ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

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Paper ID #16413

Comparison of a Partially Flipped vs. Fully-Flipped Introductory Probability and Statistics Course for Engineers: Lessons Learned

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Abstract

We implemented a fully-flipped classroom approach in the introductory probability and statistics course for engineers during the Fall 2015 semester in our school of engineering. In the Fall 2014, we implemented a partially-flipped "pilot" flipped classroom approach when we inverted one third of the course material. Based on our "pilot" results in terms of both direct measures of student learning as well as measures of the classroom environment, we were highly encouraged and motivated to implement the fully-flipped classroom approach. In our flipped classroom, students watched recorded lectures prior to the class time, and time in the classroom was replaced with more active instructional activities. This approach allowed the instructor to include problem solving elements and focus on difficult concepts, encouraged questions and more interactions, and exposed students to more realistic scenarios, while still covering required material. This course is a required course for civil, computer, chemical, electrical, mechanical, material science and bio-engineering majors in our school. Each semester we teach two or three sections of this course. Our class materials, including lecture notes, class activities, homework assignments and quizzes, were revised in order to implement the flipped classroom approach. As part of our program evaluation, the flipped and partially-flipped classrooms 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). We compared students' performance in the fully-flipped vs. partially-flipped classrooms; this allowed for direct assessment and comparison of a partially-flipped vs. fully-flipped approach for probability and statistics. The overall assessment compares the two approaches based on the conceptual knowledge gains on the Statistics Concept Inventory by Allen et al., targeted ABET outcomes, student engagement, instructor interviews, and two perception instruments measuring students' overall experiences in the class. These two instruments consist of Fraser's College and University Classroom Environment Inventory (CUCEI) and a flipped-classroom evaluation survey, which we distributed to the students near the end of the semester. We also compared the results to those of other flipped classrooms in our school of engineering, which have been implemented as part of our school-wide initiative to flip engineering courses.

1. Introduction and Literature Review

Ongoing research in engineering education suggests that teachers who aim to achieve increased student learning should adopt active learning approaches. Students who are taught in the "active learning" environment are likely to demonstrate higher academic achievement, better high-level reasoning and critical thinking skills, deeper understanding of learned material, greater motivation to learn and achieve, more positive and supportive relationships with peers, more positive attitudes toward subject areas, and higher self-esteem, when compared to students who are taught in traditional settings.[1]

The flipped classroom is an active learning pedagogical approach where students watch video lectures prior to class and focus on problem-solving and implementation in the classroom with the help of the Instructor.[2,3] The American Statistical Association previously developed Guidelines for Assessment and Instruction in Statistics Education (GAISE) for undergraduates, and one of the recommendations was to "Foster active learning in the classroom." [4]

We conducted a flipped classroom "pilot" in Introduction to Probability and Statistics (ENGR 20), during the Fall 2014 semester. ENGR 20 is an introductory course in probability and statistics for engineers. Based on our previous research we were concerned that students left the course with less understanding of difficult concepts than desired[2]. We believed that the flipped course model would help address this problem by allowing class time to be used to focus on more difficult concepts. Although our results did not show a statistical difference on the Statistics Concept Inventory at the end of the term between the "pilot" flip vs. traditional sections, the overall outcomes of the "pilot" course were positive and encouraging[2]. The instructors perceived 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[2]. Our analysis, methods and results from fall of 2014 are summarized in Vidic, Clark and Claypool.[2]

We found other statistics courses that have been flipped. In an undergraduate introductory statistics course for social science majors covering descriptive and inferential methods, there were significant improvements in exam scores ($p<0.05$; $d=0.51$) when comparing flipped instruction to traditional instruction[5]. In addition, in a standardized statistics test given at this school each semester, students enrolled in flipped sections of the introductory statistics course scored significantly higher than students enrolled in the non-flipped sections ($p=0.03$; $d=0.57$). 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 a content knowledge assessment ($p=0.04$)[6].

Although there were improvements in the evaluations of the introductory statistics course for social science majors with flipped learning, the instructor nonetheless noted some resistance by students, including dissatisfaction with the lack of traditional lecture and the increased expectations for independent learning[5]. In another introductory statistics course taken by a diverse group of 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[7]. In a flipped statistics course for PhD nursing students, survey respondents agreed that the flipped format helped to increase understanding of concepts, rating this at a 4.3 on a five-point scale, with 4 corresponding to agreement and 5 corresponding to strong agreement[8].

Partially-flipped STEM courses, in which a single or several instructional units are flipped, are also discussed in the literature, including for statistics education[9]. In fact, some have recommended a partially-flipped approach, versus a global change or overhaul in the course, to evaluate the effectiveness of the approach[10]. STEM courses in which a partially-flipped approach has been taken include linear algebra and calculus [11,12], biology[10], and physics/electricity[13]. In the linear algebra and calculus courses, the results were promising. For example, students in the calculus course who received flipped instruction on certain topics, versus those who received traditional instruction, scored four to five points higher on the topics, as assessed through exams and assignments[12]. In the biology course, the partial flip was also successful and even advocated in lieu of a full-flip. In this course, the percentage of students who correctly answered exam questions for each of the five topics that were compared was significantly higher for the flipped versus the traditional cohort. The authors concluded that a flipped strategy can be implemented incrementally and still result in significant improvements. In the physics/electricity course, the partially-flipped format was implemented by reducing the amount of lecture time for each class session throughout the semester, using web-based lectures. During the total evaluation period, there were modest, but statistically-significant improvements on three of four midterms and two of the four final exams, when comparing the partially-flipped to the full-lecture classroom. Of greater interest to the authors was the dramatic change in students' attitudes about the course, including a perceived decrease in course difficulty and more positive attitudes towards physics[13].

Our study is distinctive in that all of the above mentioned statistics courses were for non-engineering students. This is the first reported analysis for an engineering statistics course.

2. Methods

In the Fall of 2015 we implemented "flipped" approach in two sections of ENGR 20. The course was partially flipped in the Fall of 2014 by the same instructor. In the flipped class environment, students were assigned to watch video lectures prior to class and complete post-lecture online quizzes to ensure preparation. The duration of each video lecture was between five and ten minutes. Each video segment covered one or more concepts followed by one or two solved examples. Several segments were assigned prior to each scheduled class time.

Quizzes contained several conceptual questions plus the question related to "confusing" topics. In-class time was devoted to active-learning with the instructor. At the beginning of each lecture, the instructor would review students' comments related to the "confusing" topics, as defined by students after watching the lectures. The rest of the class time was devoted to solving in class problems, more complex than examples presented in video lectures. Students worked in groups with the help of the instructor.

In the traditional setting, students are required to attend recitation (once a week for ninety minutes); once the "flipped" approach was implemented, we advised students that recitation was optional and would be treated as the teaching assistant's (TA) office hours. The TA was instructed to prepare examples related to the material covered and answer questions related to homework.

For the flipped material, the instructor recorded the video lectures in small modules for the course[2], adapted lecture notes and created in-class exercises, allowing for some lecture time to review the concepts that were not grasped by students. In addition, more challenging homework assignments were selected and students were encouraged to start working on the homework assignments during the class time. For additional discussion related to methods please refer to Vidic, Clark and Claypool.[2] The flip of this course was part of a larger school-wide initiative with the flipped classroom[2].

To indirectly assess our flipped classroom implementation, we distributed the College and University Classroom Environment Inventory (CUCEI) and a flipped-classroom evaluation survey to the students near the end of the semester .[14] There are seven questions associated with each of the seven psychosocial dimensions of the CUCEI, and each question has a scale of 1 to 5, with 5 being most desirable. Our flipped-classroom evaluation survey was modeled upon the surveys of Leicht et al. and Zappe et al., who used perception surveys in a flipped undergraduate engineering course.[15] We administered these anonymous surveys in both the partially and fully-flipped classrooms, allowing for comparisons between the two. In the partially-flipped classroom, the students were asked to evaluate the portion of the course that had been flipped.

Our flipped-classroom evaluation survey contained a mixture of closed and open-ended questions. One of the open-ended questions asked the students to discuss the perceived benefits of the flipped approach. A content analysis of the responses was done using the coding scheme shown in Table 1. This coding scheme had been developed using a grounded, emergent qualitative analysis done as part of previous flipped classroom research by the assessment analyst.[16,17] For both the partially and fully-flipped sections, a total of 220 student responses to the benefits question were content-analyzed by a single coder. A second analyst coded 31% of the responses to provide a measure of inter-rater reliability. These coders consisted of the assessment analyst and an upper-level undergraduate engineering student. Their inter-rater reliability based on Cohen's Kappa was $\kappa = 0.76$, suggesting strong agreement beyond chance.[18]

Table 1: Coding Scheme for Content Analysis of Benefits to Flipped Instruction

Category	Description
Video/Online Learning	Re-watch videos Work at one's own pace; pause video Flexibility, convenience, own preferences Modularization of topics
Enhanced Learning or Learning Process	Better understanding; less confusion Enhanced learning/effectiveness/depth/ability Subject matter retention Multiple sources/resources for understanding Reinforcement and review Multiple attempts
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

Category	Description
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
No Benefit or Neutral Result	No benefits perceived Did not like flipped instruction Videos not used Instructional differences not noticed
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

Conversely, a second open-ended question prompted the students for the perceived drawbacks of the flipped approach and suggestions for improvement. A content analysis of the responses was done using the coding scheme shown in Table 2, which had also been developed using a grounded, emergent analysis as part of previous flipped classroom research. For both the partially and fully-flipped sections, a total of 216 student responses to the drawbacks question were analyzed by a single coder. A second coder coded 31% of the responses to provide a measure of inter-rater reliability. These coders were the same as for the benefits question. Their inter-rater reliability for the drawbacks question based on Cohen's Kappa was $\kappa = 0.74$, suggesting good agreement beyond chance, just below the "strong" threshold of 0.75.

Table 2: Coding Scheme for Content Analysis of Drawbacks/Suggestions related to Flipped Instruction

Category	Description
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
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) Feelings of having to "teach" oneself
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

Category	Description
	Videos did not have an appropriate pace Videos repeated information Video material was too complex
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
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
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
Student Learning	Lesser understanding or learning Difficulty learning from a video
No Drawbacks or Neutral Result	No drawbacks or suggestions

3. Results

3.1 Flipped Classroom Evaluation Survey

With our flipped-classroom evaluation survey intended to provide both formative and summative feedback, approximately 77% of the students from the partially and fully-flipped cohorts responded. One of the questions posed to the partially-flipped cohort 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?" Similarly, for the fully-flipped course, we asked, "Do you prefer a flipped classroom over a traditional lecture class?" As shown in Table 3, the distribution of responses was similar for the two versions of the course – partially versus fully flipped. In both cases, the percentage of respondents who did *not* prefer flipped instruction was above 50%. A z-test of proportions showed these two percentages (54% vs. 57%) to be statistically similar (p=0.65). However, in other fully-flipped courses in our school between fall of 2013 and fall of 2014, the percentage who responded "no" regarding their preference for flipped instruction was just 36%. Based on a z-test, this percentage was significantly lower than the percentage who responded "no" in either our fully or partially-flipped ENGR 20 course (p<0.0005). Thus, students in ENGR 20, regardless of the amount of class flipping, did *not* prefer this method of instruction compared to students in other flipped courses in our school. Since we administered our surveys anonymously to maximize students' openness, we could not associate their flipped-classroom preferences and perceptions with their actual achievement.

Table 3: Prefer Flipped to Traditional Instruction?

Preference for flip?	ENGR 20 Partially Flipped (n=123)	ENGR 20 Fully Flipped (n=115)	Other Fully Flipped Courses in School (n=562)
Yes	27%	22%	27%
No	54%	57%	36%
Unsure	19%	21%	37%

When asked to compare the use of class time for problem solving or active learning versus listening to a lecture, 39% in the partially-flipped and 41% in the fully-flipped course preferred active learning. However, for all fully-flipped courses in our school, this percentage was 57%. A *z*-test of proportions showed this percentage to be significantly higher than for fully-flipped (p=0.003) as well as partially-flipped (p<0.0005) ENGR 20. 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.[15] Thus, students in ENGR 20, regardless of the amount of class flipping, did *not* prefer problem solving versus lecture during class compared to students in other flipped courses in our school.

In the evaluation survey, we also asked the respondents to report the percentage of videos they watched. In our partially and fully-flipped ENGR 20 course, the respondents indicated having watched approximately 87% of the available videos, with 86% having watched them before (versus after) the class session for which they were assigned. This indicated a high level of responsibility for the self-directed aspect of the flipped classroom. In comparison, across our fully-flipped sophomore through senior courses in the school, respondents on average reported having watched 77% of the available videos, as shown in Table 4. Unfortunately, our freshmen watched a much lower percentage of videos compared to the sophomores through seniors (p<0.0005).[16] Based on this data, the students in ENGR 20 (both versions) appeared to take responsibility for reviewing the video materials before class. The percentage reported by Penn State engineering students provides a second point of reference in Table 4. In addition, seventy-five percent (75%) of respondents agreed or strongly agreed that they understood the rationale or reasons for flipped instruction in ENGR 20 (either partially or fully flipped instruction).

Table 4: Self-Reported Percentage of Videos Watched

	Average %	n (students)
ENGR-0020	87%	234
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 on the flipped-classroom evaluation survey, we asked students the perceived benefits or what they liked about the flipped approach. In comparing the partially versus fully-flipped classrooms, three categories from the coding scheme in Table 1 occurred most frequently for both classroom types, although at different percentages, as shown in Table 5.

Table 5: Top Perceived Benefits

Perceived Benefit (% of Respondents)	**ENGR 20 Partially Flipped (n=114)**	**ENGR 20 Fully Flipped (n=106)**
Video/Online Learning	61%	49%
Enhanced Learning or Learning Process	20%	34%
Alternative Use of Class Time	19%	32%

The most frequently mentioned benefit in both the partially and fully-flipped classrooms was the conveniences afforded by 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 learning or learning processes. Interestingly, this category was mentioned by 34% of respondents in the fully-flipped course, versus 20% in the partially-flipped version. This category included better understanding or learning, enhanced effectiveness or depth, multiple resources for learning, and reinforcement and review. Based on a z-test of proportions, these percentages were significantly different (p=0.02), suggesting a more frequent perception of enhanced learning or learning processes in the fully-flipped classroom. A similar conclusion can be drawn about the alternative use of class time in a flipped classroom, which includes activities such as active learning, instructor support, and peer assistance. More students tended to perceive this as a benefit in the fully versus partially-flipped classroom based on a test of proportions (p=0.03). We had hoped that a higher proportion of students would note preparation, engagement, and professional behaviors as benefits. However, the proportions were only 7% and 14% in the partially and fully-flipped classes, respectively.

In another open-ended question, we asked the students their perceived drawbacks and suggestions for improvement with the flipped classroom. In comparing the partially versus fully-flipped classrooms, there was a similar pattern as with the perceived benefits. Three categories from the coding scheme in Table 2 occurred most frequently for both classroom types, although at different percentages, as shown in Table 6.

Table 6: Top Perceived Drawbacks/Suggestions

Perceived Drawback/Suggestion (% of Respondents)	**ENGR 20 Partially Flipped (n=113)**	**ENGR 20 Fully Flipped (n=103)**

Use of In-Class Time	38%	43%
Load, Burden, Stressors	36%	24%
Specific to the Course or Course's Videos	27%	23%

The most frequently-mentioned drawback or suggestion pertained to how time was used in the classroom, including suggestions to allow more time for 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 students' questions could be addressed more quickly. Interestingly, a smaller percentage of students noted load, burden, or stressors in the fully-flipped course, and the difference with the partially-flipped course was just outside the range of statistical significance (p=0.06). This may have been due (in part) to the partially-flipped version being the inaugural version containing the course changes, for which adjustments must often occur. Also, in the partially-flipped course, the students had to transition from traditional to flipped, and then back to traditional instruction throughout the course of the semester.

In a related question on the survey taken by the partially-flipped cohort, 60% of respondents said that the overall time required with the flipped sessions was more than with the traditional sessions. Similarly, when students in the fully-flipped course were asked to compare their time spent relative to a traditional lecture course, 66% said the flipped class required more time. There was a higher percentage of students in the fully versus partially-flipped course (20% vs. 10%) who suggested approaching the course differently, including a preference for traditional instruction, explicit suggestions not to flip this or other courses, or suggestions to better adhere to the "flipped" model during class time.

We were happy to learn that only a small number of respondents during both the partially and fully-flipped courses (9% and 3%) perceived lesser understanding or learning with flipped instruction, including difficulties learning from a video. In a closed-ended question on the survey, only 12% of respondents from either course indicated an inability to learn from a video.

3.2 Classroom Environment Survey

With the CUCEI learning environment survey, we received a total of 120 responses in the partially-flipped class, representing a 77% response rate. In the fully-flipped class, we received 113 responses, which represented a 76% response rate. In the partially-flipped class, 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. In the fully-flipped class, the personalization dimension, which measures student interaction with the instructor, scored highest at 4.07.

We compared the responses in our partially-flipped ENGR 20 course to the responses in our fully-flipped course. Interestingly, there were five classroom environment dimensions that were rated higher by students in the partially-flipped course, with two of them being significantly higher based on an independent samples t-test. The innovation and satisfaction dimensions were those rated significantly higher in the partially versus fully-flipped classrooms, and the differences would remain significant even after correction for multiple comparisons using

Bonferroni's adjustment. Both dimensions had Cohen's *d* effect sizes in the range of small to medium, as shown in Table 7. The differences for the other dimension had small effect sizes. The Cohen's *d* effect size represents the extent of the difference between two groups and is a measure of practical significance. Cohen defined effects as small (*d*=0.20), medium (*d*=0.50), or large (*d*=0.80) (Cohen, 1987; Salkind, 2010).

These results were somewhat surprising, based on a previous comparison of partially-flipped ENGR 20 with a group of fully-flipped courses in our school of engineering. When we did this previous comparison, five of the seven CUCEI dimensions were rated higher by 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. These results suggested at the time that flipped instruction may be associated with enhanced classroom environment dimensions in comparison to partially-flipped instruction of this course. However, the current results based on fully-flipped ENGR 20 may suggest otherwise for this course. This is also surprising based on the instructor's end-of-term semi-structured interview, in which she noted the enhanced classroom atmosphere as one of the best features of her flipped classroom. She described this enhanced atmosphere as an environment in which the students were enlivened by and interested in the in-class problem solving, being encouraged to also help one another.

In the end-of-term instructor interviews for both partially and fully-flipped ENGR 20, the instructor indicated that with flipped classes, she got to know students better as well as their level of understanding and their specific misunderstandings, particularly those students who asked for one-on-one help with the in-class problems. Interestingly, the personalization dimension, which assesses instructor interaction with students, was rated as the highest dimension in the fully-flipped course and the second-highest dimension in the partially-flipped course. One of the main objectives in flipping this course was to increase interaction with students, as it is otherwise a course packed with conceptual information with little time for problem solving and interaction. The instructor noted in her interview that the fully-flipped classroom did just this – it afforded time for students to solve many more problems together in class, with the instructor directly participating in these activities.

Interestingly, despite the enhanced atmosphere and environment noticed by the instructor, four dimensions scored below the average value of 3.0 in the fully-flipped classroom. Specifically, our respondents did *not* indicate notable interaction with their peers, individual treatment, or innovative teaching and learning approaches and were not particularly satisfied with the classes, as shown in Table 7.

Table 7: CUCEI Comparisons

Dimension	**Definition**	**ENGR-0020 (partial flip)**	**ENGR-0020 (full flip)**	**t test**	**Cohen's Effect Size**
		M	***M***	***p***	***d***
Student Cohesiveness	Students know & help one another	2.34	2.23	0.26	0.15
Individualization	Students can make decisions; treated individually or differentially	2.64	2.62	0.85	0.02

Dimension	Definition	ENGR-0020 (partial flip)	ENGR-0020 (full flip)	t test	Cohen's Effect Size
Innovation	New or unusual class activities or techniques	2.88	2.63	<0.0005	0.48
Involvement	Students participate actively in class	3.03	3.11	0.26	0.15
Personalization	Student interaction w/ instructor	3.96	4.07	0.15	0.19
Satisfaction	Enjoyment of classes	3.05	2.72	0.003	0.39
Task Orientation	Organization of class activities	4.06	3.95	0.08	0.23
	n	**120**	**113**		

3.4 Direct Assessment of Student Learning

We compared students' pre and post performances on the concept inventory (CI) in the two flipped sections (Fall 2015) and the partially-flipped sections (Fall 2014). Based on a paired t-test, there was a clear statistical difference ($p < 0.000001$) between the pre-test and post-test (start and end of semester) mean concept inventory scores for both sections, as would be expected. The questions were identical across the sections.

We did however compare post-test CI scores from the Fall 2014 and Fall 2015 (partial flip vs. fully flipped) courses and found that students performed significantly better when the class was fully flipped. ($p = 0.01$). (The same instructor taught these three sections.) This is a significant result and indication that the fully "flipped" approach is adequate, if not better, for this course in engineering statistics. This as well suggests that the flipped versus partially-flipped student groups began similarly in terms of statistical concept knowledge but that the fully flipped group ended the semester significantly better.

4. Discussion and Lessons Learned

In addition to recording lectures and planning/separating videos in appropriate segments, one of the main considerations or drawbacks of the flipped instruction is increased instructor time. In this case, the instructor had to be prepared to read students' comments prior to every class and accordingly modify planned in-class activities. Students completed the quizzes (after watching the videos) at most two hours prior to the class start time; thus, the commitment from the instructor to review the responses in a timely manner and correspond to comments was of utmost importance.

After our pilot/partial flip in Fall 2014, based on our observations and results, we modified the following for the fully-flipped course in Fall 2015:

- The length of the lecture content assigned per class was too long based on students' comments as well as the instructor's observation, as the majority of students commented that they were spending too much time watching the videos. Thus, this was corrected once the course was fully flipped, and more appropriate content was assigned.

- Another important observation was the length and complexity of quizzes assigned prior to each lecture. The number of quiz questions was significantly shortened for the "fully flipped" approach.
- In class work or active learning exercises were revised in order to better reinforce concepts and incorporate problem solving. The instructor received very positive feedback related to the in-class work.
- The most common comment from both from partially flipped and flipped sections was to present more examples during the class time. The instructor began implementing more group in-class examples.

In order to successfully implement flipped instruction, it is of utmost importance that students watch lectures prior to each class. However, during the midterm times, when students are extremely busy, some students postponed watching the videos and thus were not able to follow discussions or comprehend the material.

During the pilot flip, the instructor devoted 15 to 20 minutes at the beginning of the class time reviewing the material covered in video lectures. It was clear from students' survey comments that most of the students disliked this and did not see benefit in reviewing the concepts again. In order to change that, the instructor revised the in-class examples and aimed to answer students' questions or misunderstandings through examples.

Another correction/improvement implemented related to greater individualizing the instruction. The instructor discovered that some students preferred additional examples and discussions related to concepts covered in the video lectures, whereas some students preferred working on homework and additional or more complex in-class exercises. In order to address this, the instructor separated the class into two groups, allowing some students to start working on homework and in-class work. In addition, the instructor and TA could work more closely with students who needed more clarification or reinforcement of concepts. During the Fall 2014 or Fall 2015 semesters, we were not able to assign the teaching assistant (TA) to be in the classroom with the instructor. However, we are currently teaching a fully flipped section where the TA is present during the lecture time. We believe that this will help even more with clarifying concepts and increase interaction with the students (i.e., personalization).

Some of the students' individual comments from the Fall 2015 fully-flipped course that exemplify our discussion above are as follows:

"The flipped class really allows students to learn the material at their own pace. Typically, I find that when the lecture is given in class, I tend to worry more about taking notes and writing down whatever the professor says, without fully processing the material in class."

"The flipped course allowed me to take my time learning the material so that I was fully able to comprehend the material. Subsequently, I would be prepared in lecture to ask the questions that I needed clarified."

“I liked the examples that were done in class and getting to hear feedback from the instructor regarding what was important to understand from the videos for the exam.”

“The collaborative in-class quizzes forced me to stay on top of the material. This was my favorite thing about the flipped structure.”

“The videos are nice to supplement actual learning. I had questions during the videos that I sometimes couldn't ask anyone. I had my textbook open next to me to the section of the topic that was being discussed in the videos.”

“The biggest drawback I perceive is not having the professor there to present the information, since it is a video. This meant I couldn't get immediate clarification to any issues I had.”

5. Conclusions

Our study contributes to the literature on flipping and partially-flipping statistics classrooms. As presented in our literature review, we found only a small number of studies on these teaching approaches with statistics courses, and none of the studies had been done specifically with engineering students. As recently called out, one study, or likely a small number, on a teaching approach is never sufficient, in particular to be confident in potential outcomes[19]. Thus, our study, which adds to this literature base, serves to inform our engineering teaching community.

The overall outcomes in the flipped course were very encouraging and positive. Class time in the “flipped” version of our engineering statistics course was devoted to problem solving and active learning exercises as well as reinforcement of concepts and addressing the misunderstandings. During the Fall 2015, the instructor noticed even greater engagement of students and a very good atmosphere. Students would come to class and immediately start working in groups. Students were eager to start working on in-class assignments, and more time was available to communicate to students individually. There was also more opportunity for students to work in teams and communicate among themselves.

Although there was an improvement on the concept inventory and overall engagement and atmosphere in the Fall 2015 fully-flipped course compared to the partially-flipped course, the instructor also noted resistance by some students, including dissatisfaction with the lack of traditional lecture and the increased expectations for independent learning. One of the main conditions for a successful “flipped“ implementation is that students watch lectures prior to each class. During the midterm times, when students are extremely busy, some students postponed watching the videos and thus were not able to follow discussions in class or successfully complete the in-class assignments.

One of the main goals in flipping this course was to increase interaction with students, enable opportunities for more problem solving, and create opportunities to better understand which concepts and topics are difficult for students. As stated above, the personalization dimension was rated as the highest dimension in the fully-flipped course. Transforming the class afforded time for students to solve many more problems together in class, with the instructor directly participating in these activities.

Based on our results so far, we will continue to assess improvements related to this flipped course over time. We are collecting data this semester as well, again for a "fully flipped class. However, in relation to evaluating the impact of the flipped classroom further into the future, perhaps we as an assessment community should begin to place more emphasis on longer-term measurement and evaluation after students have completed their undergraduate careers. Thus, perhaps we should be assessing flipped instruction into the future with our students to obtain a more complete understanding of its effectiveness. In addition, other outcome variables (besides exam scores) may be needed to better demonstrate improvements with the flipped classroom or other enhanced pedagogies. This is a great discussion topic for our community to determine best practices for assessing these approaches into the future.

Acknowledgement

Support for this flipped-classroom initiative was provided by the Engineering Education Research Center at the University of Pittsburgh. We also wish to thank Anita Jain, an undergraduate engineering student, who provided assistance in coding the student responses.

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