



## **Best 2019 PIC I Paper : Affects of Alternative Course Design and Instructional Methods in the Engineering Classroom**

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## **Effects of Alternative Course Design and Instructional Methods in the Engineering Classroom**

This work-in-progress paper reports on the effects of alternative course design and instructional methods in the engineering classroom. The primary method of delivery in undergraduate engineering classrooms remains the traditional lecture format, or teacher-centered instruction, despite evidence that active learning, or student-centered teaching practices, are significantly more effective. Catalyzed by the overwhelming research support for more active learning methods and the promise for creating these opportunities through alternative course models, there has been a more recent shift towards experimentation in delivery and course structure, including strategies such as flipping course content. Flipped course design allows instructors to maintain delivery of critical theoretical and background information by presenting this material to the students outside of formal classroom time, thus preserving time in-class for more active learning and problem-based activities.

The flipped learning course design continues to gain popularity in engineering education; however, large-scale quantitative statistical analysis of student outcomes and achievement in courses taught simultaneously through alternative course designs remains limited. The purpose of this study was to examine the effects of these varied instructional methods by investigating the student achievement outcomes of engineering students enrolled in the same course taught through three different instructional models. The study also aims to assess more specific flipped course design components (video lectures) on student outcomes as well as to evaluate the data through the context of the Technological Pedagogical Content Knowledge (TPACK) and Constructivist theoretical models.

Beginning in the fall of 2018, a 200-level mechanical/aerospace course, Statics, was taught by three different faculty members at a large university in the Southwest. Each of these sections were taught in different ways: (a) traditional lecture format, (b) flipped style classroom, and (c) mixed version, which utilized videos created for the flipped classroom as supplemental material but delivered course content primarily through lecture style. Student-level data were collected for all three of the Statics sections of interest in this study. Data were analyzed to determine if students enrolled in flipped or mixed sections experienced improved achievement outcomes greater than their traditional-lecture peers. Initial data showed that the mixed course design had the greatest impact on student achievement as measured by grade distribution, DEW rates, and student performance on class assignments, quizzes, and exams. The flipped and mixed courses were associated with greater improvement for DEW rates, in comparison to the traditional lecture course. Additional data analysis may provide further insight into how specific flipped delivery components, such as video lectures, impact student achievement.

### **Introduction**

This work-in-progress paper reports on the effects of alternative course delivery and instructional methods in three engineering classrooms. Flipped and alternative classroom models have gained in popularity in recent years and while the engineering classrooms in higher education have lagged behind their non-STEM colleagues in this process, the trend has continued to gain traction over the last decade [1]. Adoption of alternative course models is due in part to the

promise that the flipped classroom design holds for engineering faculty to find a compromise between the long-venerated lecture format and the research-based instructional practices of active learning. In its idealized form, the flipped design allows instructors to maintain delivery of critical theoretical and background information by presenting this material to the students outside of the formal classroom setting, thus preserving classroom time for more active learning and problem-based activities [2], [3].

Despite the enthusiasm around the flipping movement, there remains relatively little comprehensive research on student outcomes in flipped engineering courses, with most available engineering-related publications focusing on the design and instructional components of flipping rather than quantitative statistical analysis of student outcomes and achievement [4]. Of particular note is the limited number of large-scale comparisons of student learning outcomes in courses taught simultaneously through alternative methods, with accompanying data analysis and statistical significance, and explanation of relevance to broader educational theories [4]. Further, studies examining the effects of different implementations or components of flipped classroom strategies are needed to solidify the effects of and best practices around flipped course design, especially within the context of large engineering classrooms.

With this backdrop, beginning in the fall of 2018, a 200-level mechanical/aerospace course, Statics, was taught by three different faculty members at a large university in the Southwest. Each of these sections were taught in different ways: (a) traditional lecture format, (b) flipped style classroom, and (c) mixed version, which utilized flipped classroom-style videos as supplemental material but delivered course content primarily through lecture style. Student-level data was collected for all three of the Statics sections of interest in this study and included student major, year in school, course grade, average overall GPA, pre-test concept inventory scores, and demographic information (including age, gender, race, SES).

The data was used to answer three primary research objectives. The first was to analyze data from three alternatively designed Statics course sections to determine if students enrolled in flipped or mixed sections experienced improved achievement outcomes greater than their traditional-lecture peers. The second included efforts to determine, more specifically, if there were any flipped course design components (such as flipped-style videos used in the mixed section) that had a measurable effect on student outcomes in the three sections. The third objective was to review the available data through the context of the Technological Pedagogical Content Knowledge (TPACK) and Constructivist theoretical models (as described below) to provide greater continuity and application of the research from this study on flipped design in engineering to the broader theoretical models cited in the literature on the topic. This work-in-progress paper begins to address the research objectives.

## **Background and Relevant Literature**

### *Theoretical Frameworks for Flipped Course Evaluation*

Understanding the effect flipping has on engineering courses requires knowledge of relevant theoretical frameworks. Two such frameworks are the Technological Pedagogical Content Knowledge (TPACK) model and the theory of Constructivism. TPACK is visualized as three

overlapping spheres with the contexts of 1) Content Knowledge (CK), 2) Pedagogical Knowledge (PK), and 3) Technological Knowledge (TK), as the central themes (see Figure 1) [5], [6]. TPACK provides a more realistic picture of the demands placed on engineering faculty endeavoring to flip their course by underscoring that there are three separate skill sets, Technology, Content, and Pedagogy, required to deliver in the flipped format. TPACK highlights the importance of faculty knowledge in integrating technology (TK), content (CK), and pedagogical best practices (PK) as well as the ability to seamlessly synthesize all three areas to produce an effective flipped environment.

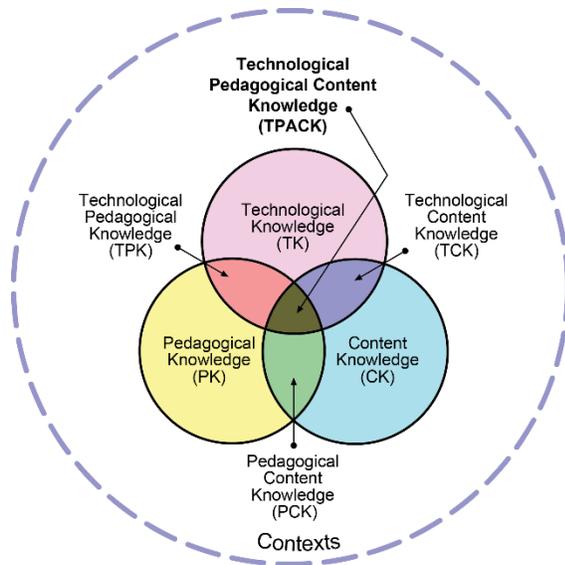


Figure 1. Technological Pedagogical Content Knowledge (TPACK) model [7]

While TPACK is a relatively recent educational model, the theory of Constructivism has been at the heart of educational frameworks since the work of Piaget nearly 100 years ago [8]. Constructivism has ebbed and flowed in popularity, but has gained more recent attention in the past few decades as it relates to active learning. Active learning, which is rooted in constructivist traditions, centers on the idea that students need to be provided with opportunities to construct their knowledge on given topics rather than learning through passive lecture transmission or rote memorization [9], [10]. Active learning, as opposed to more traditional lecture-style delivery has been shown to increase student engagement and learner accountability for knowledge acquisition [11] while resulting in increased student achievement outcomes in the STEM disciplines [12].

### *Flipped Learning in Engineering*

Flipped learning leverages many of the best practices of active learning described above, by moving some, or all, of the direct instruction out of the classroom (often through videos and online learning systems), leaving the classroom time to be devoted to more hands-on, active, and collaborative learning activities [13]. The flipped learning approach has gained significant momentum since 2012, with 27% of higher education faculty surveyed (in all disciplines) stating that they planned to incorporate flipped classroom techniques and 29% saying that they were

already using a version of flipped delivery in their instruction [14]. While the numbers of faculty employing flipping techniques tends to be lower in the engineering disciplines than in the overall higher education classrooms presented in the survey, research supporting the use of flipped learning in engineering continues to grow. Engineering faculty, who have traditionally resisted flipped and active learning instructional techniques [15], view flipping as a good compromise between the more familiar lecture style delivery and the active learning delivery that has shown repeated promise for improving student achievement [12, 16, 17].

Despite the growth in interest around flipping in engineering, relatively few comprehensive studies have been conducted. In a systematic review of literature conducted in 2015, less than 25 journal articles were available on the topic, with most of the available research focusing on the design and instructional how-to components of flipping rather than quantitative statistical analysis of student outcomes and achievement [4]. The same review showed limited research grounded in more established theoretical frameworks (like Constructivism or TPACK described above) or quantitative studies with statistical significance reported. This resulted in just seven studies that compared flipped and traditional classrooms and provided statistical analysis and significance of the results [4].

While this type of research is limited, there is a larger body of educational literature available that provides insight into ‘benefits and challenges’ of flipping courses in Engineering. The benefits of flipped learning frequently cited in literature mirror many of the instructional best practices detailed in the active learning portion of the literature review, including increased peer-to-peer interaction [18-21] and improved student engagement [22]. Benefits specific to the flipped classroom delivery approach include the flexibility afforded by asynchronous presentation of material [23-27] and better student preparedness in comparison with more traditional lecture format [25, 28, 29].

Challenges for students in flipped classrooms often includes technical difficulties and lowered engagement levels for flipped class content [30]. The length of videos used for flipped instruction was found to be an issue in many classes [31], while other videos and digital instruction were determined to simply be ‘too boring’ [30]. In addition to the difficulties with the technical and material delivery, students also voiced difficulty with the transition to the overall flipped course structure [30], [32]. Students, despite their *net generation* status, have been conditioned to learn through more traditional delivery methods and the conversion to the flipped environment, specifically learning through technology-enabled methods, can be difficult in the beginning.

When technology is leveraged productively in instruction, it has been shown to improve student motivation [33], create a sense of community [34], and encourage collaboration where it may have previously been difficult due to time, proximity, and scheduling constraints [35]. Conversely, when students are asked to learn through new technology-enabled approaches, such as flipped classes, and are not provided with the necessary support or structure, they can be left feeling isolated, with gaps in communication felt more acutely than during traditional, lecture-style instructional methods [36]. The variety and types of issues surrounding flipped learning validate the feelings of frustration and increased workload voiced by many faculty when redesigning their course in the flipped style [23], [37].

## Methodology

This study looks at three sections of a large, 200-level mechanical/aerospace course, Statics, which was taught in three different ways: (a) traditional lecture format, (b) flipped style classroom, and (c) mixed version, which utilized flipped classroom-style videos as supplemental material but delivered course content primarily through lecture style. The lecture videos, which were created for the flipped classroom and subsequently used as instructional support in the mixed class, were recorded in a studio with using a Lightboard, a transparent glass whiteboard that is filmed from the opposite side of the instructor so that the instructor is always facing the camera, but appears behind the lecture notes. The lecture videos present single concepts in statics, e.g., computing moments using Varignon's theorem, or simplifying distributed loads, with a typical duration of about 10 minutes. The videos were hosted on the Playposit learning platform, which allows for free response and/or multiple choice questions to be displayed to the students periodically throughout the video. In total students were required to watch 28 videos over the course of the semester.

Student-level data was collected for all three of the Statics sections and included information for approximately 300 students. Ninety-nine students were enrolled in the traditional lecture delivery section, 95 students were enrolled in the flipped style section, and 98 students were enrolled in the mixed version section. Data collected included: student major, year in school, course grade, average overall GPA, pre-test concept inventory concept inventory scores, and demographic information (including age, gender, race, SES), course grades for problem sets, quizzes, exams, and final course grades.

The data were used to answer three primary research objectives. Data were first analyzed to determine if students enrolled in flipped or mixed sections experienced improved achievement outcomes greater than their traditional-lecture peers. Second, the data were reviewed to determine if there were any flipped course design components (such as lecture videos) that had a measurable effect on student outcomes in the three sections. Finally, data were viewed through the lens of the Technological Pedagogical Content Knowledge (TPACK) and Constructivist theoretical models to provide greater continuity and application of the research from this study on flipped design in engineering to the broader educational models cited in literature.

### *Data Sources*

The primary data source for this study came from the gradebooks for each class. Though the classes were taught in different manners, they were identical in terms of assignments, quizzes, and exams. The classes shared a common Gradescope online grade database, in which homework sets, quizzes, and exams were uploaded and graded using a common set of metrics. Homework sets and quizzes were graded by student graders, whereas the exams were graded by instructors. Each homework, quiz, or exam problem was graded by the same person across all class sections, e.g. the first midterm exam was graded by only two instructors, who each graded one of the two exam questions across all sections. Each instructor entered grade data into a master Gradescope database, from which the data for this study were extracted. Table 1, below, summarizes the class structure and points for determining final grades. Final grades and course

items, including quizzes, problem sets, exams, and final exams, were analyzed across the three classroom types. Before conducting analysis, all student data were deidentified.

Table 1. Course Structure and Grading Components

Item	Total Number	Maximum Points per Item	Total Points
Quizzes	10	10	100
Problem Sets	12	30 – 40	465
Exams	2	100	200
Final Exam	1	100	100

### Data Analysis & Results

Individual classroom components were examined to assess for differences between the three course types. A breakdown of the average course components and results of the Kruskal-Wallis one-way analysis of variance tests are discussed in this section. In table 2, the average score on each problem set, by classroom type, and significance values for the Kruskal-Wallis tests are presented. In table 3, we present the average score and significance values for the Kruskal-Wallis tests for the quizzes, exams, and final.

Table 2. Average Score on Problem Sets & Significance of Kruskal-Wallis Tests

Problem Set	Average Score				Sig. of Independent Samples Kruskal-Wallis Tests
	Flipped	Mixed	Traditional	All Three	
PS1 (out of 40)	25.14	36.57	33.41	31.99	0.000
PS2 (out of 40)	26.92	35.85	31.48	31.85	0.000
PS3 (out of 40)	28.14	34.82	32.90	32.34	0.000
PS4 (out of 40)	27.07	34.02	33.24	31.99	0.000
PS5 (out of 35)	23.73	29.67	27.80	27.50	0.000
PS6 (out of 40)	24.77	28.72	26.34	26.87	0.051
PS7 (out of 30)	21.38	24.23	22.53	22.85	0.045
PS8 (out of 40)	30.98	36.10	33.77	33.97	0.000
PS9 (out of 40)	25.61	32.88	30.91	30.50	0.000
PS10 (out of 40)	29.29	34.89	32.38	32.71	0.000

PS11 (out of 40)	30.10	33.88	33.77	32.99	0.003
PS12 (out of 40)	32.75	33.74	33.09	33.28	0.724

Across all twelve of the problem sets, the mixed classroom had the highest average score, followed by the traditional classroom, with the flipped classroom having the lowest average scores. With the exception of problem sets 6 and 12, the differences in average score of the problem sets were significant across all three classroom types ( $p < .05$ ).

Table 3. Average Score on Quizzes, Exams, and Final & Significance of Kruskal-Wallis Tests

Course Component	Average Score				Sig. of Independent Samples Kruskal-Wallis Tests
	Flipped	Mixed	Traditional	All Three	
<i>Quizzes</i>					
Quiz 1	4.58	6.69	6.21	5.84	0.000
Quiz 2	8.41	8.63	7.58	8.20	0.026
Quiz 3	7.45	7.25	7.00	7.23	0.263
Quiz 4	5.61	7.27	5.63	6.15	0.000
Quiz 5	8.23	8.38	7.20	7.92	0.000
Quiz 6	5.23	6.20	4.77	5.38	0.000
Quiz 7	7.44	6.94	6.65	7.01	0.027
Quiz 8	7.71	7.50	6.00	7.07	0.000
Quiz 9	5.43	6.20	5.03	5.55	0.001
Quiz 10	8.21	8.35	7.83	8.12	0.272
<i>Exams &amp; Final</i>					
Exam 1	73.81	81.04	77.00	77.31	0.007
Exam 2	75.22	79.45	72.75	75.69	0.031
Final Exam	61.95	68.61	63.16	64.54	0.027

There were ten quizzes across the Fall semester. All quizzes were graded by the same hourly teaching assistant using common grading rubrics developed by the instructor of the flipped classroom. Except for the third and tenth quizzes, all of the classrooms had significantly different scores on the quizzes ( $p < .05$ ). The mixed classroom had the highest average scores on 7 of the

10 quizzes. The flipped classroom had the highest average score on the other three quizzes. The traditional classroom had the lowest average score on all but two of the quizzes.

Two exams and one cumulative final exam were given during the semester. Each exam question was graded by a single instructor (for all students across all sections). Exam 1 had two problems (two instructors graded), exam 2 had two problems (two instructors graded), and the final exam had 4 problems (four instructors graded). The instructors discussed grading rubrics prior to grading each exam, but the specific grading rubrics developed for each exam question was developed by the individual instructor. The mixed classroom had the highest average score on all three of the exams. The flipped classroom had the lowest average scores on the first exam and final exam; whereas the traditional classroom had the lowest average score on the second exam. The differences in average score was significant across all three exams ( $p < .05$ ).

Lastly, we examined differences in grade distributions across the three classroom types. Table 4, below, presents the distribution of final grades across the flipped, mixed, and traditional sections of the engineering course. In general, it appears that the mixed classroom had the highest achieving group of students. The mixed class had the largest percentage of students with a final grade of A, at 37%. The percentage of students with B's as a final grade was more even across the three classrooms. Students with C as a final grade was considerably lower in the mixed classroom (15%), but more even between the flipped and traditional classrooms (36% and 32%, respectively). The percent of DEW was greatest in the traditional classroom at over a quarter of the students receiving a D/E grade or withdrawing from the course, and nearly identical between the flipped and mixed classroom around 18%.

Table 4. *Grade Distributions, by Instructional Type*

<b>Classroom Type</b>	<b>Percent A</b>	<b>Percent B</b>	<b>Percent C</b>	<b>Percent DEW</b>
Flipped	13.68	31.58	35.79	18.95
Mixed	36.73	28.57	15.31	18.37
Traditional	17.17	25.25	32.32	25.25

A series of Kruskal-Wallis tests were conducted to assess for differences in distributions of A, B, C, and DEW grades across the flipped, mixed, and traditional classrooms. The tests indicated there were no significant differences between any of the three classrooms on the distributions of the final grades ( $p > .05$ ).

## **Discussion**

The greatest limitation of this study to date, is that it is still a work in progress. Additional analysis of the Fall 2018 data, along with data from subsequent semesters, will shed more light on the overall effectiveness of flipping in the Statics course and should provide a more holistic view than the snapshot that is currently available. With the acknowledgement that this is study is

still early in exploration of findings and conclusions, there are still several implications that can be garnered related to the research objectives.

The first research objective was to analyze data from three alternatively designed Statics course sections (flipped, mixed, and traditional) to determine if students enrolled in flipped or mixed sections experienced improved achievement outcomes greater than their traditional-lecture peers. While this question is ongoing, data has been analyzed for each of the varied instructional methods to determine if there were any statistically significant differences in the exam, grade distribution, or DEW rates of students in the three sections. On the three exams (two exams and one final), the mixed classroom had the highest average score on all three of the exams. The flipped classroom had the lowest average scores on the first exam and final exam and the traditional classroom had the lowest average score on the second exam. This data suggests that there is room for improvement in the flipped design in regards to preparing students for their exams. It is worth noting that the students in the flipped course took the same test as their peers in other sections and the common exams may not have been ideal/equitable for testing students who learned content in an active, less traditional way. While there is some debate about the necessity of updating course exams as part of the flipped course overhaul, the common exams between courses allowed data here to be more easily compared between sections and the flipped course appears to be less effective for exam preparation than the mixed delivery style.

The exam performance may also be explained, in part, by instructor differences and student demographic factors for each course. While the differences between instructors cannot be fully teased out of the data, greater information on the delivery styles and support materials provided in each of the sections may offer a more holistic picture of the classroom environment than the label (of flipped, traditional, or mixed) alone. Student demographics and distribution between the sections may also be biasing the average scores. The sections were held at different times throughout the day and the preferred time slots may have encouraged honors and higher-achieving students towards one section over another. This information, in conjunction with pre-test scores from each course, will be reviewed for the complete paper on this research.

Turning to final grades, both the flipped and mixed learning methods significantly lowered the DEW rates for students over traditional delivery instruction. This supports the use of flipped and mixed methods to improve student achievement. Despite the improvement in DEW percentages, the rate of students achieving an A in the course was significantly higher in the mixed class than in either the flipped or traditional sections. Overall, the grades reflected similar outcomes to the exams where students in the mixed section outperformed students in both the flipped and traditional sections. This indicates that, despite some promise shown in the flipped course section, students in that section were still not able to achieve at the same level as their peers in the mixed-delivery class. The reason for this outcome answer may be due to the reinforcement of ideas provided by the combination of lecture and video in the mixed section (described in more detail below) as well as the difficulty students and faculty experience with transitioning to a flipped classroom model.

As noted in the literature review, students and faculty often struggle with the initial conversion to the flipped format. Students, despite being *digital natives* often find the transition to flipped classrooms challenging after being conditioned to learn through lecture delivery for most of their

education [30], [32]. From a faculty perspective, it is a tremendous amount of work to shift an entire course to a fully flipped format in one semester [23], [37]. These challenges may help to explain why flipped method did not have a larger impact on student achievement during the first semester of implementation in this study. Additional data, from both previous semesters as well as subsequent semesters under the flipped format, should provide greater insight into the context and trends in student performance for this course. The data showing that the flipped students outperformed their traditional peers in DEW rates, even in this first semester, suggests that there is potential for this delivery method to show even greater success in subsequent semesters.

The second research objective aimed to determine if there were any flipped course design components that had a measurable effect on student outcomes in the three sections. As detailed previously, the course was taught in three different ways. One section was taught through traditional lecture format, one section was taught through a flipped style classroom, and one section was taught through a mixed version, which utilized flipped classroom-style videos as supplemental material but delivered course content primarily through lecture style. Data were compared in this initial paper by looking at the problem sets and quizzes to determine if certain types of instructional techniques were beneficial on these types of student deliverables.

For the problem sets, students in the mixed classroom had the highest average score, followed by the traditional classroom, with the flipped classroom having the lowest average scores. Apart from problem sets 6 and 12, the differences in average score of the problem sets were significant across all three classroom types ( $p < .05$ ). These initial results may indicate that the mixed delivery (traditional lecture supplemented by video lectures as a resource), was the most helpful delivery method to students as they completed their problem sets.

For the quizzes, the mixed classroom had the highest average scores on seven of the quizzes, flipped classroom had the highest average score on the three quizzes. The traditional classroom had the lowest average score on all but two of the quizzes. Interestingly, the flipped students outperformed the traditional students in the quizzes, but still did not achieve at levels as high as the students who received instruction through mixed methods. As suggested above, the results of the problem sets and the quizzes indicate that there is something unique about the mixed course structure that was not present in either the flipped section or the lecture delivery section, namely the combination of lecture and videos for reinforcement.

While previous research indicated that students often find video resources too long [31] or too boring [30], the lecture videos created for this study, which averaged 10 minutes and 45 seconds and used the lightboard technology, may have been beneficial to student learning. If the videos are beneficial, as the mixed section scores over the traditional section indicates, the flipped section should have found similar success. The fact that results were slightly lower in the flipped sections suggests that there may be a disconnect on how to best use the videos resources to more completely supplement the missing element of lecture. Students in the mixed model heard the content twice, once in lecture and again when they watched the videos, while students in the flipped model may have only listened to the video one time. The advantage of hearing content twice or of viewing the videos more recently (as a supplemental tool) may help to explain the improved outcomes of the mixed group over the flipped group, despite the use of the videos in both sections.

Finally, the third objective of the study was to review the available data through the context of the Technological Pedagogical Content Knowledge (TPACK) and Constructivist theoretical models. This was done with the goal of filling gaps in literature on this topic and providing greater continuity between research on flipped design in engineering to the broader theoretical models [4]. This research objective will be explored in greater detail as more results become available, but the initial findings support use of both the TPACK and Constructivist theoretical models in engineering classroom flipped course design.

The results of this study suggest that the initial implementation of the flipped classroom, while promising, may have been challenging for both students and faculty. The TPACK model, which outlines the necessary components of Technology Knowledge (TK), Content Knowledge (CK), and Pedagogical Knowledge (PK), supports the unavoidable struggles of the first semester of implementation and underscores the importance of considering multiple facets of student learning when designing and implementing flipped courses in engineering. The seemingly incongruous student data of fewer As but improved DEW rates in the flipped section, may suggest the beneficial components of the flipped dynamic are supported, but the initial implementation (and support for the highest levels of achievement) are difficult to realize in the first attempt.

Data from this study suggests that faculty may benefit from consideration of TPACK's Technology, Pedagogy, and Content contexts as they create and roll out their course to students. Pulling apart results from this study through the TPACK model shows that the technology components (TK) of video were helpful, but more consideration may need to be placed on the pedagogy (PK) component to determine what activities would best support student learning in the newly-freed class time. Content considerations (CK) including the high level of difficulty included in engineering content is also a factor and single-exposure videos that work in other flipped courses may not be sufficient to ensure comprehension for the challenging Statics material. By analyzing their course through this lens, faculty can evaluate multiple elements of a successful flipped course and can leverage this information to evaluate and revise the course for subsequent iterations.

The initial data from this study is less conclusive within the context of Constructivism, which focuses on the opportunity for students to construct their own learning through active learning instructional practices [9] and would suggest that the flipped section should therefore have the highest levels of student achievement. The findings that the mixed section outperformed the other sections is not in alignment with this framework. Future research with additional sections and greater understanding of what activities took place during classroom time once the lecture was removed from the flipped section would be beneficial in understanding why there was a moderate disconnect between the theoretical model and the observed results.

## **Conclusions**

Despite the limitations at this early stage, the preliminary data garnered from this study showed two key conclusions. First, the mixed course design had the greatest impact on student achievement as measured by grade distribution, DEW rates, and student performance on class

assignments, quizzes, and exams. Second, the flipped and mixed courses were associated with greater improvement for DEW rates, in comparison to the traditional lecture course. This data, in particular the improved DEW rates in the flipped section over the traditional section, is sufficient to warrant additional analysis and continued implementation of flipped methods. Supplementary findings will be reported at future ASEE conferences and through additional publications in hopes of providing greater insights into what flipped methods are most effective for improving student achievement, especially in large engineering courses.

As outlined previously, there remains limited quantitative statistical analysis of student outcomes and achievement in flipped engineering courses. As we continue to evaluate the impact of the varied instructional methods on student achievement, we anticipate that we will have a clearer picture of the role flipped design (and its components) have on student achievement. While we believe that this study and forthcoming data will provide greater insight, additional studies at other institutions would provide a more comprehensive understanding of the impact of flipping in mechanical and aerospace engineering disciplines on student outcomes. Future work could also include longitudinal data analysis to determine if students who participate in flipped sections of Statics courses fair better or worse than their peers in subsequent engineering classes. It would also be helpful for future studies to investigate which flipped classroom techniques are of the greatest benefit to mechanical engineering students, and if those findings support previously established educational models in other disciplines. Finally, future work should delve more deeply into student demographic data to determine if certain groups of students, specifically underrepresented populations in engineering, respond more or less favorably to the flipped classroom design.

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