Advances in Engineering Education

WINTER 2015

The Evolution of a Flipped Classroom: Evidence-Based Recommendations

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ABSTRACT

Engineering students benefit from an active and interactive classroom environment where they can be guided through the problem solving process. Typically faculty members spend class time presenting the technical content required to solve problems, leaving students to apply this knowledge and problem solve on their own at home. There has recently been a surge of the flipped, or inverted, classroom where the technical content is delivered via online videos before class. Students then come to class prepared to actively apply this knowledge to solve problems or do other activities. In this paper, recommendations are made for applying this educational technique to large engineering classrooms. These recommendations are based both on a literature review of flipped classes and the evaluation of a case study of a large Introduction to Environmental Engineering class. The case study evolved from a traditional lecture-based classroom through two different versions of a flipped classroom. Evaluation of students' interaction, preferences and performance are used to make recommendations about the video time, use of class time, course organization and student assessment.

Key Words: classroom flip, inverted classroom, active learning

INTRODUCTION

Instructional environments that allow for students to be more actively engaged with course material are more likely to lead to greater learning gains. The literature in engineering and science education continues to encourage faculty and instructors to use class exercises that require students to be actively engaged in the course material, as opposed to being passive recipients of information.

Chi (2009) demonstrated that student learning increases as engagement in the material shifts from passive to active, in which students physically engage somehow in the activity, and from active to constructive, in which students are required to produce new outputs that go beyond information presented in class. In his study of a large sample of physics students, Hake (1998) found that students who were in classes that incorporated interactive-engagement methods made significantly larger gains on a concept inventory as compared to those who were enrolled in traditional courses, suggesting that the instructional method impacted students' problem solving abilities. Prince (2004) conducted a literature review of the benefits of active learning and found that a variety of different active learning types do result in increased student learning, although some variability in effect sizes was evident.

Entwistle and Peterson (2004) provide a conceptual framework of the influences on student learning. One of the many factors that can influence student learning concerns the teaching-learning environment, which includes both how course content is organized and presented and how the classroom environment is designed. In an early paper, Entwistle (2000) notes that teacher-focused, content-oriented approaches to teaching in which goals are related to information transmission are more likely to result in surface learning approaches to studying and limited understanding. In contrast, student-focused orientations in which facilitation of understanding is a primary goal is more likely to lead to deeper approaches to studying and a more thorough understanding of the material.

While many instructors understand that these methods may be beneficial to students, some may be reluctant to use instructional methods that require students to engage in active or constructive learning in their courses. As Michael (2007) found, one of the primary challenges that faculty perceive is, "Active learning takes too much class time and coverage of content will suffer" (p. 43).

In the classroom flip, the activities traditionally done in class and at home are flipped, or inverted. Instead of watching the lecture in class, students are asked to complete necessary preparatory work outside of class, often times in the form of an online, virtual lecture that has been prepared by the instructor. Class time is then freed up so that the instructor can guide students to complete active, constructive, or interactive activities during regularly scheduled class time (Baker, 2000; Lage & Platt, 2000; Lage, Platt & Treglia, 2000).

The purpose of this paper is to make evidence-based recommendations to faculty interested in teaching a flipped course. These recommendations are based both on data from the literature and empirical evidence from a case study presented here. First, the paper will describe the classroom flip method and provide a literature review on the current use of the classroom flip technique in engineering education. Furthermore, a case study of the implementation of the classroom flip in a large introductory environmental engineering course will be discussed. This course evolved from a lecture-based course through two different versions of a flipped course. Changes between the two versions included shortening the length of the video content and changing the classroom activities. A description of each implementation strategy is provided, including information on what students are required to do outside of class, what activities are done during class time, and class assessment strategies that encouraged students to be prepared. Evaluation of the classroom flip was conducted in the form of post-course surveys and focus groups. Based on the evaluation data of both versions of the flipped class, specific strategies are offered to instructors who are interested in pursuing the instructional method in their own courses.

BACKGROUND AND LITERATURE REVIEW

Description of the Classroom Flip

In the traditional lecture class, the instructor acts as the information provider and as the lead of the class, sometimes termed the "sage on the stage" (King, 1993). In the most passive version of these classrooms, students do not interact with the instructor or with each other. They serve as recipients of information with little or no engagement with course material. In the traditional classroom, information primarily passes from the instructor to the students as diagrammed in the left side of Figure 1. While active learning techniques can be implemented in an interactive lecture format, such as think-pair-share activities in which students interact with their peers, some instructors have

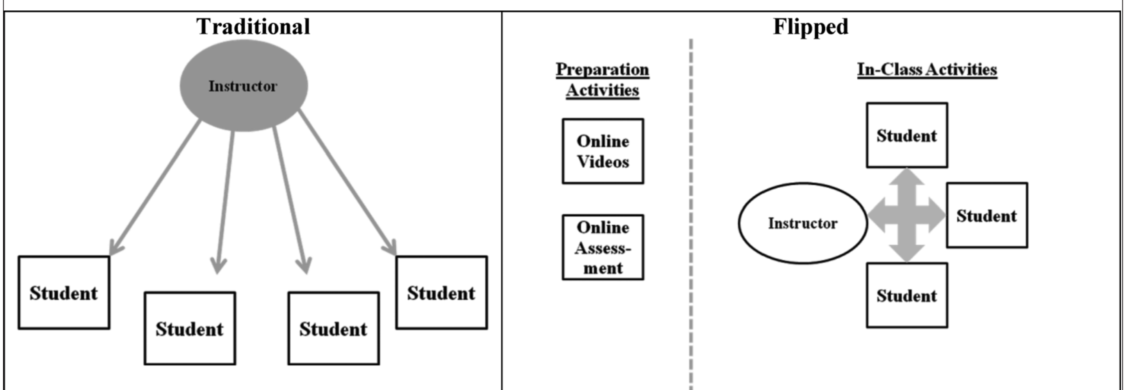

Figure 1. The traditional vs. flipped classroom. In a traditional classroom (left) the instructor is the "sage on the stage" while a flipped classroom allows the instructor to be the "guide on the side." In addition, the flipped classroom also allows for more peer interaction in the classroom.

resistance to completing these tasks during class time as it reduces the amount of time in which new material can be introduced to students.

A diagram of the flipped classroom is available on the right side of Figure 1. In the flipped class, the students gain technical knowledge through online videos and complete an online assessment, which ensures that students are sufficiently prepared to participate in the in-class activities. These in-class activities may include problem solving, discussions, brainstorming, design work, guest speakers or field trips. In most engineering classes, problem solving may be done in class, which normally would be assigned as homework. Students work with one another in groups to complete the activities. Instructors act as a guide while students complete the in-class activities, providing assistance as needed to student groups. If many students are having similar problems, the instructor can direct the attention of the whole class to discuss content relating to the common stumbling block, in a form of just-in-time teaching (Novak, Gavrin, Wolfgang, & Patterson, 1999). In all cases the instructor becomes a guide to students, rather than the "sage on the stage". In the words of Baker (2000), who wrote one of the earliest papers on the method, the instructor acts as the "guide on the side." Table 1 provides a comparison of different course characteristics of the traditional lecture and flipped classes.

The flipped class format has several benefits to both students and instructors. Shifting the lecture to out-of-class time allows the instructor to still "cover" important material while having time for students to engage in active learning exercises in class. For students, the shift in instruction from passive to more active provides an opportunity to engage more deeply in the class material. The flipped classroom also allows for more faculty-student and student-student interaction during class time. This can potentially provide students with greater opportunities to integrate higher order cognitive skills in the classroom, focusing less on remembering and memorizing material and more on applying, analyzing, and potentially creating (Anderson & Krathwohl, 2001). The classroom flip

Course characteristics	Traditional Lecture	Flipped
Role of instructor during class	Information provider	Guide
Role of student during class	Information recipient	Active participant in class
Out-of-class activities	Solving problems, reading textbook, projects, preparing for quizzes/exams	Watch online lecture or read assigned material (before class), complete problem sets & preparing for quizzes/exams (after class)
In-class activities	Instructor-led lecture	Varies (i.e. problem solving, projects, discussion, brainstorming, field trips)
Role of assessment	Primarily summative in nature	Formative "gate checks" to ensure preparedness; Both formative and summative assessment

Table 1. Comparison of traditional lecture and inverted classroom in engineering.

provides a structure for students' out-of-class time, guiding students on where their efforts should be directed. This is a skill that is troublesome for some students who may struggle with determining what is most important when assigned readings from a textbook. Watching online videos allows students to obtain the technical content in their own time and at their own pace. They can re-watch portions that were unclear to them or prepare for later course assessments. Most importantly, students receive help from the instructor during class time during critical periods of learning.

Prior work on the classroom flip in engineering education

Some of the earlier work on the classroom flip was done by Lage and colleagues (2000) who coined the phrase "inverted classroom." Since then, the method has begun to proliferate in both K-12 school settings (e.g. Fulton, 2012; Bergmann & Sams, 2012) and in higher education. The classroom flip instructional method appears to be growing in popularity in engineering education, given both the number of conference papers dedicated to the method as well as the proliferation of informal discussions by faculty at these conferences.

The first paper in the engineering education literature that discussed the classroom flip was by Bland in 2006, who presented at the annual meeting of the American Society for Engineering Education (ASEE). The instructor used a low-tech version of the method to assign pre-class activities and assignments in an electrical engineering course (Bland, 2006). Gannod and colleagues followed this study by implementing the flip in a software engineering class (Gannod, 2007; Gannod, Burge, & Helmick, 2008).

In 2009, the use of the classroom flip instructional method began to proliferate in engineering education, with several conference papers published. Zappe, Leicht and colleagues describe how a portion of an architectural engineering class was flipped (Zappe, Leicht, Messner, & Litzinger, 2009; Leicht, Zappe, Messner, & Litzinger, 2012). They collected data on how students used video lectures and students' perceptions of the instructional method. Their primary suggestions on the method included: 1) require an online quiz to ensure students come to class prepared, 2) keep the videos fairly short in order to encourage students to watch them, 3) briefly review course content to make sure students are prepared, and 4) consider adding multi-media to online lectures to increase student interest. An examination of the impact of the classroom flip on learning gains was not found to be significant across different semesters with the same instructor.

In a series of papers starting in 2009, Dollar, Steif, and Ulseth describe efforts to implement the classroom flip in a statics course (Dollar & Steif, 2009; Dollar, Useth, & Steif, 2011; Steif & Dollar, 2012). The authors used an online system consisting of simulations and other interactive activities to teach students statics. Papadopoulos and colleagues (Papadopoulos, & Santiago-Roman, 2010; Papadopoulos, Santiago-Roman, & Portela, 2010) followed the efforts of Dollar and Steif and implemented similar strategies in statics courses at the University of Puerto Rico using the same online learning environment.

In 2009, Toto and Nguyen worked with a faculty member from industrial engineering to flip portions of a junior level course. The authors found that students had a positive perception to using class time for problem-solving and hands-on activities, but admittedly preferred face-to-face lectures as compared to virtual lectures. Kellogg (2009) describes another variation of the classroom flip, in an industrial engineering course on cost estimation in which the students were required to read online texts and complete embedded activities prior to coming to class.

Demetry (2010) describes the evolution of her use of the classroom flip in a materials science course. In her revised version of the course, Demetry used online "microlectures" followed by a short readiness assessment test. During class time, Demetry asked students to work in teams to complete a problem set that required higher level cognitive skills. The role of the teacher was to provide assistance and whole-class clarification as needed. Although Demetry collected assessment data, because the paper was a Work in Progress, no information on the project impact was provided.

The 2012 conference of ASEE had several papers dedicated to the classroom flip. Laman, Brannon, and Mena (2012) presented a paper on a low-tech version of the classroom flip in which they required students to complete a preparation reading and a pre-class assignment concerning a design problem. The instructor did not flip the entire course, but used a scaffolding strategy in which students had increasing responsibility for being prepared as the semester progressed. Talbert (2012) used the inverted classroom in an introductory MATLAB course at a liberal arts college. Students were required to watch either MATLAB tutorials or instructor-created screencasts. Instead of using online quizzes to assess preparedness, the instructor required students to complete a quiz via classroom response systems (clickers) at the start of class. Thomas and Philpot (2012) compared student grades in sections of a mechanics of materials course that were inverted and traditionally taught. No significant differences were found in exam scores between the two formats, although a threat to the validity of the study is that different instructors taught the sections. At a regional ASEE conference in 2012, Warter-Perez and Dong describe their efforts at flipping a portion of their course. They required students to engage in pre-project activities outside of class and then used class time for a variety of purposes, including interactive problem solving and inquiry-based activities.

Table 2 provides a listing of the papers found describing or using the classroom flip method in engineering education. While the number of conference papers in engineering education about the classroom flip seems to be increasing, as of this paper submission, there have been no works in peer-reviewed journal articles in engineering education describing the method and its impact.

Author and year	Discipline	Sessions flipped	Out-of-Class Activities	In-Class Activities	Assessment of Preparation
Bland (2006)	Electrical engineering	Whole course	Pre-class activities and assignments	Problems, case studies, physical examples, group-work	Assignments
Demetry (2010)	Materials Science	Whole course	Online microlectures	Group problem solving	Readiness assessment tests
Dollar & Steif (2010); Dollar, et al., (2011); Steif & Dollar (2012); Papadopoulos & Santiago-Roman (2010); Papadopoulos, et al. (2010)	Statics	Whole course	Online modules and simulations	Concept questions discussed with peers; active learning exercises	"Learning by Doing" and "Did I Get This" Exercises; Student perception surveys
Gannod (2007); Gannod, et al. (2008)	Software engineering	Whole course	Podcasts (Powerpoint with voiceovers)	Programming projects	Not described
Kellogg (2009)	Industrial engineering	Course segment	Online embedded interactions; online text	Active/collaborative problem solving in class	Online quizzes
Laman, et al. (2012)	Civil engineering	Course segment	Pre-class preparation readings and design problems	Collaborative work on design problems	Online evaluations of reading comprehension
Talbert (2012)	MATLAB	Whole course	Mathworks videos; Instructor-created screencasts	MATLAB assignments	Quizzing via clickers at start of class
Thomas & Philpot (2012)	Mechanics of materials	Whole course	Readings, animations, and videos	"Homework" either individually or in groups	Not described
Toto & Nguyen (2009)	Industrial engineering	Course segment	Online lecture	Problem solving and hands-on activities	Online quizzes
Warter-Perez & Dong (2012)	Digital Engineering	Course segment	Pre-project assignments	Problem solving, inquiry-based activities, interactive lectures, collaborative projects	Assignments
Zappe, et. al (2009); Leicht, et. al (2012)	Architectural engineering	Course segment	Narrated screencasts using Tablet PC	Work on group projects	Online quizzes

Table 2. Flipped courses in the engineering education literature

No studies have yet been determined as to why the method is attractive to faculty or why the method seems to be growing in popularity. However, there are some hypotheses. One primary reason is that modern technology has made it fairly easy to capture a lecture. In the engineering education literature, the earliest innovators used podcasts (i.e. Bland, 2006; Gannod, 2007). More recent adopters of the method are using online simulations and narrated screencasts (i.e. Zappe, et al., 2009; Talbert, 2012). Software programs for creating screencasts abound and include both free versions such as Jing and sophisticated tools for purchase such as Camtasia. Tablet PCs also provide instructors with the opportunity to communicate through writing and problem solving. Faculty can easily upload videos to university-owned, account-controlled streaming servers or publicly to sites such as YouTube.

A second potential reason is the increase in the amount of online information that is readily available to students. Using Google, students can access a plethora of information immediately. If information is so readily available at the push of the button, some instructors may question whether or not their role as "information givers" is no longer needed. With the advent of massive open online courses (MOOCs), perhaps some instructors may wonder what the future may hold for the traditional face-to-face classroom. A possible model for the classroom flip is using a MOOC as the material that students complete outside of class and then using class-time to complete activities or projects relating to the MOOC.

A third reason is that many instructors are being asked to teach online courses. Some of these instructors create video content that is intended to be used for streaming content in an online course environment. Given that these videos are already created, instructors have an easy entry into flipping their face-to-face courses. This latter reason is the primary impetus for flipping the course described in this paper.

CASE STUDY

The instructor had previously taught a large (80 – 90 students) Introduction to Environmental Engineering course in a traditional lecture format for two semesters before deciding to flip it. In the traditional offering, she used the class time to present lecture material and included some active learning components such as brainstorming and short problem solving in the classroom. Outlines of lecture notes were provided to the students; the instructor filled in the notes using a Tablet PC which was projected to the class.

Students' use of office hours motivated her to flip the course in order to increase active learning. During these office hours, an average of 8 -10 students would come with questions regarding the homework problems. Although the instructor had covered this material in detail in the class lecture, students still had many questions. One possible reason for these questions is that students did not need the information covered in class until the homework assignment was due. Once the students in office hours asked questions directly applied to the problem set, they seemed to better understand the material and were then able to complete the problems successfully. In addition the instructor noticed that the students were teaching each other. This benefitted both the student acting as "teacher" and the student acting as the "learner." The idea of flipping the classroom appealed to the instructor in order to mimic this student-centered learning in the classroom for all students, not just those who attended office hours. In addition, she hoped to increase both faculty-student and student-student interaction during class time, not just during office hours.

Figure 2 shows the progression of teaching of this course through two different versions of flipping, including changing the format of the online videos and the type of activities completed during class time. During Version 1 of the flipped course, the instructor observed that the students were indeed more actively involved during class time but she also observed some challenges. The students were concerned with the amount of time they were spending on the class. Because they had to come to class once per week and still watch 3 lectures online, they expressed a desire to

Format	**At home Before class**	**Monday & Wednesday**	**Friday**	**At home After or during week**	**Assessment**
Traditional		Lecture in class		Homework Study for Quizzes/Exams	**3 Exams** Weeks later (F08, F09) **6 Quizzes** 1 – 2 Weeks later (S12) Cumulative Final
Flipped Version 1 (V1)	Watch Full video lectures Take On-line assessments	Smaller groups Once per week (M,W or F) Review material Work on extra problems Field trips		Homework Study for Exams	**3 Exams** Weeks later Cumulative Final
Flipped Version 2 (V2)	Watch Short video segments Take On-line assessments	Review material Work on homework problems Field Trips	Quiz	Homework (if necessary) Study for Quizzes	**10 Quizzes** same week Cumulative Final

Figure 2. Comparison of a Flipped Class with a Traditional Class taught by the same instructor. In each flipped format, the students watched online video lectures before coming to class and worked on problem sets during class time. In V1, the online lectures were created by recording the lecture during class time while in V2 the lecture material is presented in shorter video segments. Also in V1, the class time was used for additional problem sets while in V2 the class time was used to work on homework problems. Finally in V2, the student learning was assessed at the end of each week via an in-class quiz while in V1 the learning was assessed via two mid-term exams. The shading represents time the students spent in class with the instructor.

earn 4 credits for the course instead of 3. In addition, the students were required to come to class and work on class problems in addition to the homework problems. This resulted in students being present in class but not actively involved in the class discussion and problem solving.

In Version 2, the time of the lecture material was reduced, although the content remained the same, based on recommendations from prior studies (Zappe, Leicht, Messner, & Litzinger, 2009; Leicht, Zappe, Messner, & Litzinger, 2012). In addition, the class time was used for the homework due at the end of the week and students were invited (but not required) to come to class every day. With the revisions in Version 2, the students did not comment negatively about the time commitment and were more engaged in problem solving in class since they knew they were getting help on the "homework" problems. Details of the lectures and class time are given below.

COURSE DESCRIPTION

Use of Videos

All the videos in both versions were created with assistance from the Continuing and Distance Education Office, located in the College of Engineering at Penn State. Outline notes were created using Word and these notes were converted into Portable Document Format (PDF) documents. During the lectures the instructor filled in the notes using PDF Annotator®. The videos were housed on a streaming server in the College of Engineering and provided to students through links in the course management site (ANGEL).

Videos created during class time (Version 1): During Fall 2010, the instructor's videos were recorded during live lectures. Notes were filled in using a Tablet PC. Forty, 50-minute lectures were created for a total of 33 hours of video. These videos included student questions, class administration (reminders of due dates, etc.), exam reviews and brainstorming time. Each week students were required to watch three of the 50-minute videos.

Short video segments (Version 2): For Version 2 of the flip, the lecture material was reorganized into 11 self-contained modules. These modules were recorded in a recording studio without a student audience the semester before the course began. The videos were created with a Wacom interactive pen display screen and video capture. Outline notes were created using PDF Annotator software. These videos contained contextual stories, derivations ad sample example problems. Each week, students were required to watch one module consisting of multiple video segments. The module lengths varied from 87 minutes to 143 minutes for a total of 21.7 hours of video created. Each module contained 7 to 18 short video segments (for a total of 126 video segments). These segments varied from a few minutes to up to 20 minutes in length. Although the goal was to create videos no longer than 10 minutes, which is consistent with the prior literature (Zappe, et al., 2009), the segments were created to the length necessary to communicate information relating to the primary objectives of that segment. The short video segments were titled appropriately, allowing students to selectively re-watch segments of interest. The length of each video was also presented to the students so they could budget their time effectively.

The preparation of these videos took approximately 30 hours to create in total. One module was re-recorded after the first semester to improve content. Although creation of the videos took more time upfront, the lecture-prep time was saved in subsequent semesters.

In class time

During each version of the flipped course, the class met in person three times a week for 50 minutes each. In both versions of the flipped course, the instructor used a short amount of time (5 – 15 minutes) at the start of class to address students' concerns and questions from the online lecture material. These concerns and questions were ascertained from the weekly online assessment (see online assessment "gate check" below).

In addition, students in both versions of the flipped course were able to attend field trips. These trips were taken to locations at or near campus and included tours of the recycling facilities on campus, a wastewater treatment plant, and a LEED-certified building. These field trips were previously prohibitive because of the size of the class. By flipping the class the instructor could take one third of the students at a time on the field trip. In a normal class that would mean that the students would miss a whole week of course content. In the flipped class the students don't miss technical content since they can obtain that content from the videos.

Version 1: During the first version of the flip, the instructor divided the large class into three smaller groups. Each group was assigned only one day of the week to attend class. The purpose of this was to mimic a small classroom experience. Attendance, which counted for 10% of their grade, was recorded for each group on that day. The students were given additional problem sets to complete in class. These problem sets were not handed in and not graded. Although these problems were similar to the problems assigned for homework, the in-class problems were an additional activity that the students did during class. The students still had to complete their regular homework assignments outside of class. During Fall 2011, the class time was used for the following:

1. Problem solving (8 class periods). Students came to class once per week for a total of 8 problem solving sessions. (The instructor attended 24 class periods in total as each class period was repeated three times to accommodate the three smaller groups.) After addressing students' questions and concerns, the instructor took attendance and then handed out class problems. The students would work on these problems during class individually or in groups.

The instructor would sometimes solve parts of the problem on the board. As mentioned above, these problems were assigned in addition to homework.

2. Field trips (3 class periods). Students went on three field trips in smaller groups.
3. Review sessions (3 class periods). Each student attended one review session before each of the three exams.
4. Student presentations (1 class period). Students could choose to prepare an extra credit presentation on a topic of their choosing.

Version 2: In Version 2, the in-class time on Monday and Wednesday was devoted mostly to solving the homework problems due on Friday. Attendance was not recorded. A quiz was given each Friday. During Fall 2012, class time was used for the following:

1. Solving "homework" problems (20 class periods). The instructor would open the class by addressing students' concerns and questions from the online assessment. Then the students would work on the homework problems assigned for the week. The instructor and teaching intern would walk around the room to answer questions. Students were encouraged, but not required, to work in groups. If common questions were asked, the instructor would address the question at the board for all students.
2. Quizzes (10 class periods). The students would take an in-class quiz on 10 Fridays during the semester.
3. Field trips (4 class periods). Students were divided into 2 or 3 groups and went on 4 total field trips. In Version 2, two trips to different wastewater treatment plants were made. One of these was on campus; the other was located in the township.
4. Guest speakers (2 class periods). There were two guest speakers that discussed Marcellus Shale drilling and indoor air quality.

Class Assessment

Online assessment (gate check)

In both versions of this flipped course, students would take a short (12 – 18 question) online assessment after watching the videos but before coming to class. This occurred on Sunday evening before the Monday class. This online assessment served as a "gate" for students to check for understanding and to hold them accountable for watching the videos. Most of the questions on the online assessments were multiple-choice and addressed qualitative concepts and/or required simple calculations. On each online assessment, the students were also asked to share the clearest and muddiest parts of the video lecture. This question was open-ended and counted in their final assessment grade. The instructor addressed the "muddy" points in class. In both versions of the flipped course, the online assessments were worth 10% of the grade. In addition, the lowest online assessment grade was dropped.

In-class Assessment

In Version 1, students completed two midterms exams and one cumulative final exam. The mid-term exams were given in the evening, not during class time and were each worth 20% of the final grade. The Final Exam was worth 20% of the final grade.

In Version 2, the students did not take the mid-term exams but did have a cumulative final. The instructor decided to have the students take shorter in-class quizzes corresponding to each module. There was one exception of a quiz that covered two modules. These quizzes replaced semester exams and were worth 50% of the total grade. Similar to Version 1, the final exam was worth 20% of the final grade.

Evaluation Methods

Previous studies on flipping have indicated many advantages including active learning in the classroom for the students and a move for the instructor from a "sage on the stage" to a "guide on the side". However, many faculty members will be reluctant to incorporate flipping in their classroom if it creates significant student resistance. It was our aim in this work to assess students' perceptions and performance during two different versions of the flipped classroom over several semesters so that we could make specific recommendations to faculty interested in flipping their engineering courses. We specifically hypothesized that the more customized and shorter videos and the use of in-class time to complete homework rather than additional problem sets would result in more positive feedback from students.

In order to answer this hypothesis and make recommendations to faculty, several guiding questions were used to understand the use of the classroom flip and to understand the differences between the two versions of the flipped class. These questions follow:

1. How do students interact with both on-line lectures and flipped classroom time?

For this research question, students' behaviors with online lectures were explored, including how many of the videos they report watching, how often they review the videos, and reasons why they reviewed the videos. In addition, because faculty may be concerned about the potential increase in number of absences, students were also asked how often they were absent.

2. What are students' preferences for on-line content delivery and use of class time?

For this question, students are asked about their preferences regarding length of the online videos, their preference for coming to class for a lecture versus watching a lecture online, and the perceived benefits of using class time for problem solving. Comparisons are made between the format of Version 1 and Version 2 to better understand which model is preferred by students.

3. How does the type of instruction affect student learning as measured by cumulative final exam scores?

One of the most important questions asked when an educational innovation is implemented is whether student learning is impacted. In order to understand impact on student learning, final exam scores were compared for six semesters in which the instructor had taught the course. The instructor taught traditionally using lecture for three of these six semesters. During the other three semesters, the instructor taught using Version 1 of the flipped course twice and Version 2 of the flipped course once. (The instructor taught the course one additional time in Fall of 2010. However, because of different grading policies during this semester, final exam score data was not included in this analysis.) During each semester, the students were administered a two-hour cumulative final exam. The content was not exactly the same but care was taken to ensure that the questions were as similar as possible.

4. What do the students find most valuable about the flipped course?

For this section, students' preferences for the flipped format versus traditionally-taught courses are discussed, using results from both surveys and focus groups. Additionally, students' reasons for their preferences were collected.

The evaluation of the classroom flip was conducted using a combination of qualitative and quantitative measures. The quantitative measures included post-course surveys that focused on students' preferences for the flipped versus traditional instruction, their behaviors regarding video watching and class attendance, and perceived impact on interest and learning. The format of the items varied, including both closed and open-ended questions. Data from the open-ended questions was coded to find common themes in students' responses. The survey was developed by education experts located in the College of Engineering's teaching and learning center. The Leonhard Center for the Enhancement of Engineering Education. The instruments were customized for understanding the impact of the specific course situation. Because the survey was primarily constructed with individual, stand-alone items of students' behaviors and preferences rather than inclusion of summated rating scales, no psychometric analyses (such as an item analysis or reliability analysis) would be appropriate to conduct. However, the items were reviewed internally by multiple researchers in order to ensure that items were functioning as intended. A copy of the survey for Version 1 and Version 2 are available in Appendices A and B.

The surveys were administered online using a commercial surveying software tool called Qualtrics. Participants in the evaluation were first asked to complete an informed consent document, in accordance with Penn State's Institutional Review Board. Out of 59 enrolled students, 36 students (61% of students) filled out the post-surveys for Version1 while 66 out of 86 (77% of students) filled out the post-survey for Version 2. Participants received 1% extra credit on their final grade as an incentive for completing the surveys.

Descriptive data from the post-course surveys is presented for the first two research questions. In addition, for certain questions, comparisons are made between students' perceptions during Version 1 and Version 2 of the course. These comparisons will help to determine if the changes made during Version 2 result in more positive student perceptions.

In addition, during Version 2, focus groups were conducted to gather additional information on students' perceptions of the instructional technique. Eight students attended each of three focus groups.

In order to encourage participations, students were offered additional extra credit for attendance. The students attended the focus group for approximately 45 minutes. A semi-structured format was used to initiate discussion and assess the students' opinions regarding the flipped format of the course. Questions concerned their perceived value of the course and the instructional methods. The focus group protocol was devised by the research team, including an expert in educational assessment. All sessions were audio recorded and summarized for later analysis. As an additional source of evaluation data, during Spring 2013, four students were identified who enrolled in two separate environmental engineering courses with the instructor. One of the courses was taught in Version 2 of the classroom flip and one of the course was taught with a lecture format. These four students participated in a one-hour focus group to discuss their perceptions of the classroom flip and which instructional method they preferred, given the same instructor. Copies of the focus group protocols are available in Appendices C and D.

EVALUATION RESULTS

How do students interact with both on-line lectures and flipped classroom time?

The majority of students reported watching the online video content. In both versions of the flipped class, the majority of the students watched almost all the videos. Figure 3 shows that 53% of

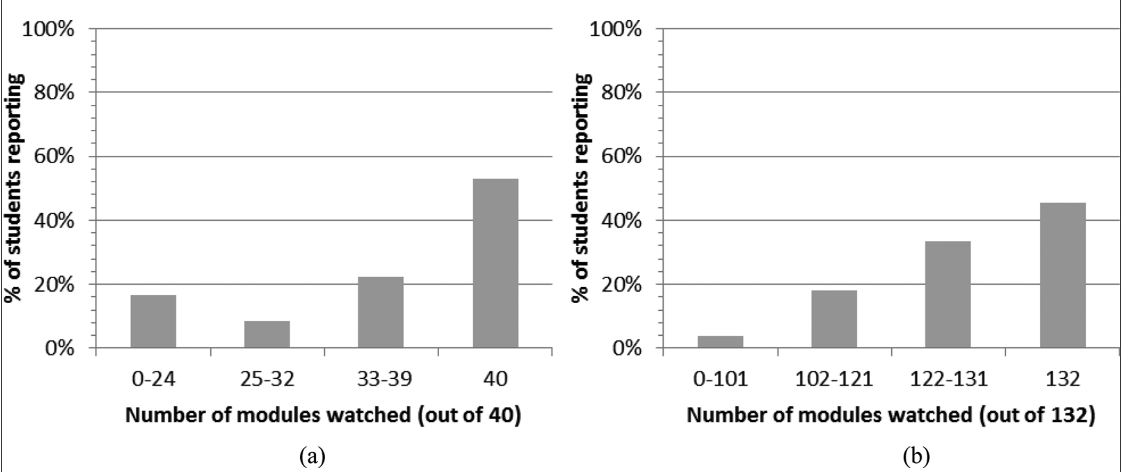

Figure 3. Number of modules and video segments watched by students. In Version 1 (a), there were 40 videos and 53% students reported watching all 40 videos while total of 75% of students reporting watching between 33 and 40 of the lecture videos. In Version 2 (b), 45% of the students reported watching all 132 video modules while 78% reported missing less than 10 out of 132 video segments.

the students watched all 40 videos in Version 1 while 45% watched all 132 video modules in Version 2. Although it is difficult to compare directly since there are not the same number of videos in each Version, 17% of the students in Version 1 reported missing 60% of the content (watching less than 24 of the 40 videos) while in Version 2 only 4% of the students reported missing 76% of the videos (watching less than 101 of the 132 videos). This data suggests that regardless of video format, whether they are longer or shorter in length, students will generally watch the videos in the flipped class.

One of the main advantages of online lectures for students is the ability to re-watch portions of the videos. Figure 4 shows that the likelihood of re-watching the video lectures is about the same for both versions. Approximately 10% of the students reported re-watching the lectures all the time

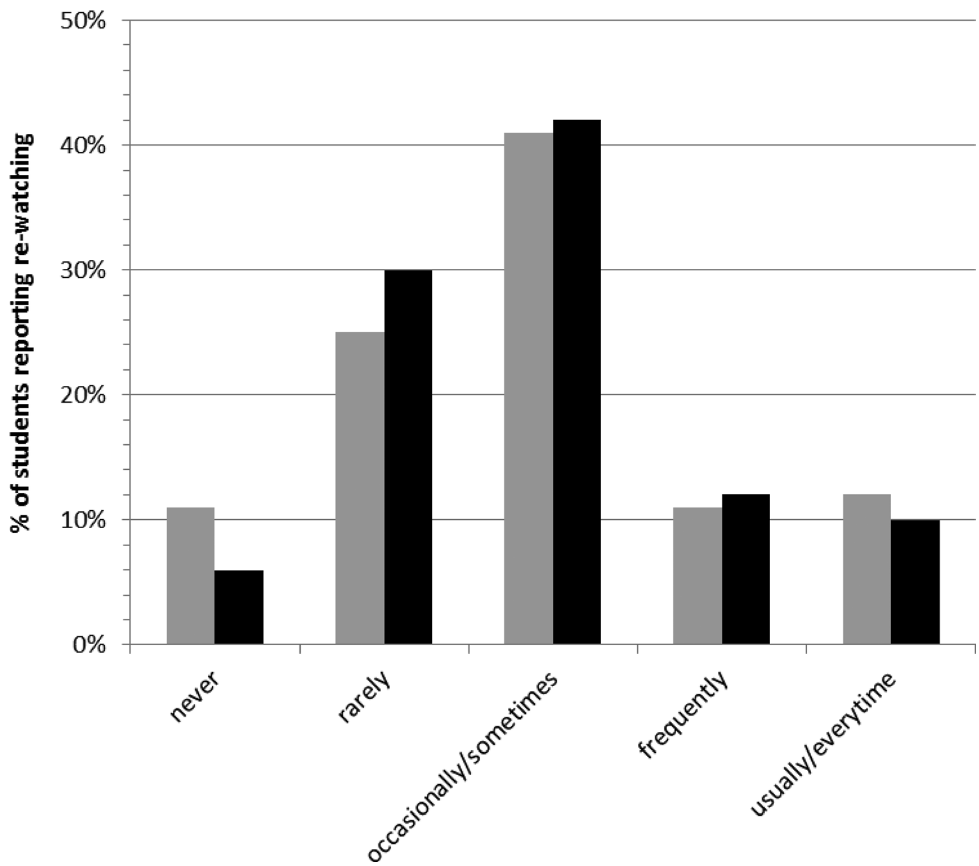

Figure 4. Students' responses to the question: "Did you review portions of the online modules that seemed unclear to you?" for Version 1 (gray) and Version 2 (black). Over 65% of the students reported reviewing unclear portions of the video at least occasionally in both versions of the course offered.

Reason for re-watching	% reported
To clear up a misunderstanding	70%
For the online assessments	70%
Help with HW	67%
Because I was distracted the first time I watched it.	55%
Review for quiz in class	47%

Table 3. Reasons students reported re-watching the video lectures during Version 2.

while 11% (in Version 1) and 6% (in Version 2) report never re-watching the videos.

During the evaluation of Version 2, we specifically asked students why they re-watched video segments. They were able to select more than one response. As shown in Table 3, 70% of the students stated that they re-watched to clear up a misunderstanding and to work on the online assessment while 67% percent reviewed the videos in order to receive help with homework problems. In addition over half (55%) of the students re-watch the lectures because they lost focus the first time around while 47% re-watch lectures to help study for the in-class quiz.

During Version 1, the students were required to come to class once a week and attendance was taken. However during Version 2, the students could choose to come to class two days a week to review the material (attendance was not recorded) and work on problem sets. During the evaluation of Version 2, we asked students about their classroom attendance. Figure 5 shows that 24% reported coming to all the class periods and 50% reported missing two or less class periods. In addition, 62% said they missed class as many times in this course compared with their other courses while 9% said that they were absent fewer times as compared to other courses. Reasons for not coming to class included: being able to finish the problems on their own (55%) or preferring to work on problems on their own (33%). They also reported having other academic priorities (34%) and that they "didn't feel like coming" (25%). Although we did not take attendance every day during Version 2, the students' reported absences are consistent with the instructor's general observations during the semester.

What are students' preferences for online content delivery and use of class time?

An area of interest was students' preferences in terms of the length of each video segment. Is it better to have the lecture broken up into smaller videos, even though the students have to manually start each video segment? During Version 2, we asked the students about their preferences regarding the length of videos, by asking how they would divide 120 minutes of online lectures. Students report preferring shorter mini-lectures instead of one long lecture. Figure 6 shows that 62% of stu-

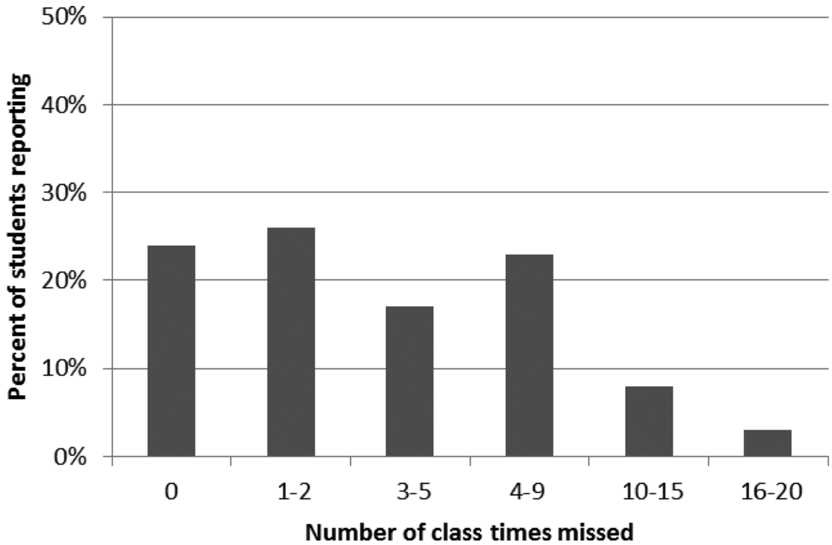

Figure 5. Number of problem solving class times students reported missing during Version 2 of this course. Attendance was not recorded for these class times. There were a total of 20 problem solving class times (in addition to 10 quiz class times, 8 class times for field trips and 2 class times for guest speakers).

dents would prefer twelve 10-minute videos while 24% would prefer six videos at 20 minute each.

How do the student preferences change with the type of online delivery? Recall that in Version 1, the videos were recorded from a live class; each video was 50 minutes in length. In Version 2, the videos were much shorter in length, although a greater number of videos were provided.

Students in both versions were asked to rate their level of agreement with the several statements using a Likert-type scale from Strongly Disagree (coded as 1) to Strongly Agree (coded as 5). Average scores were calculated for each item. The results are given in Table 4. First, students were asked their level of agreement with the following statement: "I would prefer to use class time for problem solving activities, rather than listening to a lecture." Students in both sections seemed to find this helpful. There was no significant difference in the average rating for this item between versions [$t(99) = 1.17$, $p = 0.24$].

Students were asked about the benefits of moving lecture material out of class with the question: "I feel that moving lecture material out of class and having more time to work during class is a beneficial use of course time." Students in Version 2 rated this item significantly higher [$t(98) = 2.65$, $p = 0.0093$]. This suggests that students in Version 2 found working in class to be more beneficial than those in Version 1. Recall that in Version 1 the students were only required to come to class once per week and used that time to work on additional problem sets. In Version 2, the students were not

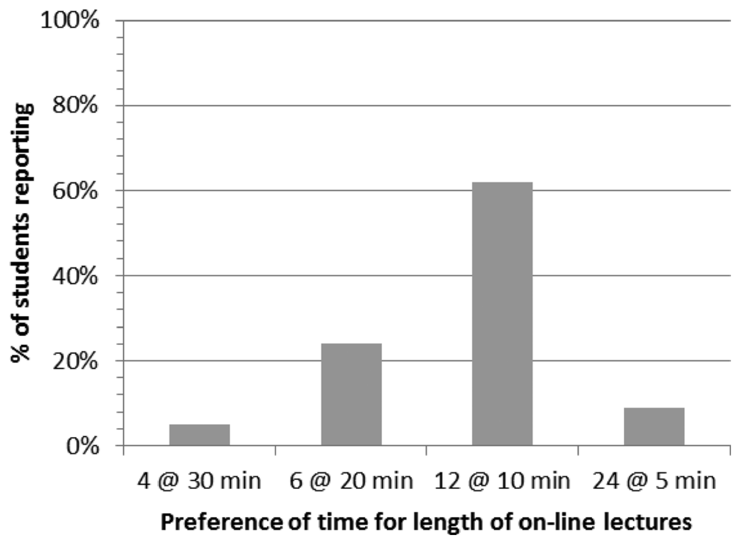

Figure 6. During Version 2, students were asked to choose how to watch 120 minutes of video. 62% of the students choose 12 videos of 10 minutes each.

required to attend class. However, class was used to work on "homework" problems which were due at the end of the week. The data from this item suggests that the Version 2 model was more effective in using the class time for homework rather than for supplemental problems.

Students were then asked to rate their level of agreement with: "My ability to do homework problems on my own was improved because of additional time spent problem solving in class." Once again, students in Version 2 rated this statement significantly higher [$t(100) = 2.0969$, $p = 0.0385$].

In addition to class time, students in both sections were asked to rate their level of agreement with the following: "I prefer coming to class to listen to a lecture versus watching a lecture online." An independent t-test showed that students in Version 1 had a greater average for this item [$t(100) = 4.10$, $p < 0.0001$]. Students who were required to watch the longer videos which were recordings of class would rather attend a class lecture than watch online. Those who watched the shorter videos in Version 2 were more likely to disagree with this statement.

Students were asked their preferences on how long the instructor should review material at the start of class. Previous work (Zappe, et al., 2009) recommended reviewing for shorter periods of time in class. This can be a challenge for faculty who are accustomed to presenting material in class. We found 91% students preferred using class time for problem solving rather than for reviewing online lectures. Furthermore, 85% of students recommended using less than 20 minutes (out of 50 minutes) for review in class (Figure 7).

Item	Version 1	Version 2	p value
I would prefer to use class time for problem solving activities, rather than listening to a lecture.	3.83 (s = 0.94)	4.06 (s = 0.95)	0.2449
I feel that moving lecture material out of class and having more time to work during class is a beneficial use of course time.	3.22 (s = 1.05)	3.79 (s = 1.03)	0.0093*
My ability to do homework problems on my own was improved because of the additional time spent problem solving in class.	3.14 (s = 1.18)	3.58 (s = 0.91)	0.0385*
I prefer coming to class to listen to a lecture versus watching a lecture online.	3.69 (s = 1.22)	2.67 (s = 1.19)	<0.0001*

Table 4. Students in both versions were asked to rate their level of agreement with the several statements using a Likert-type scale from Strongly Disagree (coded as 1) to Strongly Agree (coded as 5). Means and standard deviations and p value for items administered to students in Version 1 and Version 2. *indicates significant differences in the responses between Version 1 and Version 2 using $\alpha = 0.05$.

How does the type of instruction affect student learning measured with cumulative final exam scores?

Figure 8 shows the average final exam score grades by semester. A one-way ANOVA was conducted on the data which showed no significant difference in average exam grades across the semester [$F(5) = 0.255$, $p = 0.937$]. The average grades on the final exam were surprisingly similar across the semesters, varying only a few points.

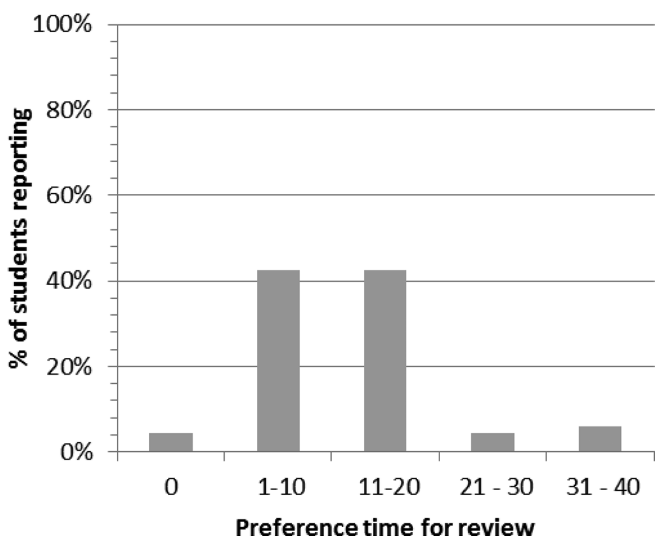

Figure 7. Students from Version 2 report that they would like to spend less than 20 minutes (out of 50 minutes) of class time reviewing material from the lectures.

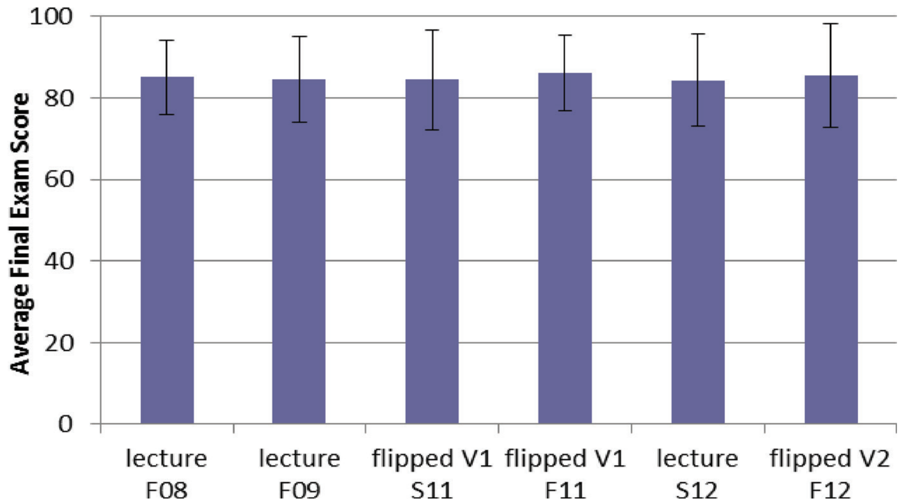

Figure 8. Average Final Exam Scores for the same course with varying instructional strategies from Fall 2008 (F08) until Fall 2012 (F12). The grades are similar for traditional lecture-based courses and both versions of the flipped course. Vertical bars represent the points that are one standard deviation above and below the mean.

What aspects of the flipped format do students find most valuable?

In general students prefer the flipped format of class to a traditional lecture format, even if they are a bit hesitant at first. For example in Fall 2012 a student was initially against the flipped method but by the end of the semester had changed his mind.

> *"Initially, I was extremely against the idea of a flipped course. To me it sounded like self-teaching. But after the first few weeks I realized it was not so and was surprisingly easy to learn from."(Fall 2012 Post Survey)*

On the survey for Version 2, students were asked whether they would prefer to take a flipped-course or a traditional course with the same instructor. In the post-survey about three out of four (77%) of the students stated that they would prefer to take a flipped course with the instructor. The students were asked to explain their reasons. The major themes that emerged from students' comments included: A. flexibility in learning, B. being able to re-watch the lectures and C. interacting with peers and faculty in order to have homework questions answered in class. An example of a quote including all three of these themes follows:

> *"I really like watching lectures out of class. I am able to watch them at my own pace (A.) and can rewind when I lose focus (which I often do) (B). Also, working out problems in class*

Code	% of students	Exemplar quotes
A. Flexibility in learning	38%	"Flipping the course gave me more freedom toward how I wanted to complete the work."
B. Reviewing lectures & helping with focus	35%	The pause and rewind features of the flipped classroom…allow me to pay more attention to the lecture." "If I miss something or I just want to go into a daze for a minute, I can go back and watch that part again."
C. Interaction with students and faculty	33%	"I…have more questions about the homework than the lectures." "Coming to class ready with questions or homework lets the student interact with the instructor more hands-on." "I found really interesting the fact of solving in-class problems since I have the opportunity to exchange my ideas with others and to have a different perspective of what is shown."

Table 5. Student explanations for preferring flipped course to traditionally taught courses.

helps me to understand the concepts that I learned out of class better and it better prepares me for quizzes/exams (C.)."

Table 5 provides example quotes illustrating the themes from this question on the survey.

Flexibility in Learning and ability to re-watch segments

Thirty eight percent of the students mentioned enjoying flexibility of freedom in learning. They mentioned being able to watch the videos "on my own time." This flexibility benefits the student's schedules as they can decide when they have the time to fit in watching the video segments. In addition, 35% of students specifically mentioned preferring the fact that they can review the lectures on their own time. They can also pause the video and take a break when they start to lose focus which allows them to control their learning environment.

During the Spring 2013, a focus group was held with students that had the same instructor for both the Flipped Version 2 class and a lecture-based course. One student shared:

"[The flip method] definitely hammers down the concepts better just because I can learn on my own time and I can always go back within a lecture and look it up and watch it again if I don't understand something." (Spring 2013 Focus Group)

In contrast a student who is taking a traditional lecture-based course with the same instructor said:

"Sometimes I find myself just copying down whatever she writes on the board and not really absorbing it."(Spring 2013 Focus Group discussing live lecture)

Interactive class time

Approximately one third of the students mentioned preferring the interaction with both students and faculty during class time on the post-survey.

> *"[One advantage is] working with other students, being able to immediately have questions answered whether it be by a classmate, [the teaching intern], or [the instructor]." (Fall 2012 Post survey)*

> *"I liked being able to ask both the professor and TA questions about the problem sets during the scheduled time for class because I didn't always have the time to ask questions during either of their office hours. Receiving help on problems leads to less frustration and a better understanding of the material." (Fall 2012 Post survey)*

During the Spring 2013 focus group students were comparing this course with a traditional course and discussed that the class time allowed them to get questions answered without feeling embarrassed.

> *"And with the homework, you can do it in class with your friends, your peers, it makes it easier because you're bouncing ideas off each other. It helps, it makes you think better." (From Spring 2013 focus group)*

> *"I would much rather ask one of my friends a question, that's why 370 [the flipped course] was a lot better, just because you didn't have to ask her [the professor]. When you go to do your homework your friends would help you out. It's easier when you do have a question because not everyone is looking at you and critiquing your question or calling you an idiot." (Spring 2013 focus group)*

Opportunities for Field Trips

In addition to working on problems in class, students really enjoyed the ability to go on field trips in this course. 78% of the students agreed or strongly agreed that "going on field trips increased my interest in Environmental Engineering."

> *"You get a feel for what you're actually doing [while on field trips]" (Fall 2012 Focus Group)*

> *"The field trips are interesting. I don't think we've done field trips with any other class." (Fall 2012 Focus Group)*

> *"You actually get to see things close to campus that are relevant to the class and you get to relate back to the class." (Fall 2012 Focus Group)*

> *" ...the field trips were very informative and interesting. They allowed us to see in reality the things we had been discussing in class and that PSU is a leader in many aspects of "green" engineering and science." (Post survey 2012)*

The students also preferred the organization of the flipped class.

During the Fall and Spring Focus Groups a number of students commented on the organization of the flipped Version 2 course – especially having the quiz the same week as the material covered.

> *"I like the idea of quizzes every week. It keeps you on top of all the information. You don't have to cram it in once every two months." (Fall 2012 Focus Group)*

> *"This is a very well organized class...For each section [module] we are given a specific due date for each part - when the assessment is due, when the homework is due, when the quiz is taken, so we know what's going on all the time." (Fall 2012 Focus Group)*

> *"I definitely like how you have to take the online assessments Sunday prior to the week of what would normally be lecture. So then you already have the lecture material done by Sunday and the whole week you can relearn it/learn it better. Just apply it." (Spring 2013 Focus Group)*

Finally, students see that this is the future of education

> *"I have the feeling that more classes are switching to this format, or at least becoming fully online classes at Penn State. I'd personally rather see more classes become flipped classes than online classes, as I feel there's more value to meeting in class to discuss things and review material and solve problems. The way online classes are currently run, from my experience, there really isn't much interaction, and I don't feel like students really get their money's worth. I've had a couple other flipped classes before this, and they have contributed to my learning more than most conventional classes I've taken. It definitely seems like an ideal format for teaching, and I hope there are more like this in the future." (Post survey 2012)*

DISCUSSION

The main goal of flipping a course is to actively engage the student during class time. By moving the lecture time out of the classroom, class time can be used for any number of activities that engage the student. In this publication, we are interested in determining students' preferences in the delivery of the flipped course. We specifically hypothesized that the refinements made, particularly the more customized and shorter videos and the use of in-class time to complete homework rather than additional problem sets, will result in more positive feedback from students. In addition we wanted to determine how student learning, as determined by Final Exam scores, was affected. Finally we wished to ascertain what specific benefits the students' observed being in a flipped classroom.

How do students interact with both on-line lectures and flipped classroom time?

The majority of students watched the online videos to obtain the technical knowledge required in this course. The students re-watched the video content for a number of reasons including: to clear up a misunderstanding, when taking the online assessment, preparing for quizzes and working on the homework assignments. Over half of the students also admitted they re-watched the videos because they were distracted the first time they watched it. Comments from students indicated that they felt more comfortable in the flipped setting and would have been more embarrassed to raise their hand for clarification in a traditional lecture classroom.

When given an option to come to class or not (in Version 2), most students still chose to come to class to participate in the problem solving activities. The largest reason for not coming to class is "being able to finish the problems on their own" or "preferring to work on their own" although students also mentioned "having other academic priorities" and "I didn't feel like coming."

What are students' preferences for on-line content delivery and use of class time?

Students prefer to use class time for problem solving rather than listening to a lecture. They prefer to watch 10 minute video segments and to spend less than 20 minutes reviewing material from the lecture. In addition we hypothesize that the refinements made, particularly the more customized and shorter videos and the use of in-class time to complete homework rather than additional problem sets, will result in more positive feedback from students. Using a Likert scale, we found that students in Version 2 were more likely to think that moving the lecture out of class was beneficial. In addition, they were less likely to state that they prefer coming to class to listen to a lecture versus watching a lecture online. In addition students in Version 2 were more likely to state that their ability to do their homework was improved because of time spent in class. This indicates that the changes to Version 2 resulted in more positive feedback from the students.

How does the type of instruction affect student learning as measured by cumulative final exam scores?

Investigation of student grade data did not demonstrate significant differences in final exam scores across semesters in which the course was taught traditionally versus in the flipped format. At minimum, the flipped format certainly did not "harm" students in terms of their grades. It is possible that the classroom flip instructional method does not impact understanding of technical content in the course, as measured by the final exam grade. However, grades are very complex, resulting from a variety of factors, some of which are external to the instructor (i.e. student motivation). Final exam score might not be the most appropriate measure to determine the impact of the classroom flip. Other measures, such as those measuring students' perceptions of classroom climate may be more likely to yield significant differences between traditional and flipped offerings of the course. Strayer (2012) began to explore the impact of flipping a statistics course on students' perceptions of climate. Exploring this in the Environmental Engineering course is planned for the next phase in our research, for which we are beginning to collect data. In addition, the benefit for students seeing the engineering concepts applied through field trips cannot be measured by a final exam.

What do the students find more valuable about the flipped course?

Based on the surveys and focus groups and the experiences of the instructor using the classroom flip for multiple, iterative semesters, we have identified four main benefits of the classroom flip. In Table 6, we list these four benefits and corresponding recommendations.

Benefits of Classroom Flip	Recommendation
The on-line video segments allow students to control their own learning of the technical content. They can watch the videos when and how they want. Most of them make use of the ability to re-watch videos in order to clarify a difficult concept.	For instructors using videos for a classroom flip, we recommend that these video segments are approximately 10 minutes in length. A shorter length will make it easier for students to further control their learning and allow them to selectively review course material. This is also collaborated by previous research.
Students benefit from using class time to work on relevant problem sets. The students feel more confident to learn and complete the required assignments when they are able to work with instructors and peers actively in the classroom.	We recommend that students be given time in class to work on relevant problems or projects that are part of the course requirements.
Flipping the class allows more time to incorporate real life applications to the course content. In this Introduction to Environmental Engineering course we were able to incorporate real life applications by using class time to go on relevant field trips. Most of these field trips were on or near the campus.	We recommend using a part of class time to bring in real life applications of the course content. This could be through the use of field trips, guest speakers, projects or discussion of current events.
Flipping the course increases the organization of the material and helps keep students on track. In Version 2, we incorporated weekly homework and in-class quizzes that corresponded with the video content. This ensured that students did not fall behind.	We recommend that flipped courses use at least weekly assessments in the form of an on-line assessment before class time and have homework assignments and in-class quizzes be due at the end of the week.

Table 6. Benefits and Recommendations for flipping a course based on our observations.

STUDY LIMITATIONS

The study has several limitations that need to be discussed. The study relies primarily on student self-reports through focus groups and surveys, which may contain potential biases. Students may not always be forthright on certain questions (for example, student may not honest about their attendance behavior). Future studies should include additional types of measures, such as tracked data on online video watching (available through many course management systems) and actual attendance data. The use of final exam scores as a direct measure of student learning also has limitations, which are discussed above. Another future study may consider examining the impact of the classroom flip through the use of external measures of student learning, such as concept inventories. The difficulty with using these tools is that most are not specifically aligned with the objectives of a specific course. However, some existing inventories have strong psychometric properties which may be appealing to use in an experimental or quasi-experimental design. This is especially true if an instrument is available in the discipline where the classroom flip is being implemented. Another limitation of this study is that we did not include any measure of prior performance or achievement levels of the students in the course.

Perhaps most importantly, these recommendations are a guide based on teaching a third-year large environmental engineering course during a 15 week semester. The specific strategies used in this course may not be appropriate or feasible in other courses or at other institutions. For example, planning field trips during class time at other institutions may be difficult if appropriate venues are not close to campus.

That being said, the classroom flip model can be easily adapted to many different course settings. In-class activities can be varied based on instructor preferences or to better suit specific course objectives. For example, some faculty members may choose to use an online assessment before every class period or use exams instead of quizzes. As another example, if a course objective emphasizes teamwork, an instructor may choose to use class time to have students work in small teams or on larger project-based learning activities. If a course objective emphasizes creativity or innovation, in-class time can be used for idea generation or for other steps in the creative process. Out-of-class time would focus on making sure students have the appropriate exposure to material that allows them to be successful in the in-class activity. Instructors interested in using the classroom flip should consider what in-class activities would suit their instructional style as well as their course objectives and adapt the model to best fit their situation.

CONCLUSIONS

Engineering faculty are faced with two challenges when teaching a large engineering class: Covering appropriate content while maintaining a classroom where students can actively interact with the technical material in order to better learn and apply it. Unfortunately these two challenges can seem mutually exclusive – class time must be used to cover content and students are left learning and applying the material on their own. One solution to this conflict is to have the students obtain new material at home through online video modules and then use class time (and faculty interaction time) to apply these new concepts. Our work has shown that students prefer this technique because they like having the flexibility to learn the new concepts on their own time and in their own way and they enjoy interacting with the faculty and students during class time. We believe that flipping a course can allow students the opportunity to become active learners in class through a variety of activities such as problem solving, guest speakers, idea generation, and field trips. The classroom flip model can be adapted to instructors to fit a variety of course settings. Instructors are encouraged to consider their own specific course, including course objectives, when determining the most appropriate in-class activities.

ACKNOWLEDGEMENTS

The authors would like to thank the Leonhard Center for the Enhancement of Engineering Education at Penn State for providing funding support for this project. In addition, we would like to thank Roxanne Toto, e-Learning Specialist in the Leonhard Center, for assistance with development and delivery of online surveys.

REFERENCES

Anderson, L. W. & Krathwohl, D. R. (eds.) (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* New York: Longman.

Baker, J. W. (2000). The "classroom flip": Using web course management tools to become the guide by the side. Paper presented at the 11th International Conference on College Teaching and Learning, Jacksonville, FL.

Bergmann, J. & Sams, A. (2012). *Flip Your Classroom: Reach Every Student in Every Class Every Day.* Washington, D.C.: International Society for Technology in Education.

Bland, L. (June, 2006). Applying flip/inverted classroom model in electrical engineering to establish life-long learning. Paper presented at the annual meeting of the American Society for Engineering Education, Chicago, IL.

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science.* 73–105.

Dollar, A., & Steif, P. (June, 2009). A web-based statics course used in an inverted classroom. Paper presented at the annual conference for the American Society for Engineering Education, Austin, TX.

Dollar, A., Ulseth, R. R., & Steif, P.S. (June, 2011). Blending interactive courseware into statics courses and assessing the outcome at different institutions. Paper presented at the annual meeting of the American Society for Engineering Education, Vancouver, B.C.

Demetry, C. (October, 2010). Work in Progress – An Innovative Merging "Classroom Flip" and Team-Based Learning. Paper presented at the annual meeting of Frontiers in Education, Washington, D.C.

Entwistle, N. (November, 2000). Promoting deep learning through teaching and assessment: conceptual frameworks and educational contexts. Paper presented at the Teaching and Learning Research Programme Conference, Leicester, United Kingdom.

Entwistle, N. J. & Peterson, E. R. (2004). Conceptions of learning and knowledge in higher education: Relationships with study behaviour and influences of learning environments. *International Journal of Educational Research.* 41(6): 407-428.

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

Gannod, G. C. (October, 2007). Work in Progress – Using podcasting in an inverted classroom. Paper presented at the annual meeting of Frontiers in Education, Milwaukee, WI.

Gannod, G. C., Burge, J. E., & Helmick, M. T. (2008). Using the inverted classroom to teach software engineering. Proceedings of the annual International Conference on Software Engineering. Leipzig, Germany.

Hake, R. R. (1998). Interactive-engagement versus traditional methods. A six-thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics,* 66 (1), 64–75.

Kellogg, S. (October, 2009). Developing online materials to facilitate an inverted classroom approach. Paper presented at the annual Frontiers in Education Conference, San Antonio, TX.

King, A. (1993). From sage on the stage to guide on the side. *College Teaching,* 41, 30–35..

Lage, M. J., & Platt, G. J. (2000). The internet and the inverted classroom. *Journal of Economic Education*, 31, 11.

Lage, M. J., Platt, G. J., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *Journal of Economic Education*, 31, 30–43.

Laman, J., Brannon, M., & Mena, I. (June, 2012). Classroom Flip in a Senior-Level Engineering Course and Comparison to Previous Version. Paper presented at the annual conference of the American Society for Engineering Education, San Antonio, TX.

Leicht, R., Zappe, S. E., Messner, J. & Litzinger, T. (2012). Employing the classroom flip to move "lecture" out of the classroom. *Journal of Applications and Practices in Engineering Education.* 3(1), 18–31.

Michael, J. (2007). Faculty perceptions about barriers to active learning. *College Teaching. (55)*2: 42–47.

Novak, G., Gavrin, A., Wolfgang, C., & Patterson, E. (1999). Just-in-Time Teaching: Blending Active Learning with Web Technology. Prentice Hall.

Papadopoulos, C. & Santiago-Román, A. (June, 2010). Implementing an inverted classroom model in engineering statics: Initial results. Paper presented at the annual conference of the American Society for Engineering Education. PLACE.

Papadopoulos, C., Santiago-Román, A., & Portela, G. (October, 2010). Work in Progress – Developing and implementing an inverted classroom for engineering statics. Paper presented at the annual meeting of Frontiers in Education, Washington, D.C.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education. 9*3(3), 223–231.

Steif, P.S. & Dollar, A. (June, 2012). Relating usage of web-based learning materials to learning progress. Paper presented at the annual conference of the American Society for Engineering Education, San Antonio, TX.

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation, and task orientation. *Learning Environment Research.* 15: 171–193.

Talbert, R. (June, 2012). Learning MATLAB in the inverted classroom. Paper presented at the annual conference of the American Society for Engineering Education, San Antonio, TX.

Thomas, J. S. & Philpot, T.A. (June, 2012). An inverted teaching model for a mechanics of materials course. Paper presented at the annual conference of the American Society for Engineering Education, San Antonio, TX.

Toto, R. & Nguyen, H. (October, 2009). Flipping the work design in an industrial engineering course. Paper presented at the annual meeting of Frontiers in Education, San Antonio, TX.

Warter-Perez, N. & Dong, J. (2012). Flipping the classroom: How to embed inquiry and design projects into a digital engineering lecture. Proceedings of the 2012 ASEE Pacific Southwest Section Section Conference, San Luis Obispo, California.

Zappe, S. E., Leicht, R., Messner, J., & Litzinger, T. (June, 2009). "Flipping" the Classroom to Explore Active Learning in a Large Undergraduate Course. Paper presented at the annual conference of the American Society for Engineering Education, Austin, TX.

AUTHORS

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Sarah E. Zappe is Director of Assessment and Instructional Support in the Leonhard Center for the Enhancement of Engineering Education at Penn State University. Dr. Zappe holds a doctorate in educational psychology specializing in applied testing and measurement. In her position, Dr. Zappe is responsible for supporting curricular assessment and developing instructional support programs for faculty in the College of Engineering. In her research role, Dr. Zappe is interested in the integration of creativity into the engineering curriculum, innovation, and entrepreneurship. Her measurement interests include the development of instruments to measure the engineering professional skills and using qualitative data to enhance the response process validity of tests and instruments.

Emily Mahoney graduated from the Schreyer Honors College at the Pennsylvania State University in December 2013 with a Bachelor of Science in Civil Engineering. Her Honors hesis was titled: The Impact of the Classroom Flip on Student Motivation. She was the teaching intern for the course discussed in this paper for four semesters from Spring 2012 through Fall 2013. Emily now works at Langan Engineering & Environmental Services as a civil engineer in their land development group.

APPENDIX A: POST-SEMESTER REFLECTION SURVEY FOR VERSION 1

1. There were 40 lectures posted on-line. How many did you watch?
   a. 0 – 10
   b. 11 – 15
   c. 16 – 20
   d. 21 – 25
   e. 26 – 30
   f. 31 – 35
   g. 36 - 40
2. How many times during the semester did you watch a lecture video more than one time? (e.g. before the Final Exam or for help on homework assignments.)
   a. 0 times
   b. 1 time
   c. 2 times
   d. 3 times
   e. More than 4 times
3. Did you review portions of the lecture that seemed unclear to you?
   (Almost always, Often, Sometimes, Rarely, Never)
4. Did you watch the video straight through, or watch it in pieces and take breaks?
   a. Straight through
   b. Pieces
   c. Straight through, then reviewed unclear pieces
   d. All in one sitting, but I would pause and review certain sections
   e. none of these
5. Each lecture is 50 minutes long. How long did you typically spend watching the lectures at one sitting?
   a. less than 10 mins,
   b. 15 mins
   c. 20 mins
   d. 30 mins
   e. 45 mins
   f. 1 Hour
   g. More than 1 hour

6. What length of posted lectures would you find optimum?
   a. 10 min
   b. 20 min
   c. 30 min
   d. 40 min
   e. 50 min
   f. 1 hour
7. How many weeks did you miss at least one lecture (never watched it or watched it late)
8. How many weeks did you miss at least one lecture (never watched it or watched it late). Number of weeks; _______________
9. Did you find the time spent in class problem solving helpful to your understanding of the concepts? (Yes, Somewhat, No)
10. If yes or somewhat, please explain what you found most valuable.
11. As a Professional Engineer you will be required to have 30 hours every 2 years to maintain your license. At this point how likely are you to obtain these hours in the following ways. (not sure, unlikely, somewhat unlikely, likely, very likely)
   a. On-line webinars (1 – 3 hour on-line lectures)
   b. Attend a certification live class
   c. Attend a technical conference
   d. Attend a university seminar
   e. Teach a technical course

Please rate how much you agree with the following statements (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

12. I prefer to coming to class to listen to a lecture vs. watching a lecture on-line.
13. I would prefer to use class time for problem solving activities, rather than listening to a lecture.
14. There were a number of times during the on-line lectures that I would have asked a question if I were able.
15. It was easy to get distracted when listening to the video lecture.
16. Too much time was dedicated to the in-class activities.

17. My understanding of the estimating methods was improved because of the additional time spent problem solving in class.
18. I felt prepared to complete problems in class after listening to the video content.
19. I feel that moving lecture material out of class and having more time to work in groups in practicum is a beneficial use of course time.
20. The online quizzes were beneficial for my understanding of the course material.
21. I would have watched the videos if we were not required to take quizzes on the material.

How do student's current interact with their peers outside of class?

22. Working with other students in the smaller groups helped me
23. I understand the concepts in the class.
24. I often let others lead the problem solving in class.
25. I often felt lost in my group.
26. I was often the leader in the problem solving in the class.
27. I thought that some of the students did not participate enough in the problem solving in class.
28. There are 7 homework assignments in this course. For how many of these assignments did you work with students outside the classroom?
    a. 0
    b. 1
    c. 2
    d. 3
    e. 4
    f. 5
    g. 6
    h. 7

APPENDIX B: POST-SEMESTER REFLECTION SURVEY FOR VERSION 2

1. If Dr. Velegol were teaching another course in your major both as a traditional course and as a flipped course, which one would you choose?
   Traditional
   Flipped
2. Please briefly explain your reasons for this choice.
3. For CE 370 with Dr. Velegol, which is a better use of class time?
   Reviewing Online Lectures
   Problem-Solving
4. How long should Dr. Velegol spend on reviewing the modules in class?
   0 min, 1-10 min, 11-20 min, 21-30 min, 31-40 min, 41-50 min
5. What other things would you have preferred to do during classtime?
6. Given the choice, which module schedule would you prefer?
   Four - 30 minute videos
   Six - 20 minute videos
   Twelve - 10 minute videos
   Twenty-four - 5 minute videos
7. How many of the 11 modules did you watch completely?
   (0, 1-2, 3-4, 5-6, 7-8, 9-10, 11)
8. How many of the 132 video sections did you watch more than once?
   (0, 1-10, 11-30, 31-60, 61-100, 101-132)
9. What were your reasons for re-watching the video sections (select all that apply)?
   a. Review for quiz
   b. Help with problem sets
   c. To clear-up a misunderstanding
   d. Other
10. We met as a group (without quizzes) about 20 times for in-class problem solving. How many of these class times did you miss during the semester?
    0, 1-2, 3- 5, 6-9, 10 – 15, 16-20
11. What were your reasons for missing class?
    Was able to finish problem set on my own
    Prefer to work on the problems at home

Illness

Interviews

Didn't feel like coming

Other

12. How many class times did you miss in other courses in your major this semester?

    Much less than in this class

    Less than in this class

    About the same as in this class

    More than in this class

    Much more than in this class

13. How many times were you able to complete your homework during classtime?

    0 (I did not attend class to work on homework)

    0 (I attended class but was not able to complete my homework)

    1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Please indicate your level of agreement/disagreement with the following statements (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

14. I feel confident in my ability to use the material learned in this course to solve course problems.
15. I feel confident in my ability to use the material learned in this course to solve problems in my future career.
16. I feel confident in my ability to use the material learned in this course to solve problems in my other courses.
17. I feel confident in my ability to use the material learned in this course to solve important problems in the field.
18. I feel more comfortable taking an online course having taken this flipped course.
19. I feel more comfortable taking a flipped course having taken this flipped course.
20. I feel more comfortable taking a MOOC having taken this flipped course.
21. This course is more structurally organized than my other courses.
22. The format of this class makes me feel more comfortable asking questions/interacting with my professors.
23. The format of this class makes me feel more comfortable asking questions/interacting with my peers.
24. Open Comment Box

APPENDIX C: FOCUS GROUP QUESTIONS FOR V2 (FALL 2012)

(Given to students in flipped class only)

Why are you taking this class?

Would you take this class if you weren't required to? Why?

What were your goals going into this course?

What was your primary motivation to achieve this/these goals?

What value do you see in this course?

Value definition: in other words, what do you feel you might be getting out of this course either personally or professionally?

From a professional standpoint, which part of this course has the most value (ie you'll be most likely to use in the future)?

Was this what you initially thought?

How has this course changed your opinion on Environmental Engineering, if at all?

What other CE classes have you taken/are you currently taking?

Describe the structure of this/these courses.

What aspect of 370's flipped structure has been most beneficial to your learning in comparison to this other course?

What aspect of 370's flipped structure has been least beneficial to your learning in comparison to this other course?

Pretend this course is taught in the same format by another professor. **If students mention teacher attitude.**

How would you describe the classroom environment in CE 370?

For example, how do you feel that the instructor interacts with students in the class?

Do you feel that the environment is support or unsupportive to your learning?

Describe why you feel this way.

Open Forum ending

APPENDIX D: FOCUS GROUP QUESTIONS FOR V2 (SPRING 2013)

(Given to 4 students who had the same instructor for both a flipped class and a traditional lecture-based course.)

Why are you taking this class?

Would you take this class if you weren't required to? Why?

What were your goals going into this course?

What was your primary motivation to achieve this/these goals?

What value do you see in this course?

Value definition: in other words, what do you feel you might be getting out of this course either personally or professionally?

From a professional standpoint, which of these courses has the most value? Why?

In which course do you feel more able to do well? Why?

What aspect of 370's flipped structure has been most beneficial to your learning in comparison to 371?

What aspect of 370's flipped structure has been least beneficial to your learning in comparison to 371?

How would you describe the classroom environment in CE 371 compared to CE 370? For example, how do you feel that the instructor interacts with students in the class?

Do you feel that the environment is support or unsupportive to your learning?

Describe why you feel this way.

Open Forum ending