant for the high achieving group and 10 were significant for the low achieving group, while only 4 were significant for the middle achieving group. The significant variables for each group are detailed in Table 9. These results can also be visualized graphically in Figures 3, 4, and 5. The results seem to indicate that the high and low achieving students have a larger increase in self-efficacy and focus/engagement in lecture. Interestingly, the support was enjoyed universally. It should also be noted that of the 105 students who participated, 32% were high achieving, 40% were middle achieving, and 28% were low achieving.

Table 9. Significant Variables for Different Achievement Groups

Survey Instrument Questions		Significant?			
Self-Efficacy		**Total**	**A**	**B**	**C**
1.	I can get the grades I want in MAE 213.	Yes			Yes
2.	I can do well on exams in MAE 213.	Yes	Yes		
3.	I can do well on assignments in MAE 213.	Yes			Yes
4.	I can explain class concepts well to others in MAE 213.	Yes	Yes		Yes
5.	I have a strong understanding of class concepts.		Yes	Yes	Yes
Lecture Quality					
6.	I generally feel prepared for each class session.				
7.	I am focused and engaged in lecture.	Yes	Yes		Yes
8.	During class time I often miss important points because I'm thinking of other things.				
9.	Lecture helps me to learn the material.				
10.	Going to lecture motivates me to do well/be engaged.	Yes			Yes
11.	Lecture attendance:				
Practice					
12.	OUTSIDE of class, I am satisfied with number of problems worked/amount of practice worked.				
13.	INSIDE of class, I am satisfied with number of problems worked/amount of practice worked.	Yes	Yes		Yes
14.	Hours Spent Outside of Class for MAE 213 (lecture videos, homework, study, test prep, etc.) per week.	Yes			
Support					
15.	I have a sense of community with other students.	Yes	Yes	Yes	
16.	I receive the assistance I need from the instructor/teaching aides.	Yes	Yes	Yes	
17.	I receive the assistance I need from peers.	Yes	Yes	Yes	Yes
18.	I feel free to express ideas and questions in class.	Yes	Yes		Yes
	Total:	12	9	4	10

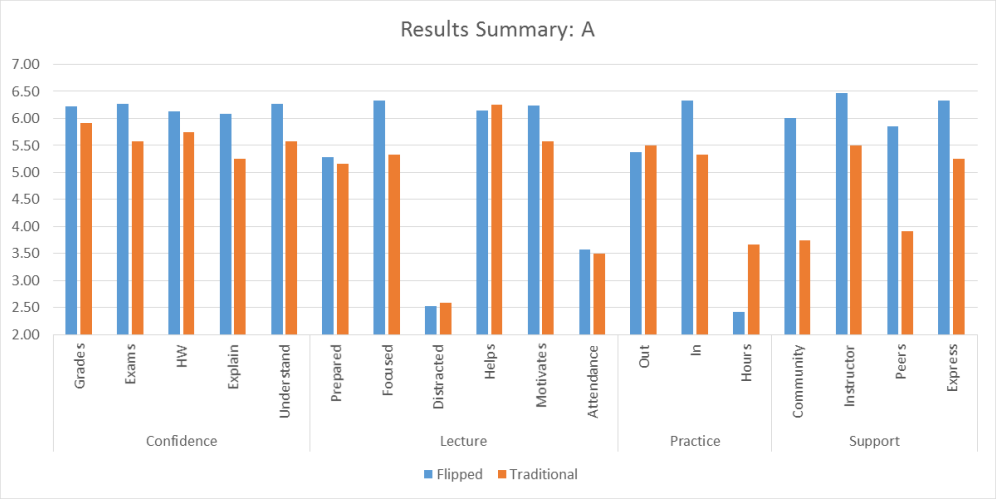

Figure 3. Mean Scores for High Achieving Students

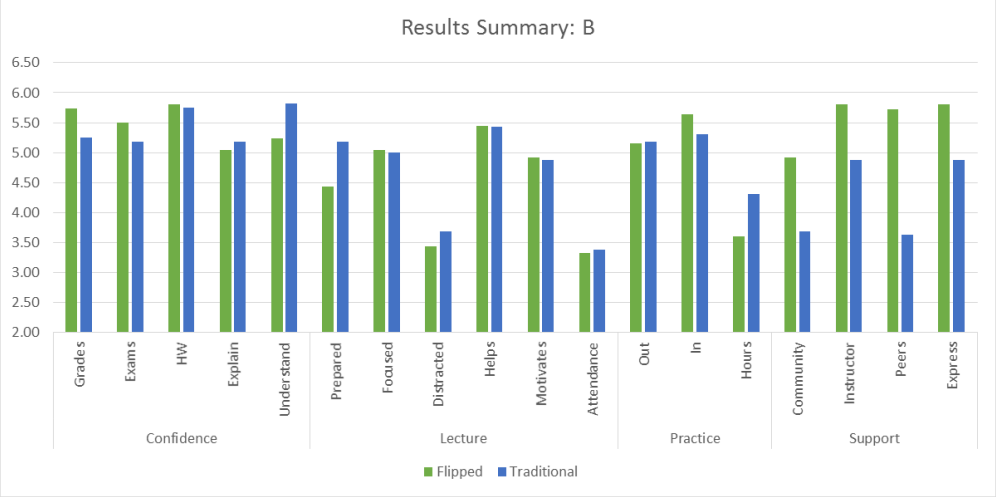

Figure 4. Mean Scores for Middle Achieving Students

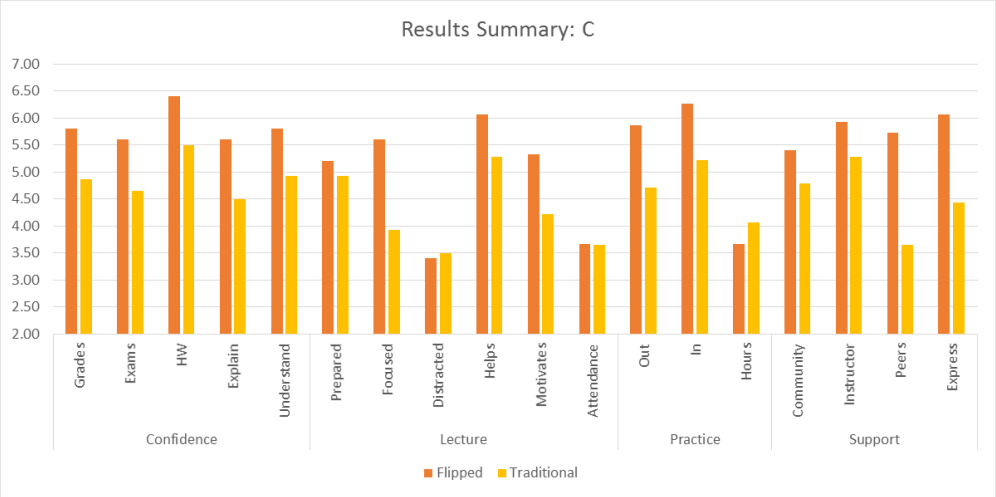

Figure 5. Mean Scores for Low Achieving Students

In addition, the high and low achieving students were much more satisfied than the middle achieving students with FC, as seen in Figure 6. Both of these results indicate that the FC has a greater positive impact on high and low achieving students. Perhaps high achieving students enjoy the active discussion and the low achieving students benefit highly from the ability to learn at their own pace. It is interesting to see that the middle achieving students did not benefit or were satisfied with FC as much.

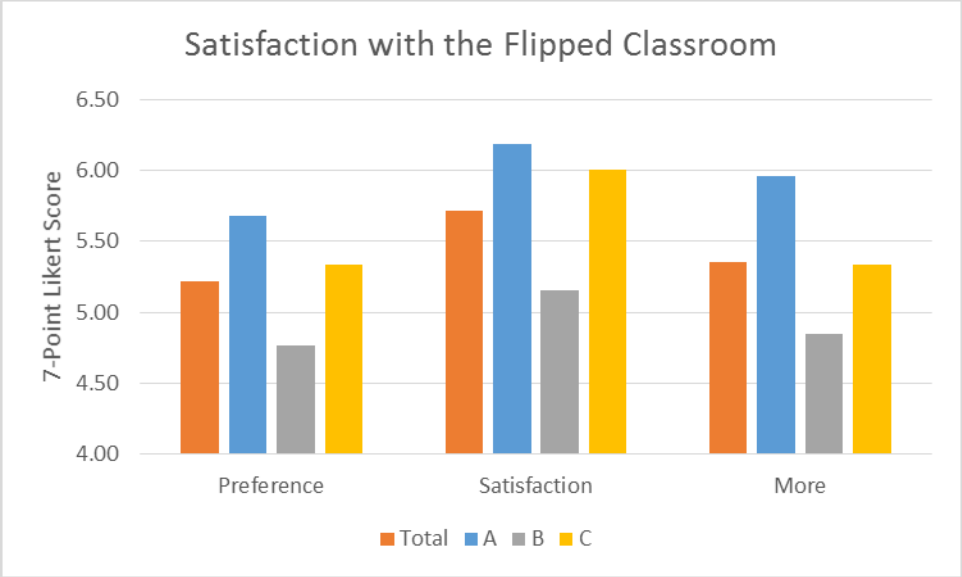

Figure 6. Satisfaction with the Flipped Classroom for Different Achievement Groups

To explore why middle achieving students might not be as satisfied, the four comments from dissatisfied middle achieving students were examined. Unfortunately a general theme or reason is unclear. The first student disliked many things, including the lack of instructor-worked examples, group worksheets, and lack of feedback from the worksheets (solutions were provided instead). The second student disliked that class participation was factored into their grade and noted that he/she should not need to attend class. The third student was dissatisfied with PDF notes and Pencast™ videos, noting the lack of examples. The last student commented that they stopped watching the Pencast™ videos halfway through the semester and was able to earn an A+ on the first two tests and that the allotted time for quizzes was not enough. The most general theme to be found is the lack of worked examples. Again, this issue can be easily addressed. Perhaps using new Pencast™ videos, middle achieving students might be more satisfied with FC.

Conclusion and Future Work

This paper described the implementation of a specific flipped classroom system in a relatively large Mechanics of Materials course, where four teaching aides were utilized to assist students in the completion of their assignments. The purpose of this was to determine if the flipped classroom was more effective than the traditional classroom in a Mechanics of Materials setting. The useable objective data indicates a 15% increase in performance while the detailed subjective data outlines many benefits, including increased self-efficacy, engagement, motivation, student-teacher interaction, student-student interaction, benefit for high and low achieving students, and

less time spent outside of class on coursework.

Since this study utilized different instructors, there are many extraneous variables such as teacher quality, exam practices, and grading methods that may have affected this study. In order to mitigate these affects, more collaboration should be utilized between the instructors or the FC instructor should teach the same course traditionally to provide control data. In addition, more worked examples should be provided in lecture videos, as described by the qualitative analysis. It might also prove interesting to explore further on why middle achieving students were least satisfied with FC or if this result is due solely to a lack of worked examples. Last removal of homework assignments may be considered to maintain a true flipped classroom and to also explore if any performance differences occur.

Overall, this study provides a strong, adaptable framework to be able to apply the flipped classroom method to a Mechanics of Materials course and be successful.

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