Highlights and Lessons Learned from a Partially Flipped Civil Engineering Classroom Study

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Introduction and Rationale

To handle the complex challenges associated with engineering and other STEM fields, it is important that students engage higher-order cognitive skills including the ability to critically analyze, conceptualize, and synthesize knowledge. Bloom and Krathwohl's taxonomy [1], [2], [3] measures a student's level of understanding based on the following six cognitive levels (from lowest to highest): 1) remember, 2) understand, 3) apply, 4) analyze, 5) evaluate, and 6) create. The American Society for Civil Engineers (ASCE) adopted Bloom's taxonomy to define levels of achievement associated with the body of knowledge necessary for entry into civil engineering professional practice [4]. Additionally, the Accreditation Board for Engineering and Technology (ABET) currently requires the evaluation of student outcomes that rely on the higher levels of Bloom's taxonomy [5].

In a *traditional* classroom environment, students are typically introduced to course content using methods associated with the lower levels of Bloom's taxonomy as the instructor states, repeats, describes, and/or discusses factual and conceptual information in person. Consistent student feedback indicates that engineering students commonly want instructors to slow down the pace, work more numerical examples, and use real world applications. However, most engineering classes are content heavy so it is difficult to provide students with time to practice concepts and reinforce fundamental concepts in a traditional classroom. Due to pace and lack of time, many students report that they 'write down now and learn later'. Subsequently, students are expected to practice the higher levels of the Bloom's taxonomy on their own. Homework assignments are assigned to help students solve problems, implement strategies, and/or demonstrate that they have learned the concepts presented in the classroom. In other words, instructors teach the material using methods associated with lower levels of Bloom's taxonomy, but expect the students to function on their own at higher levels without sufficient opportunity to practice the concepts.

In general, a *flipped* classroom enables the student to begin the learning process prior to class and at their own pace (e.g., video content is commonly utilized). Subsequently, students use the in-class time to participate in active learning strategies that involve them more directly in the learning process, provide students with more direct guidance from the instructor, and encourage group work. When an instructor serves as a guide (instead of a lecturer) inside the classroom, students feel supported and engaged. They build confidence in their own skills, and they can more easily move forward to accomplish homework on their own.

This study evaluated the use of a Partially Flipped Classroom (PFC) teaching model using mixed methods, control group design. The PFC instructional model was piloted and evaluated at UNC Charlotte in a required geotechnical engineering course to determine if the PFC instructional model 1) would impact student performance and gains, 2) had the potential to increase cognitive levels of learning in accordance with Bloom's taxonomy, and 3) more effectively used the classroom time to enable active learning and promote student engagement.

Literature Review

Research in all fields of STEM indicates that comprehension of the material is increased when students participate in active learning [6], [7], [8], [9], and take ownership in the learning process instead of serving as passive recipients of information [10], [11], [12]. Much of the literature focuses on what the instructor is ‘going to do to deliver content’ instead of focusing on ‘how best to get a student engaged with the content’ and/or take responsibility for their own learning [13]. Active learning techniques increase their ability to apply skills, solve problems [14], and will likely lead to increased gains [15]. Because engineering courses are both challenging and heavy in technical content, it is difficult to find adequate time to incorporate active learning techniques [16].

While some authors reported early efforts to flip engineering classrooms [17], [18], [19], flipped classroom methods gained popularity in more recent years. Varying methods have been described in the literature [20], [21], [22], [23]. In theory, flipped classroom models can potentially make effective use of time, technology, and accommodate various learning styles [17], [24], [25]. They are designed to help students become self-directed learners [15], [24], foster collaborative and personalized learning [17], [26], increase engagement and student-faculty interaction [15], [25], [26], [27], and have been shown to improve student performance [17], [24], [28], [29], [30], [31]. Students appreciate the ability to re-watch videos [27] [29], interact more directly with the instructor [31], utilize class time used to work additional problems and activities [32], [24], and improve their performance on quizzes and tests [24]. One study highlighted their ability to customize classroom activities based on student struggles and learning styles [23]. Other studies confirmed that active learning principles driven by the flipped classroom model lead to an increase in student performance in comparison to a traditional lecture model [33], [34], [35], [36], [37].

Flipped classroom studies measuring student performance and/or student perceptions of the instructional model have also shown mixed results [6], [13], [30], [31]. The author of [38] quoted, “Flipping the classroom is not simply about shifting lectures out of the classroom…it must involve students as active learners, shifting control of both learning and the classroom from the instructor to the students…it should promote a focus of higher-order cognitive work”. The same author stressed the importance of the on-line content and the face-to-face interactions supporting each other [38]. The literature indicates that flipped classroom studies are inconsistent in their design. It is not clear which studies accomplish the important criteria outlined by [38]. At the conclusion of a study involving the review of 24 flipped classrooms [20], the authors encouraged future research to include performance measures and controlled study designs.

While most flipped classroom studies do not provide assessment data related to level of cognition, select studies demonstrate that students engaged in active learning improve their higher-order thinking and problem solving skills [6], [7], [30], [36], [39], [40]. For example, students in a flipped classroom performed better than those in the control group on course projects that involved a deeper evaluation of the material and, therefore, higher-order learning [30]. The same study found little difference in performance involving lower-order learning outcomes, but valued the fact that flipped models always provided students with increased time to interact and discuss.

Research Design

This study investigates the impacts of a Partially Flipped Classroom (PFC) model in a junior level civil engineering course required for a BSCE degree at UNC Charlotte. The material was divided into four 'content modules': 1) soil structure, classification, compaction, and exploration; 2) seepage and soil stresses; 3) consolidation settlement; and 4) shear strength fundamentals and applications. Students were tested on each content module. The control and treatment groups were conducted during the fall 2018 and spring 2019 semesters, respectively. Content coverage, course notes, learning objectives, student expectations, and assessment instruments were identical for both groups. To pilot the new instructional model, the instructor of this course elected to flip four select course topics: soil compaction fundamentals, 2D soil seepage fundamentals, consolidation settlement calculations, and shear strength fundamentals. Researchers recommend 'starting small' due to the preparation required to prepare video content and the challenges associated with implementation. In general, this study was designed to evaluate the impacts of increased active learning in the classroom, measure differences in student performance between the control and treatment groups, determine the potential for treatment students to exhibit increased levels of learning from the PFC format, evaluate student perceptions of the new model, and identify and overcome challenges associated with implementing a PFC model. While the full details of this research design are provided in a previous paper [41], this paper will focus on select highlights of the quantitative and qualitative results.

With the exception of the flipped lectures that were created for the treatment group, the instructor taught both the control and treatment groups using standard lecture format with supplemental examples, as time permitted. In general, the instructor prepared and expected the students to print out a set of partially completed course notes that contained the backbone of all lectures. These notes included blank spaces to complete their notes, highlight discussion details, and work examples. The course notes were displayed on a document camera while the instructor lectured at the front of a traditional classroom. Notes and examples were completed while class discussion took place. The number of practical examples and the ability to use class props and/or demonstrations were dependent upon topic and available time in class.

The instructor utilized the Academic Multimedia Production Team on campus to create professional videos for the flipped lectures. The camera was configured to view a table top setting and record (audio and visual) the lecture while the instructor filled in the course notes (as if in the classroom). Figure 1 displays an example from a compaction fundamentals video (left side of Figure 1) and a sample from a shear strength testing video (right side of the same figure). This configuration enabled the treatment group students watching video content to take notes during the video just like they would in the classroom. It is important to note that the treatment group students had the benefit of pausing the video and/or replaying the video as needed to confirm details. The pace was controlled by the student, which is particularly helpful for students that normally struggle with pace, and specifically, for student with learning disabilities.

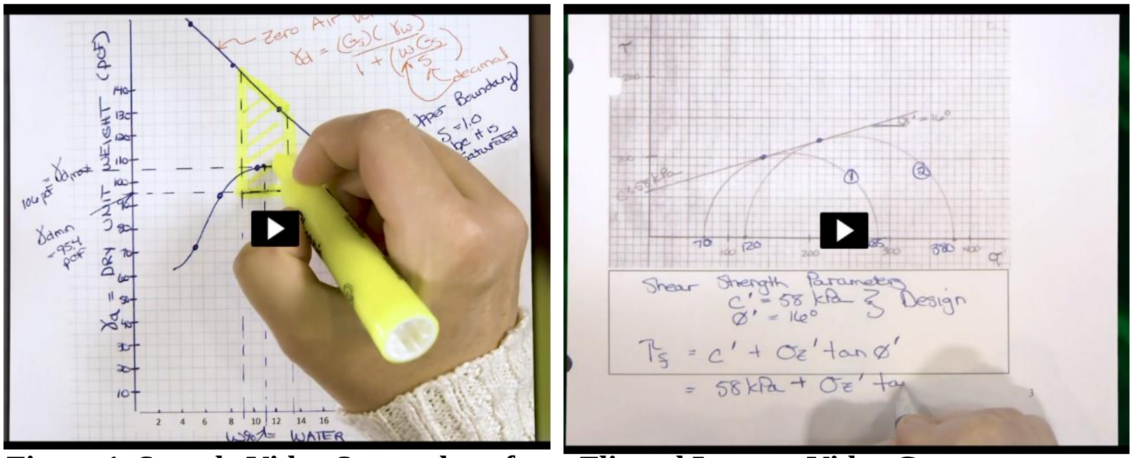


Figure 1. Sample Video Screenshots from Flipped Lecture Video Content.

Not only did the video content provide students with a resource to review at their own pace, it cleared up time inside of the flipped classroom to work additional examples, address confusions, and facilitate both student-faculty and student-student interactions. To ensure participation, treatment group students were required to complete a quiz covering the video content watched. Post-video surveys were also conducted to collect feedback. The classes immediately following the required video lectures were structured to: 1) answer immediate questions from the video, 2) reinforce the most important concepts with a mini (e.g., 5-10 minute) lecture, and 3) have students work problems in small groups as the instructor rotated around the classroom. Table 1 details the activities that were conducted during each post-video class.

Table 1. Post-Video Classroom Activities by Content Module.

Content Module 1: Compaction Fundamental	Students watched a full lecture on compaction: Compaction Fundamentals (11 minutes) and Compaction Curve and Specifications (25 minutes). 1. Instructor led a mini-review on the important components of a compaction curve (10 min). 2. Students completed 7 compaction problems designed to increase their comprehension of the fundamentals (65 min). Permitted to work with one other person but some groups combined during discussion.
Content Module 2: 2D Seepage Fundamentals	Students watched a lecture and example on 2D seepage: 2D Seepage Fundamentals (22 minutes) and Flow Net Example (11 minutes). 1. Instructor led a mini-review of 1D and 2D seepage fundamentals using page 1 of a handout, answering 9 problems together using active questioning techniques (25 minutes) 2. Students completed 7 2D seepage problems to review the calculations associated with a flow net (50 minutes). Permitted to work with one other person but some groups combined during discussion.
Content Module 3: Consolidation Fundamentals	Students watched a full lecture on consolidation fundamentals (40 minutes). 1. Instructor led a mini-review on the consolidation process (10 minutes). 2. Students completed a 3 page handout with 21 questions designed to lead them through the consolidation fundamentals and process. They were asked to work on their own and ask the instructor when they had questions.
Content Module 4: Shear Strength Fundamentals	Students watched 3 full lectures on shear strength: Direct Shear Testing (25 minutes), Triaxial Shear Testing (35 minutes), and Unconfined Compression Testing (13 minutes). 1. Instructor led a review of the different shear strength tests and their failure curves on the surrounding blackboards in the classroom and included a discussion of drained versus undrained behaviors. Instructor engaged the students fully during this time with active questioning to fill the boards up and demonstrated differences between the tests. 2. Instructor worked 1 example for the students. 3. Students completed 2 shear strength problems. Permitted to work with one other person but some groups combined during discussion.

Participants

Participants of this study included the instructor of the course and 96 consenting undergraduate students enrolled in two semesters of a required geotechnical engineering course at a southeastern urban research university in the United States. This study was approved by the Institutional Review Board at UNC Charlotte. There were 42 out of 44 students (95.5%) that elected to participate during the first semester (control group) and there were 54 out of 55 students (98.2%) that elected to participate during the second semester (treatment group). Of the 99 students that registered during these two semesters, approximately 97% elected to participate in this study. The control group student sample had 84.4% males and 8.9% females while the treatment group student sample had 64.3% males and 32.1% females. Out of the 96 consenting students, 77.08% were male and 22.91% were female. The demographic distribution of each student group is presented in Table 2. There were 52 juniors, 43 seniors, and 1 graduate student that participated in this study and the distribution of age was approximately normal with a mean of 22.45 years and a standard deviation of 3.72 years.

Table 2. Summary Demographics of the Participating Students.

	Control	Treatment
Caucasian	66.7%	64.3%
African American	4.4%	7.1%
Hispanic	6.7%	10.7%
Other	15.6%	10.7%
Enrolled	44	55
Participants	42	54

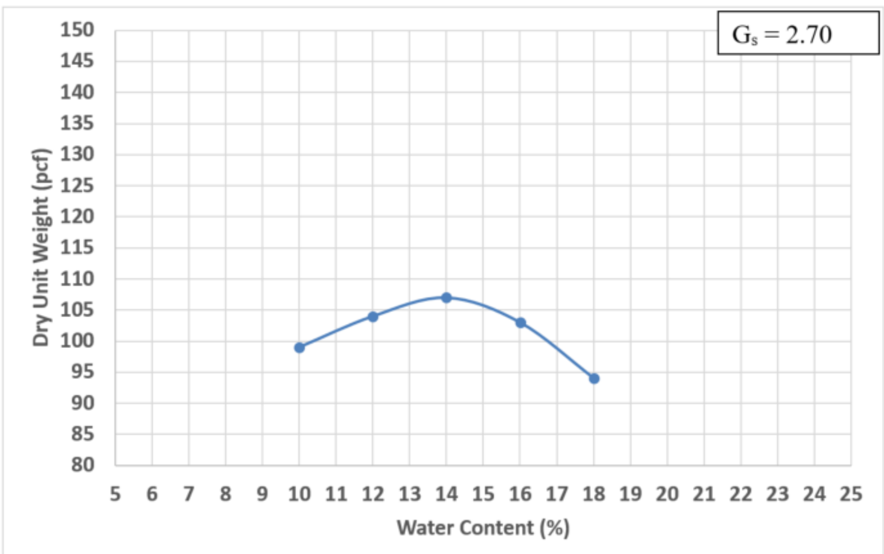
Evaluation Plan

A psychology graduate student with expertise in quantitative analysis from the College of Education served as the program evaluator for this study under the guidance of Dr. Chuang Wang, an education assessment expert and Professor in the College of Education at UNC Charlotte. The evaluation plan, which included both quantitative and qualitative assessment instrumentation, was developed to evaluate the educational impacts of flipping specific lectures. The skills, perceptions, and gains developed by student participants in a control group were compared to the same data collected from the treatment group. While all quantitative instrumentation questions were identical for the control and treatment groups, it is important to note that this methodology assumed the overall intellect of the students was equivalent across student samples and, therefore, comparable when analyzed as a control group versus a treatment group. Extensive data were collected from the students via online survey and from their student files to evaluate individual differences including demographic information, previous employment experiences, credit hours completed, and cumulative Grade Point Average (GPA).

Quantitative Test Data

To evaluate whether the PFC instructional model impacted the students ability gain a deeper understanding of the concepts on the content module tests, the assessment criteria for each test problem associated with a flipped topic was coded by difficulty in line with the Levels associated with Bloom's taxonomy. As an example, Figure 2 displays a test problem for the flipped topic of compaction in content module 1. Table 3 displays the assessment rubric this test problem. The Bloom's Level associated with each assessment criteria is identified in the second column of Table 3. There were fewer criteria to evaluate for Level 4 and no criteria that could be coded Level 5 or 6. A description of the grading scheme is provided in the last column to ensure consistency during the evaluation process.

Problem 5 (20 points)



a. Assuming a relative compaction value of 95%, calculate the minimum dry unit weight that an inspector would need to read on a nuclear gage to 'pass' the inspection. Place a box around your final answer (don't forget units).

b. Assuming optimum moisture conditions, what is the maximum possible dry unit weight that can be achieved using compaction for this soil?

c. If the specifications require the water content to be within 2% of the optimum value, determine and shade in the full 'acceptable range' on the figure above (as discussed in class). You must show the work necessary and label the coordinates associated with the 4 corners of the 'acceptable range'. You do not need to conduct any calculations that are outside of the 'acceptable range' for this problem (don't waste time completing work that is not needed.

Figure 2. Content Module 1 Test Problem for Flipped Topic.

Table 3. Evaluation Rubric for the Content Module 1 Test Problem (Compaction).

Part	Bloom's Taxonomy Level	Assessment Criteria	Likert Scale
(a)	4	Examine correct equation for $\gamma_{d(min)}$	0 = No work 1 = Method and/or understanding significantly below standard 2 = Touches on right method but significant errors in concept 3 = Correct method with minor errors in concept 4 = Correct method with simple mistakes but understand concept full 5 = 100% correct
	3	Interpret $\gamma_{d(max)}$	
	3	Execute the equation	
	1	Report units	
(b)	4	Examine correct zero air void line equation	
	1	Remember to use specific gravity in equation	
	3	Interpret optimum water content	
	2	Identify S = 1.0 for the zero air void line	
	3	Execute the equation	
	1	Report units	
(c)	4	Differentiate acceptable compaction range	
	3	Interpret 2% of optimum water content	
	3	Calculate 4 coordinates	

For the quantitative analysis presented in this paper, average performance data for all participants and for all four test problems associated with flipped content were combined, and the performance of the control group was compared to the performance of the treatment group, collapsed by Bloom's levels 1-4. As part of the following analysis, three potential covariates were considered: 1) the student's self-reported previous experience with flipped courses, 2) whether the student was a transfer student or native incoming freshman, and 3) cumulative GPA. There were no statistically significant differences between the students grouped on these variables ($\chi2$ (df =1) = 0.25, p = .62; $\chi2$ (df =1) = 0.08, p = 0.78).

Subsequently, two-way ANOVAs were conducted to see if significant differences existed between the groups on these potential covariates and the interaction of them on the outcomes. This analysis yielded no significant differences on any of the dependent variables so these covariates were not included in the final model (p > .05). GPA was also considered as a covariate; the relationship between each dependent variable and GPA was tested via scatterplots (i.e., to check for linearity). Scatterplots revealed that GPA does not have a linear relationship with any of the outcomes, and therefore was excluded from the following analyses as a covariate.

Assumption checks were performed for a multivariate analysis of variance (MANOVA). The assumption of independence of observations and independent observations were met in this analysis. Box's test of equality of covariance matrices violated the assumption of homogeneity

(Box's M = 37.39, F (10, 39863.67) = 3.57, $p < .0001$). However, MANOVA is robust on this assumption. Stem and leaf and box plots of the dependent variables indicate that there are no univariate or multivariate outliers in either group. Additionally, examination of Mahalanobis distances revealed no problems with multivariate outliers ($p > .001$).

Results from MANOVA suggested a statistically significant difference in performance based on group (i.e., treatment or control), (F (4, 92) = 5.912, $p < .001$; Wilk's Λ= 0.796, partial $\eta^2 = .204$). Students exposed to the partially flipped topics had statistically significant better performance on both Bloom's Level 2 (F 1, 95) = 14.143; $p < .001$; partial $\eta^2 = .13$) and Bloom's Level 3 (F (1, 95) = 9.582; $p < .01$; partial $\eta^2 = .092$) coded criteria. Specifically, the control group performed, on average, 10.087 points lower than the treatment group on Bloom's level 2 (understand) and 6.974 points lower, on average, on Bloom's Level 3 (apply). Figure 3 displays these results graphically.

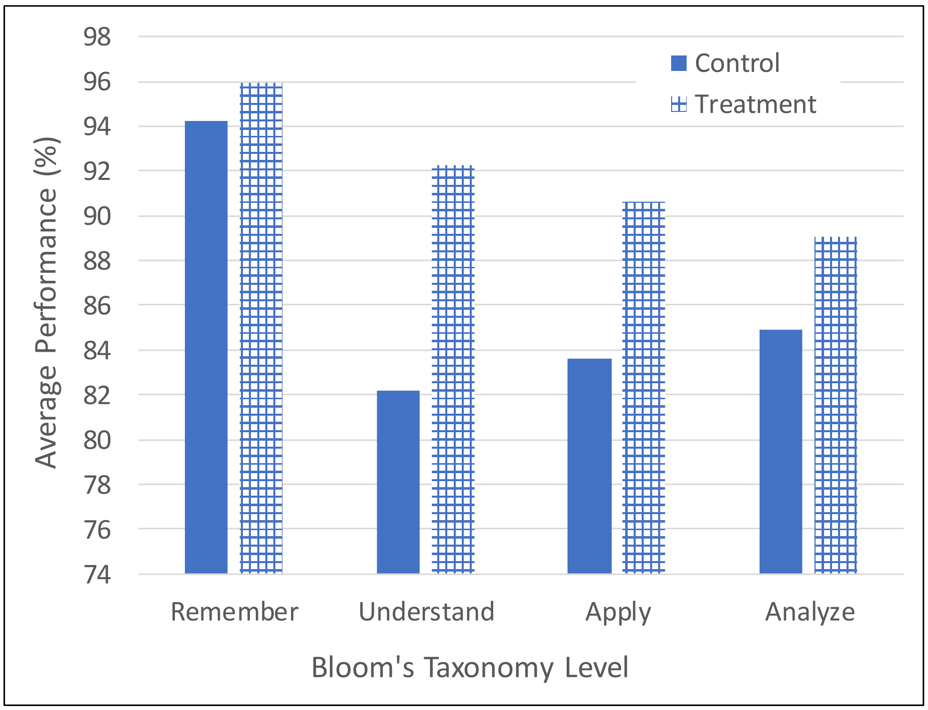


Figure 3. Average Performance on Flipped Topic Test Questions by Bloom's Level.

Quantitative Survey Data

All students participated in a survey at the end of the semester to provide feedback on perceived clarity of instruction, knowledge gains, level of engagement during class, instructional pace, quality of interactions with the instructor, enthusiasm for group activities in the classroom, their comfort level with the use of technology in a course, experience with flipped classes, preferred learning styles, teaching/delivery methods, and study/preparation methods. Treatment group students answered additional questions regarding use of technology, instructional pace and level of engagement during the video and during the subsequent class, and the alignment of classroom activities with material presented in the video. Survey questions were either multiple choice or had a Likert scale where '1' stood for "strongly disagree" and '5' stood for "strongly agree". The intention of the survey was to determine if there were significant differences in the feedback and perceptions recorded by the control group in comparison to the treatment group.

Chi Square tests were performed on student responses to each survey question at the end of the semester. This paper highlights the statistically significant differences of the following three survey responses between the control group and the treatment group.

1. Survey Question: "*If given the opportunity to choose, my preferred delivery method for a CE course like this one is*:" Most (78.9%) treatment group students preferred some degree of content flipping whereas most (61.4%) control group students preferred traditional lecture with or without instructor interaction, $\chi 2$ (df =2) = 16.01, $p < .001$.
2. Survey Question: "*When given the opportunity to work example problems in class, I learn best when:*" Most (57.9%) treatment group students reported that they learned best when examples were worked in small groups and/or with the instructor whereas most (72.7%) control group students reported that they learned best when the instructor led the example, $\chi 2$ (df =2) = 20.34, $p < .001$.
3. Survey Question: How strongly do you agree or disagree to this statement: *"I am enthusiastic about online resources as part of a course:"* Most (68.5%) treatment group students held positive (agree or strongly agree) attitudes toward online resources as part of the course whereas only a small portion (25.0%) control group students held such attitudes, $\chi 2$ (df =4) = 17.78, $p < .001$.

Qualitative Focus Group Interview Data

A focus group interview (three students per group) was conducted by the evaluator at the completion of each of the four selected topics during both the control and treatment group semesters. This resulted in 24 student volunteers and eight focus interviews. The control group student perceptions of the standard lecture style were compared to the perceptions of the treatment group students who experienced flipped classroom instruction on these four select topics. The evaluator systematically asked questions from a focus group guide, and enabled the students to speak freely about their experiences inside and outside of the classroom. All interviews are recorded and transcribed verbatim by the evaluator. These data were analyzed using a constant comparison method from grounded theory where statements are grouped by common themes. The emerging themes were adapted during the data analysis procedure.

Table 4 summarizes student feedback by emerging theme while comparing conventional delivery to flipped delivery. Feedback was solicited from both focus group participants and informal student surveys administered at various times during the semester. The symbols added to the last column of the table serve only as visual indicators of perceived changes (improvements) as a result of the PFC instructional model. An upward arrow indicates a notable improvement and the double arrow next to the last emerging theme in Table 4 indicates some improvement but more adjustments are needed.

Table 4. Focus Group Feedback Summarized (Conventional versus Flipped Delivery)

Conventional Lecture Delivery	Flipped Classroom Delivery	Result
Course Notes: Course notes were a good learning tool, helped students stay focused, enabled the class to keep up with the pace of the course, and provided a useful reference.	*Course Notes:* Course notes were a good learning tool, helped students stay focused, enabled the class to keep up with the pace of the course, and provided a useful reference.	=
Instruction and Pace: Some students felt the pace was on par but others felt it was a little fast. Due to the pace, students focused on completing the course notes during the lecture, and then worked on their understanding the material after class and before tests.	*Instruction and Pace:* Students appreciated having the ability to watch the video content at their own pace while stopping, digesting, and/or re-watching content as needed. During the post-video class, students valued the time available to work problems on their own, discuss issues with their peers, and interact directly with the instructor.	↑
Comprehension: Students reported that they don't always comprehend the concepts presented for the first time in class and can struggle when they begin homework on their own. Course notes served as a good resource.	*Comprehension:* Students who watched video content felt more prepared in class and were more comfortable working with other students. The additional time spent working problems in the post-video class and the additional guidance received from both instructor and peers helped them better understand difficult concepts.	↑
Classroom Activities: The limited examples led by the instructor were helpful, but students expressed the need for additional examples. They see benefits in getting help from their peers or working problems together as long as they have the ability to see the problem prior to class so they can digest and feel like they have something to offer. They also appreciated physical demonstrations and liked when the instructor moved around the classroom.	*Classroom Activities:* Students valued the additional time to work more problems in the post-video class. More specifically, they liked working problems on their own and discussing issues with their peers. They liked having the instructor circulate and clear up confusions during this class period. They indicated that they did not feel anxiety about working in small groups because they felt more prepared after the video. They also appreciated physical demonstrations and liked when the instructor moved around the classroom.	↑
Instructor Interactions: Students generally felt the instructor was organized, structured, responsive to student needs, held high expectations for the students, and was passionate about teaching.	*Instructor Interactions:* Students generally felt the instructor was organized, structured, responsive to student needs, held high expectations for the students, and was passionate about teaching.	=
Time Management: Students generally felt that the course was managed well, but would like additional time to work examples either in class or via additional workshop sessions.	*Time Management:* Students generally felt that the course was managed well, and appreciated the opportunities to work problems in the post-video class. As the semester progressed, students offered suggestions regarding what they liked and what could be improved to better utilize the time during the post-video class. They stressed the value of working problems on their own, self-directed learning, and the value of interactions with the instructor and peers. Some specifically asked for less review and more meaningful problems in class. However, there were some students who were bothered by the amount of time required to watch video content prior to class with their current workload (all classes), and suggested modifying the homework expectations to compensate for that.	↕

Based on student feedback, all students recognize that the instructor is passionate about teaching and holds high expectations for the students. One treatment group student stated, *"Seeing the instructor be passionate about their work, and their class, makes me feel like I should know this material and I should learn it to the best of my capacity."* Another treatment group student stated, *"I feel the need to, not only expect higher out of myself, but I feel like I have to do that because the professor expects something out of me."* Generally speaking, the students in this course appreciate the structure of the class and the course notes provided by the instructor. In line with the opinion of most students, one control group student indicated that, *"the course notes allow me to pay more attention to the instructor and what is being said instead of focusing on getting everything down on paper"*. Another control group student stated, *"The instructor's way of notes is probably superior to the other classes I'm taking. It keeps you focused on the notes, writing in the blanks and everything, it really does help you learn."*

Some students think the pace of the traditional lecture delivery is a little fast. When referring to the traditional lecture style, one treatment group student stated, "*I think it's a little fast for me. But maybe that's the reason why the instructor has us print out and fill in, because you get an opportunity later to kind of review things without having missed an entire sentence in your notes.*" A control group student stated, "*If someone has a question, the instructor will slow down. The instructor knows exactly how much time to spend on each important topic*." When referring to the traditional lecture delivery style, it is key to note that students recognize their lack of time to digest the material and unanimously request more examples in class. In line with many other students, one control group student commented, *"In class, I'm so stuck on writing things down, and trying to get as much material as possible, and trying to have things to reference later, that I don't even think up questions until later on, when I'm reviewing or doing homework. And they could have been easily answered in class, it's just that I'm not fully focused on the concept of the lecture – it's something that I figure I'm going to go back and go over on my own."* Another control group student indicated, "*To improve the class, I feel like more examples would be better because sometimes there's only one example for the whole thing and it's just not thorough enough for the different kinds of problems the instructor presents us."*

In comparison, when referring to the flipped course delivery style, a treatment group student commenting on the video content stated, *"I'm more engaged in the video because I'm able to rewind for something that I'm getting stuck on or that I don't really grasp completely."* Another treatment group student commented on the dynamics of the post-video classroom interaction with the instructor, *"I think that the group work that we had was much more productive because everyone had time to watch the video on their own time. So we were able to help each other with, like, small, little things. And then the instructor was walking around the class like 'what do you need help with?' and helping us out. I thought that was very productive and it was more like a workshop than a lecture. It was very helpful."* The post-video classroom appears to make some students more comfortable in asking questions. One treatment group student stated, *"I'm definitely more willing to ask a question in a workshop-structure where the professor comes over and I'm able to actually show the professor what I'm asking….sometimes I feel like it might be a dumb question……you don't really want everybody to hear what you need to know."*

Discussion of Results

The assessment criteria for each test problem associated with a flipped topic was coded by difficulty in line with the Levels associated with Bloom's taxonomy, and the performance data for all four problems were displayed on Figure 3 by Bloom's Level for both the control and treatment groups. Most flipped classroom studies do not investigate whether this type of instructional model has the potential to increase cognitive levels of learning in accordance with Bloom's taxonomy.

The average performance of the treatment group in Figure 3 was observed to be higher for all four Levels of Bloom's revised taxonomy. Statistically significant differences were measured for Levels 2 (Understand) and 3 (Apply). Similar to another study [26], Figure 3 indicates that there is potential for an increase in student performance on higher-order learning outcomes when students are provided with video content that they can review at their own pace ahead of class, and subsequently, active learning strategies are effectively incorporated into the classroom while providing instructor support and a supportive peer working environment. It is important that the students are actively involved in the learning process.

While the same content was delivered to both groups, the treatment group had the added advantage of absorbing the course content by video at their own pace, re-watching concepts that were challenging, and using the video as a reference at any point during the semester to reinforce concepts. In the flipped classroom, the instructor had more time to discuss and explain the content as needed, and students had an opportunity to describe and explain concepts to each other as they worked in small groups (Level 2 skills). The flipped classroom also enabled the students to practice the skills while solving problems, demonstrate concepts learned (Level 3 skills), and build confidence in their own abilities.

Based on the key survey data collected at the end of each teaching semester and presented in the quantitative data section of this paper, the majority of the treatment group students (78.9%) expressed an interest in flipping course content to some degree in comparison to 38.6% of the control group students. Only 18.4% of the treatment group reported a greater interest in traditional lecture delivery in comparison to 61.4% of the control group students. However, student interview and survey feedback indicated that their interest in traditional lectures may be tied to the time management issue highlighted in Table 4. Given their heavy course load (all classes), they expressed some frustration regarding the time spent watching the video content outside of class, and indicated that if students were given more credit to watch the videos and/or had less homework on those particular topics, they would be more inclined to favor the flipped model. One of the biggest student struggles with the PFC model was time management and the perceived credit that students received for their effort in all flipped activities. The instructor of this course continues to adjust activities and the credit for those activities accordingly. Additionally, the instructor recommends chunking the material into shorter videos, and providing the students with additional on-line examples that can be made optional for students who need them.

While the focus group and survey feedback data indicated both groups of students wanted more example problems, it is interesting to note that the majority of the treatment group (57.9%) reported that they learned best in small groups and/or with the instructor. Only 13.6% of the control group agreed. In comparison, 72.7% of the control group and only 26.3% of the treatment group preferred instructor-only led examples (without peer group work). Roughly the same percentage of students in both groups (approximately 14 – 16%) preferred to work examples on their own. These data indicate that the treatment group students valued and benefited from peer interaction and the ability to get one-on-one help with the instructor during the post-video class time.

Summary and Conclusions

This study investigated the implementation of a Partially Flipped Classroom (PFC) instructional model in a junior level geotechnical engineering course using a mixed methods, control group design. The authors were interested in whether the PFC instructional model could increase the level of learning and/or depth of comprehension of difficult concepts in this course. They also collected a wealth of interview and survey data to evaluate student perceptions and challenges associated with this delivery method. The following conclusions can be advanced from this study:

1. While students were generally satisfied with the level of engagement, had positive interactions with the instructor, and valued the course notes regardless of group, the treatment group students felt like they benefited from interacting with their peers after watching the video content, and they valued their ability to get convenient help from the instructor inside the flipped classroom. They informally (via survey) and formally (via focus group interviews) expressed a desire to have more workshop environments like the flipped classroom. The author recommends that the flipped classroom time be utilized (in majority) to work problems, the problems be designed to target higher levels of learning and encourage interaction among peers, and the video content should support the work inside the classroom. Unlike the control group students, the treatment group students recognized the benefits of working problems on their own and appeared to be more willing to take an active role in the learning process. They also recognized that the video content prepared them for the classroom activities and provided them with the confidence to work in groups.

2. The instructor recognizes the need to manage time wisely in a flipped instructional model, whether it is partially or fully flipped. Several students expressed frustration with the length of some videos and the credit (or lack thereof) that they received for additional out-of-class effort on top of normally assigned work. Students reported that this method was too much work given their other academic obligations. Management of workload and the ability to motivate student buy-in can be a challenge with this method. It is easily overcome by keeping video content short (15 minutes or less), creating opportunities for students to earn credit for watching the video content (e.g., daily quizzes), and shortening homework assignments and/or utilizing one or more homework problems inside the flipped classroom. This strategy enables the students to complete the same amount of work ultimately, but reduces the out of class homework.

3. The quantitative analysis described in this paper indicates that the increased performance of the treatment group was statistically significant for assessment criteria coded Bloom's Level 2 (Understand) and Bloom's Level 3 (Apply). The control group performed an average of 10.087 points lower than the treatment group on Bloom's level 2 and an average of 6.974

points lower on Bloom's Level 3 criteria with results graphically displayed in Figure 3. Based on these promising results, the authors support the use of a flipped classroom with careful structure and planning, and intend to conduct future research to evaluate the ability to reach higher-order cognitive skills using this instructional model.

This was a small Scholarship of Teaching and Learning (SOTL) grant intended to pilot an idea that would solve current time-management challenges in an engineering classroom at UNC Charlotte. It provided a wealth of quantitative and qualitative data that support the future development of this instructional pedagogy. The author/instructor intends to develop this research into a larger initiative that will further investigate the use of flipped classrooms to create a more student-centered learning experience, incorporate more active learning in the classroom, increase cognitive levels of learning, and create opportunities for students to participate in their own learning process. Once refined, the author hopes to encourage other faculty members in the same Department to incorporate all or some of the best practices developed from this work. This could be effective for challenging courses that often create roadblocks in the critical path of a civil engineering curriculum (e.g., statics and solids). The use of video content, which does double duty for additional online resources, in combination with effective, student-centered learning in the classroom is a perfect formula for these types of classes to create consistency and adequate student support. The author/instructor is in the process of fully flipping this course and will utilize the data from this study to develop best practices.

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