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Flipped Classroom approach: Probability and Statistics Course for Engineers

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Abstract

We implemented a pilot of the "flipped classroom" in the introductory probability and statistics course for engineers during the Fall 2014 semester at our school of engineering. Three sections of the introductory probability and statistics course were taught. This is a required course for civil, electrical, mechanical and bio-engineering majors in our school. The flipped approach was implemented in two sections; the third section was taught traditionally and will serve as a comparison. The "flipped" or "inverted" classroom is an instructional technique in which lecture is removed from class time and replaced with more active instructional opportunities. Students practice their skills during class time and can receive individualized help from the instructor or TA as needed, versus passively taking notes while the instructor teaches the concepts. The flipped classroom approach shifts instruction from passive to more active and allows the instructor to include problem solving elements while still covering necessary material. It provides greater opportunities for integrating higher order cognitive skills in the classroom and better structures students' out-of-class time. In the literature, we found implementations of the flipped classroom in other undergraduate statistics classrooms, and these flipped classrooms were associated with significant improvements in both direct measures of student learning as well as measures of the classroom environment. Our class materials, including lecture notes, class activities, homework assignments and quizzes, were modified in order to implement the flipped classroom pilot during four weeks of the semester, or eight lecture periods. The remaining lectures were taught traditionally. As part of our program evaluation, the two flipped sections were observed for the degree of active learning, problem solving, and student engagement during class using a structured behavioral observation protocol known as the Teaching Dimensions Observation Protocol (TDOP). Several of the traditionally-taught class sessions were also observed for comparison, with positive results noted. Also, a comparison of students' conceptual and exam performance in the two flipped sections versus the "traditional" section enabled direct assessment of the benefits of the new approach, with significant differences not being detected. Further assessment of the flipped "pilot" classroom included student engagement, instructors' reflections, and two perception instruments measuring students' overall experience in the class.

1. Introduction and Literature Review

Numerous researchers demonstrate that faculty teaching methods can improve student learning, motivation and interest in engineering[1,2]. Unfortunately, the implementation of this research to practice is slow at many undergraduate institutions. The National Academy of Engineering[3], National Academy of Sciences[4] and National Science Board[5] emphasize the need to improve the quality of science, technology, engineering, and mathematics (STEM) education to better support students and prepare engineers to be competitive in a global work force[6]. Many researchers emphasize that teachers who aspire to achieve increased student learning should adopt active learning practices. When compared to students taught traditionally via lecture, students who are taught in the "active learning" environment tend to demonstrate higher academic achievement, better high-level reasoning and critical thinking skills, deeper understanding of learned material, greater motivation to learn and achieve, greater ability to view situations from others' perspectives, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem[21] .

The flipped classroom is an active learning pedagogical approach where the lecture and out-of-class elements are reversed. Short video lectures are viewed by students at their convenience before the class session at students' desired time and re-viewed if they did not grasp a concept. In-class time is devoted to active-learning with the instructor[7].

In the fall 2014 semester, we conducted a flipped classroom pilot with Introduction to Probability and Statistics (ENGR 20), which is a basic course in probability and statistics for engineers. Topics covered include: data analysis, probability, random variables, discrete and continuous probability distributions, sampling, estimation and hypothesis testing, analysis of variance, and introduction to linear regression analysis. Based on our previous research we were concerned that students left the course with less understanding of difficult concepts than desired. We believe that the flipped course model will help address this problem by allowing class time to be used to focus on more difficult concepts while using available technology.

Implementing a flipped-classroom approach in an introductory statistics course for engineers is beneficial for numerous reasons – it allows for interactive problem-solving activities, more challenging homework problems, better interaction between the students and the instructor and additional time to reinforce the concepts not grasped when viewing the lectures. Students are required to complete quizzes after viewing the lectures, which ensure that the students are prepared for class. These quizzes also reveal areas of confusion to the instructor. The class time can then begin with a review of concepts that students are struggling with, and the instructor has the option to challenge the students, stimulate their thinking, and make sure that the misunderstandings and/or misconnections are corrected.

In a review of the literature, we found other statistics courses that have been flipped. In an undergraduate introductory statistics course required for social science majors covering both descriptive and inferential statistics, there were significant improvements in course exam scores ($p<0.05$; $d=0.51$) when comparing flipped instruction to traditional instruction[10]. In addition, in a standardized statistics test given by the psychology department at this school at the end of each semester, students enrolled in flipped sections of the introductory statistics course scored significantly higher than students enrolled in the pre-flipped sections ($p=0.03$; $d=0.57$). Although there were improvements in the evaluations of the course and instructor with the flipped style of learning, the instructor still noted some resistance by students. Some students were unhappy with the lack of a traditional lecture and the increased expectations for initial learning outside-of-class[10]. Likewise, in an undergraduate statistics course taken by psychology majors, students in the flipped sections scored significantly higher than students in the traditional sections on an end-of-semester content knowledge assessment ($p=0.04$)[11].

In another introductory statistics course taken by a diverse group of business, education, and arts and sciences students, the classroom learning environment was compared in flipped and traditional sections of the course using a variant of the College and University Classroom Environment Inventory (CUCEI). Students in the flipped sections reported experiencing significantly more innovation and cooperation in the classroom compared to students in the traditional sections[12]. We also administered the CUCEI as part of our assessment in this course.

Based on the instructor's prior collaborative research related to the implementation of Model-Eliciting Activities (i.e., authentic, client-based open-ended problems) in the probability and statistics course for engineers, she felt that this active learning method of instruction would be very beneficial and highly applicable in this course. This was based on the prior impact on conceptual learning, performance analysis (i.e., concept inventories implemented at the beginning and end of the semester), and results obtained from teaching evaluations, particularly ABET-outcomes related questions. [20].

2. Methods

Three sections of ENGR 20 were taught in the Fall of 2014 at our school of engineering. Each section was taught by a different instructor with varying levels of teaching experience. The flipped classroom "pilot" was implemented in two sections, and the third (comparison) section was taught in a traditional manner with weekly homework assignments and weekly quizzes assigned during the recitation sessions. The flipped "pilot" was implemented during four weeks of classes covering material from four chapters. The remaining lectures were taught in a traditional manner. All sections consisted of different engineering majors (i.e., civil, chemical, computer, electrical, industrial, etc.) and had enrollments of 79 and 75 in the flipped sections and 79 in the comparison section and most students take this course during their sophomore year.

During the summer of 2014, prior to the fall implementation, the instructor recorded the set of pilot video lectures in small modules for the course. This videotaping of lectures was supported by the school's IT staff using the Camtasia software. The instructor modified lecture notes, designed in-class active learning exercises allowing for some lecture time to review the concepts that were not grasped by students, and developed more challenging homework assignments to be started in the classroom. Students were required to watch recorded lectures and complete a short post-lecture quiz to ensure preparation for class.

The instructor recorded material from four chapters that was divided among approximately 15 modules having an average length of 10 minutes. Example module titles included the following: Discrete Probability Distribution, Discrete Cumulative Distribution, Continuous Probability Distribution, Continuous Cumulative Distribution, Joint Probability Distributions, Marginal Distributions, etc.

The flip of this course was part of a larger school-wide initiative with the flipped classroom. The school-wide initiative also included the formation of a learning community in the spring 2013 by the school's Engineering Education Research Center (EERC). In addition to the instructor, other engineering instructors who were flipping courses within the school participated in the meetings. The assessment analyst and the IT staff doing the video creation and editing were also part of the group. During the meetings, various topics were discussed including challenges regarding students and video development, assessment plans, classroom logistics, active learning techniques, and the overall goals.

To directly assess learning, students completed pre and post concept inventories (CI) in order to measure conceptual gains attained during the semester and determine if there were any differences between the traditional and two “flipped” sections. The concept inventory was administered at the beginning and end of the term in all three sections. The concept inventory was a selected subset of 20 multiple choice questions from two different pre-established Statistics Concept Inventories[8,9]. The pre and post CI tests were exactly the same. The CI that we used is a multiple choice assessment tool designed for introductory probability and statistics courses, and it consists of the following four categories: Descriptive, Probability, Inferential, and Graphical. Both the questions and the response choices were the subject of well-designed research, and each question included one correct answer and several distractors based on students’ customary or common sense ideas (i.e., commonly held misconceptions)[8,9]. The same content was covered in all three sections. In addition, there were three exams during the semester, with each instructor creating his/her own exam. Two exam questions that were identical across the flipped versus non-flipped sections were statistically compared for differences in student performance. The assessment analyst for the project conducted a semi-structured interview with the instructors after the course to discuss learning gains and student preferences with the flipped classroom.

To further assess our flipped classroom pilot, we distributed the College and University Classroom Environment Inventory (CUCEI) to the students in the flipped sections near the end of semester[17]. Given the lack of pre-flip classroom environment data for this course, we compared the results to those of other flipped classrooms in our school of engineering. We also administered a flipped classroom evaluation survey near the end of the term to obtain students’ perceptions and behaviors relative to our flipped pilot. To evaluate student engagement and activity, two flipped class sessions (in each section) were observed using the Teaching Dimensions Observation Protocol (TDOP) to determine the level of instructor-supported active learning[19]. This protocol entails a series of small observation windows and codes for recording teaching and learning behaviors. Classroom observation was done using either one or two trained observers with established inter-rater reliability. One observer was the assessment analyst for the school of engineering, and the other was a university-level teaching and learning consultant. These observers were able to achieve an inter-rater reliability score of Cohen’s κ=0.86 for the protocol as a whole. This value of kappa was based on observation of multiple flipped courses in the school. Values of Cohen’s kappa above 0.75 suggest strong agreement beyond chance[15].

3. Results

3.1 Student Evaluation of Flipped Classroom Survey

Near the end of the semester, the students in the flipped sections were asked to evaluate the classroom sessions that were inverted via a survey that provided both formative and summative feedback. Approximately 78% of the students responded. Our survey was modeled upon the surveys of Leicht et al. and Zappe et al., who used perception surveys in a flipped undergraduate architectural engineering course at Penn State[7,13].

On our evaluation survey, one of the questions we asked was the following: “Did you prefer the class sessions that were ‘flipped’ in this course versus the sessions that have been taught in the traditional method?” The distribution of the responses was as follows: Yes (27%), No (54%), and Unsure (19%). In the fully-flipped courses in our school between fall of 2013 and fall of 2014, the percent that responded “No” was just 36%. Based on a z-test, these two percentages of a “No” response were significantly different ($p<0.0005$). Similarly, when asked to compare the use of class time for problem solving or active learning with the instructor present versus listening to a lecture, 39% preferred the former, as shown in Figure 1. For all fully-flipped courses in our school, this percentage was 57%. A test of proportions showed these percentages to be significantly different also ($p<0.0005$). In comparison, Zappe et al. found a value in between these percentages, with 48% agreeing or strongly agreeing that they preferred problem solving versus lecture during class[7]. In a post-course semi-structured interview, the instructors indicated that one of the disadvantages for the students in the partially-flipped course was the transition during the semester from traditional to flipped and then back to traditional instruction. It’s possible that if the students had been exposed to more flipped instruction with fewer adjustments during the term, more students would have preferred the flipped method along with its associated active learning.

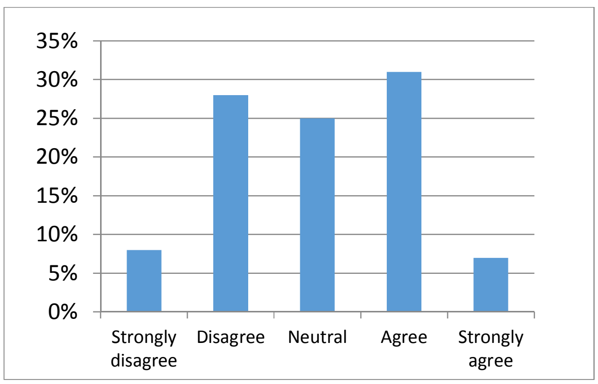

Figure 1: Prefer Using Class Time for Problem Solving? (flipped sections)

In the evaluation survey, we asked the respondents to report the percentage of videos they watched. In our partially-flipped ENGR 20 course, the respondents indicated having watched 87% of the available videos, with 89% of the respondents having watched them before (versus after) the class session for which they were assigned. This indicates a high level of responsibility for the self-directed portion of the flipped classroom. In comparison, across our fully-flipped sophomore through senior courses in the school, respondents reported having watched 77% of the available videos, as shown in Table 1. Unfortunately, our freshmen watched a much lower percentage of videos compared to the sophomores through seniors ($p<0.0005$)[14]. Based on these various findings, we believe that the students in the flipped sections were motivated to take responsibility for the independent learning aspect of the flipped classroom. The percentage reported by Penn State upper-level engineering students provides a second point of comparison in Table 1.

Table 1: Self-Reported Percentage of Videos Watched

	Average %	n (students)
ENGR-0020	87%	121
All Flipped Courses (Sophomore through Senior)	77%	321
Zappe et al. (Penn State)	92%	77

3.1.1 Content Analysis of Benefits and Drawbacks

In an open ended question in the evaluation survey, we asked the students what they liked about the flipped class sessions and the benefits they perceived. The frequencies associated with the categories in our coding framework are shown in Table 2. The most frequently mentioned benefit was noted by 61% of respondents and related to the conveniences associated with video or online learning, including the ability to re-watch videos, self-pacing, flexibility, and accommodation of one's preferences. This was followed by enhanced or deeper learning, as mentioned by 20% of respondents. This category included better understanding and learning, enhanced effectiveness or depth, multiple resources for understanding material, and reinforcement and review. Unfortunately, there were only 7% who identified higher engagement, better class preparation, and the promotion of professional behaviors.

These results were based on a content analysis of 114 student responses by a single coder, a junior engineering student. A second coder, the assessment analyst for the project, coded 31% of the responses, corresponding to 35 responses, to provide a measure of inter-rater reliability. The inter-rater reliability based on Cohen's Kappa was $\kappa = 0.72$, which suggests good agreement beyond chance[15]. In previous work involving the fully-flipped courses in the school, these two raters achieved $\kappa = 0.75$, which was based on a 30% sampling of 389 students responses for inter-rater reliability[14]. The categories in Table 2 were established prior to the coding based on a grounded, emergent qualitative analysis performed by the assessment analyst using all student responses in the fully-flipped courses[16].

Table 2: Summary of Open Ended Responses to Benefits

Frequency	% of Respondents	Category	Description
69	61%	Video/Online Learning	Re-watch videos Work at one's own pace; pause video Flexibility, convenience, own preferences Modularization of topics
23	20%	Enhanced or Deeper Learning	Better understanding; less confusion Enhanced learning/effectiveness/depth/ability Subject matter retention Multiple sources/resources for understanding Reinforcement and review Multiple attempts
22	19%	Alternative Use of Class Time	In-class active learning, problem solving, clickers In-class support and questions In-class group time for projects Student interactivity and peer support

Frequency	% of Respondents	Category	Description
14	12%	Specific to Course or Course's Videos	Videos concise or had a good pace Overall work time less Videos had relevant content (e.g., demo or examples) or were of high quality
11	10%	No Benefit or Neutral Result	No benefits perceived Did not like flipped instruction Videos not used Instructional differences not noticed
8	7%	Preparation, Engagement & Professional Behaviors	Engaged during class; paid attention; not bored Enjoyed class Arrived to class prepared Ability to learn on one's own; independence Drove motivation and accountability

In another open-ended question, we asked the students what drawbacks they perceived with the flipped classroom and their suggestions for improvement. The frequencies are shown in Table 3. The most frequently mentioned drawback or suggestion, which was mentioned by 38% of respondents, related to how time was used in the classroom. This included suggestions to devote more time to solving problems, including those assigned as "homework," to provide more appropriate amounts of content review or lecture, and to provide more "instructor types" so that individual-level questions could be addressed quickly. Over one-third of respondents (36%) noted increased load, burden, or stressors with this flipped classroom, such as increased amounts of time or work required as well as the post-video accountability quizzes, which caused concerns over their grades. In a closed-ended question on the survey, 60% of respondents said that the overall time required with the flipped class sessions was more than with the traditional sessions. Twenty-seven percent (27%) of the respondents provided feedback specific to the particular instructor, videos, or online quizzes, such as "include more examples in the video" or "videos have low visual quality." This was followed by issues inherent to online or video learning (15%), such as an inability to ask questions during a video or distractors when watching a video in a non-classroom setting. Only 10% wanted or recommended a different teaching and learning approach than they had been exposed to in the course. We were happy to learn that only a small number of respondents (9%) perceived decreased learning with flipped instruction, including difficulties learning from a video. In a closed-ended question on the survey, only 12% indicated an inability to learn from a video.

These results were based on a content analysis of 113 student responses by the assessment analyst for the project. A second coder, the junior engineering student previously mentioned, coded 30% of the responses, corresponding to 34, to provide a measure of inter-rater reliability. The inter-rater reliability based on Cohen's Kappa was $\kappa = 0.77$, which suggests strong agreement beyond chance[15]. In previous work involving the fully-flipped courses in the school, these two coders achieved an inter-rater reliability of $\kappa = 0.83$ for this question, which was based on a 32% sampling of 356 students responses[14]. The categories in Table 3 were established prior to the coding based on a grounded, emergent qualitative analysis by the assessment analyst using all student responses across our various flipped courses in the school[16].

Table 3: Summary of Open Ended Responses to Suggestions/Drawbacks

Frequency	% of Respondents	Category	Description
43	38%	In-Class Time	Increase time for active learning or problem solving Increase effectiveness or relevancy of problems; grade them Provide appropriate amount of lecture or content review Have more instructor-types during class to assist Synchronize class activity and video content
41	36%	Load, Burden, Stressors	Insufficient time to complete out-of-class activities Increased work load Increased time burden Concerns over grades or impacts to the grade Accountability quizzes (including surprise)
30	27%	Specific to Course or Course's Videos	Include more examples or problems in the videos Videos needed editing or bug/technical fixes Videos were too long Videos were not sufficiently described Videos were dry or boring Videos did not have an appropriate pace Videos repeated information Video material was too complex
17	15%	Video/ Online Learning	Students unable to ask questions during a video Instructor unable to sense student understanding in a video Distractors to viewing videos in a non-classroom setting Less motivation to attend class
17	15%	Prepare, Equip & Incentivize Students to Flip	Prepare students for the flipped learning style Incentivize students, including video quizzes Clarify/emphasize expectations, including video watching Provide video "lecture" notes Ensure videos available in advance for students
11	10%	Approach Differently	Do not flip courses in general; use traditional teaching Do not flip this course in particular Provide students with a choice on flipping Flip only a portion of the class periods
10	9%	Student Learning	Lesser understanding or learning Difficulty learning from a video
8	7%	No Drawbacks or Neutral Result	No drawbacks or suggestions

3.2 Classroom Environment Survey

We assessed the psychosocial dimensions of our partially-flipped classroom, as shown in Table 4, using Fraser's College and University Classroom Environment Inventory (CUCEI) [17]. There are seven questions associated with each of the seven dimensions, and each question has a scale of 1 to 5, with 5 being most desirable. We received a total of 120 responses, representing a 77% response rate. The task orientation dimension scored the highest of the seven dimensions, with a dimension mean of 4.06 on the five-point scale. This dimension assesses the clarity and organization of class activities.

We compared the classroom environment responses in our partially-flipped ENGR 20 course to the responses in our fully-flipped courses throughout the school, which were collected between fall of 2013 and fall of 2014. Given some resistance to the flipped method of instruction by our freshmen and seniors, we considered two comparisons – 1) ENGR 20 versus all fully-flipped courses in the school (n=793), and 2) ENGR 20 versus sophomore and junior flipped courses only (n=469).

In comparing the responses in the fully-flipped sophomore and junior courses to the responses in our partially-flipped course, there were six classroom environment dimensions that were rated higher by students in the fully-flipped courses. In addition, four of the six were rated as very significantly higher (p<0.0005) – student cohesiveness, innovation, involvement, and satisfaction. Two dimensions were not significantly higher – individualization (p=0.20) and personalization (p=0.57). Student cohesiveness had a large effect size (d=0.91), and the other three significantly-higher dimensions were associated with medium effect sizes. The Cohen's d effect size represents the extent of the difference between two groups. Cohen defined effects as small (d=0.20), medium (d=0.50), or large (d=0.80)[18].

When considering all fully-flipped courses (including freshmen and senior offerings), five of the seven dimensions were still rated higher by the students in the fully-flipped courses. Three dimensions were very significantly higher (p<0.0005) – student cohesiveness, involvement, and satisfaction. Student cohesiveness had a large effect size (d=0.89), and involvement and satisfaction had small effect sizes. Innovation was significantly higher (p=0.04) with a small effect size but would not be considered significantly higher if corrected for multiple comparisons using Bonferroni's adjustment. Individualization was not significantly higher (p=0.85). These results suggest that the flipped method of instruction may lead to enhanced classroom environments across several classroom dimensions. In an end-of-course semi-structured interview, the instructors indicated that they got to know the students and their level of understanding better as a result of the flipped classes, particularly those students who asked for one-on-one assistance with the homework problems. Interestingly, the personalization dimension, which relates to instructor interaction with the students, was rated higher by students in our partially-flipped ENGR 20 course than by students in all of our fully-flipped courses in the school, although not significantly so (p=0.15). One of the main objectives in flipping this statistics course was to increase interaction with students, as it's a course packed with conceptual information with little time for problem solving and interaction.

Interestingly, student cohesiveness scored lowest and below the average value of 3.0, with a dimension mean of 2.34. Thus, our respondents in the partially-flipped course did *not* indicate notable interaction with their peers. This is a key goal of our flipped classrooms throughout the school and may increase as this course becomes more fully flipped.

Table 4: CUCEI Comparisons

Dimension	Definition	ENGR-0020 (partially flipped)	Pitt Flipped (sophomore & junior)	Pitt Flipped (all courses)
		M	***M***	***M***
Student Cohesiveness	Students know & help one another	2.34	3.07	3.04
Individualization	Students can make decisions; treated individually or differentially	2.64	2.69	2.64
Innovation	New or unusual class activities or techniques	2.88	3.19	2.99
Involvement	Students participate actively in class	3.03	3.46	3.29
Personalization	Student interaction w/ instructor	3.96	4.00	3.88
Satisfaction	Enjoyment of classes	3.05	3.49	3.39
Task Orientation	Organization of class activities	4.06	3.89	3.74
	n	**120**	**469**	**793**

ENGR-0020 *SD* values: Cohesiveness 0.735; Individualization 0.457; Innovation 0.547; Involvement 0.547; Personalization 0.566; Satisfaction 0.816;Task Orientation 0.455

3.3 Classroom Observation

Classroom observation was conducted in both the flipped and non-flipped sessions in the two “flipped” sections. Two flipped and two non-flipped sessions were observed for each instructor using the TDOP, for a total of eight observation periods. Both types of sessions were observed to illuminate the differences in instructor and student practices and behaviors with the different instructional approaches. This served as a means of formative feedback as well as program evaluation for our flipped classroom initiative within the school. The class period was observed in five-minute segments. In each segment, the occurrence of various activities and practices within our protocol were recorded as observed.

As shown in Table 5, the students asked questions (SCQ) in a greater number of observation segments during the flipped sessions, suggesting the possibility of greater engagement and inquiry during these sessions. As anticipated, problem solving (PS), student discussion (ART), and active student work (DW) were higher during the flipped sessions. Many student questions were asked during the problem solving exercises as the instructors circulated among the students (MOV) to monitor progress and address questions. Instructor circulation (MOV) among the students was higher in the flipped sessions, pointing to greater interactivity between the instructor and students during class. As anticipated, the number of segments in which lecturing of any type occurred was higher during the non-flipped sessions.

We compared the occurrences of each classroom element (non-flip vs. flip) using Fisher’s Exact test, which can be used in lieu of a *z*-test of proportions when the numerators are small. Each element had a significantly different number of occurrences in the flipped versus the non-flipped sessions, although to different degrees of significance, as indicated in Table 5. The symbols used to denote the levels of significant differences are defined at the bottom of the table.

Table 5: TDOP Elements of Interest: Non-Flip vs. Flip

		% of Observation Segments	
Classroom Element	**Description**	**Non-Flip**	**Flip**
SCQ	Student comprehension question	29%	58% ∞
PS	Problem solving	24%	53% ∞
ART	Student articulation/discussion	20%	53% §
DW	Students actively work at desk/PC	19%	47% ∞
MOV	Instructor circulates in classroom	10%	44% *
LEC	Lecture (of any variety)	95%	64% *

*$p < 0.0001$
§ $p <= 0.001$
∞ $p <= 0.01$
£ $p <= 0.05$

3.4 Direct Assessment of Student Learning

We compared students' performance on the concept inventory (CI) in both flipped and traditional sections. Based on a paired t-test, there was a clear statistical difference ($p < 0.0001$) between the start and end of term mean concept inventory scores for all sections. This is not an unexpected result. We also compared pre and post CI scores between the two flipped and the traditional section and did not find any differences in the pre or post scores ($p > 0.232$ for all comparisons). This suggests that the flipped versus non-flipped student groups both began and ended the course similarly in terms of statistical concept knowledge. We also asked two questions on the second midterm related to the topics that were "flipped". Again, we did not see any differences in the mean scores between sections, and the questions were identical across the sections. In a similar manner, accounts of exam, homework, and grade performance in flipped vs. non-flipped STEM courses at other universities have shown mixed results, as we also found with our school-wide initiative[14]. Thus, our direct assessments with other engineering courses in our school have shown both statistically improved as well as statistically equivalent results between the pre-flipped and flipped versions of the course[14].

The same homework assignments were assigned throughout the semester in all three sections. Although we have not compared student performance at this time, we believe that this comparison could also be a valuable indicator of any possible differences in students' performance.

4. Conclusions

The Swanson School of Engineering at the University of Pittsburgh officially began promoting the flipped classroom in the fall of 2013 across its multiple programs. Flipped instruction allows an instructor to implement more active learning in the classroom while still teaching required course content. Our school-wide initiative with the flipped classroom has highlighted the advantage to introducing this method of instruction early in the undergraduate career. Although our freshmen did not engage with the pre-class videos as intended, introducing this instructional method nonetheless better prepared them to engage with the flipped classroom in their sophomore years and beyond. One of the goals in flipping our freshmen computing course was also to provide multiple resources to the students (i.e., videos, textbook, live demonstrations) so as to accommodate different learning styles.

Although our preliminary results did not show a statistical difference in the CI scores or the exam questions of the "pilot" flip vs. traditional, the overall outcomes in this "pilot" course were positive and encouraging. Class time during the "flip" portion was dedicated to problem solving and active learning exercises. The instructors noticed greater engagement of students during the flipped portion of the course as well as increased opportunity to communicate with students individually. This enabled instructors to address students' misunderstandings earlier when compared with the traditional instruction.

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