Design and Preliminary Data from a Partially Flipped Classroom (PFC) Study in a Geotechnical Engineering Course

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Abstract

The pace and delivery style of a traditional engineering lecture makes it difficult for students to stay engaged, motivated, and achieve higher levels of learning in the classroom. Even with an excellent instructor, many students have a hard time managing their time in the classroom and are forced to use a ‘write down now, learn later’ strategy. Flipped classrooms have gained traction in recent years because this instructional method enables the student to begin the learning process outside of class at their own pace (still under the guidance of the instructor), digest the material prior to class, and subsequently, use the in-class time to participate in active learning strategies that increase engagement between faculty and students, and enhance comprehension of the material. This study pilots a Partially Flipped Classroom (PFC) instructional model in a required geotechnical civil engineering course at UNC Charlotte to formally assess student engagement, perceptions, learning, and gains. This study will investigate whether a PFC model enables students to reach higher-order cognitive skills in accordance with Bloom’s Taxonomy. This paper is a work in progress but it presents the extensive research design, summarizes the preliminary student data from this study, and compares the data acquired from the control and treatment groups for the first two content modules (Test 1 and Test 2 data). Extensive qualitative and quantitative data were collected, and the preliminary results are promising. There appears to be a trend of improved overall student performance on quiz and test questions in some areas of the course and there are indications that this instructional model impacts the student’s ability to reach higher order cognitive skills in accordance with Blooms Taxonomy. Qualitative feedback collected during focus group interviews clearly align with the objectives of this study, and the treatment group participants have expressed value in the additional time created from the PFC instructional model. Students describe the flipped classroom model as a more relaxed and effective learning environment. The formative feedback regarding the technology and use of time in the flipped classroom collected during this study has been invaluable to the continuous improvement process of this instructional model during the semester.

Introduction

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. The pace and delivery of a traditional lecture makes it difficult for students to stay engaged, motivated, and achieve higher levels of learning in the classroom. More importantly, it does not provide them an opportunity to digest the material before they are asked to work independently. Studies suggest that active learning strategies enable students to achieve higher levels of learning, but effective use of this pedagogy takes time in the classroom. Time is difficult to budget inside an engineering classroom taught in a traditional lecture format due to the amount of content that must be delivered to accomplish the learning objectives for the course. Additionally, for some subjects, it is not effective to hold the students responsible for pre-class assignments to save time (e.g., preliminary textbook
reading and problems) before they have been formally introduced to the material. Students benefit from direct teaching methods and active learning strategies but time is the issue.

Flipped classrooms have gained traction in recent years because this instructional method enables the student to begin the learning process outside of class at their own pace (under the guidance of the instructor), and subsequently, use the in-class time to participate in active learning strategies that increase engagement between faculty and students. Active learning is an instructional approach that attempts to engage students as active participants in the learning process. The authors are implementing and assessing a Partially Flipped Classroom (PFC) teaching model using mixed methods, pre-test/post-test control group design. For the treatment group in this study, the instructor flips the course content during four specific lectures to increase engagement and active learning in the classroom, but is careful to customize the learning experience so that commonly cited weaknesses of a flipped model are avoided in this study.

The objective of this study is to pilot and evaluate a PFC instructional model in a required geotechnical civil engineering course to determine what impacts this model has on student engagement, perceptions, learning, and gains. Additionally, this study will investigate whether a PFC model can help students reach higher-order cognitive skills in accordance with Bloom’s Taxonomy [1]. This paper is a work in progress. The study and all analysis will be completed in May 2019. However, this paper presents the extensive research design, summarizes the preliminary student data from this study, and compares Test 1 and Test 2 data acquired from the control and treatment groups.

Research Rationale

With increasing classroom sizes and the competing power of personal technology in the classroom, it is difficult to maintain consistent student engagement using the current lecture delivery format. Engineering courses are forced to deliver content in high volume. Using standard lecture-delivery format, the pace of core engineering classes makes it difficult for students to achieve even the lower levels of Bloom’s Taxonomy [1] during class. Students are getting lost and/or feeling obligated to ‘write down now and learn later’. Even though the required content volume is high, students generally want all instructors to slow down, work more numerical examples, and show them more real world applications. Additionally, at UNC Charlotte, a University wide teaching schedule change was also mandated, impacting the contact hours that Civil Engineering instructors have in the core classes. Monday/Wednesday (MW) and Wednesday/Friday (WF) classes (75 minutes per class) were replaced with MWF classes (50 minutes per class). There are no differences in this substitution, but prior to this change, this Department scheduled the core Civil Engineering courses on MWF (75 minutes per class) and used the extra time period on Friday as a supplemental instruction period. In other words, the Department was able to claim an extra 75 minute time period on the student schedules to allow for supplemental instruction time in that course. When the teaching schedule change was implemented, that extra class period was no longer available, which reduced valuable contact hours with students at critical points in the curriculum. Students verbalized their frustration with this change during the focus group interviews conducted as part of this study.

To remedy all of these challenges and enable students more opportunities for success while achieving higher levels of learning, a course re-design is necessary. As part of a Scholarship of
Teaching and Learning (SOTL) grant, the instructor is currently evaluating the use of a Partially Flipped Classroom (PFC) instructional model in a geotechnical engineering course at UNC Charlotte. It is hypothesized that the proposed PFC model will provide additional time to create and/or increase classroom engagement, improve learning for individuals with diverse learning styles, improve overall student performance in the course, and increase student performance on test problems coded with a higher level of Bloom’s Taxonomy [1].

Literature Review

Bloom and Krathwohl’s Taxonomy [1], [2], [3] measure a student’s level of understanding based on the following six cognitive levels: 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 engineering accrediting body (ABET) currently requires the evaluation of student outcomes that rely on the higher levels of Bloom’s taxonomy [5].

Research studies suggest that student retention in STEM fields requires modification of the classroom environment to better access varying learning styles [6]. The typical teaching approach utilizes abstract, verbal, passive, and sequential characteristics of the common learning styles, preventing many students from reaching their full potential [7]. The National Academy of Engineering proposes a dramatic and fundamental transformation of engineering education to better prepare engineering students for the future as part of the Engineer of 2020 Project [8]. However, much of the literature focuses on what the instructor is going to do to deliver content rather than focusing on how best to get a student to interact with the content and/or take responsibility for their own learning [9].

In a traditional lecture class, an instructor serves as an information provider while the students commonly serve as recipients of that information. Students should, instead, be active participants in the learning process. While many traditional classrooms attempt to incorporate active learning techniques in the classroom to better engage students, there is commonly not enough time for students to take the notes, process the concepts, and then work examples on their own. A geotechnical engineering instructor incorporated Geotechnical Concept Tools (GCT), a relevant active learning technique, into the classroom with some success [10] but reported these same limitations. STEM students benefit from an interactive classroom environment where they can be guided through their problem solving process [11]. Instructional environments where students are actively engaged with the material instead of serving as passive recipients of information have been found to increase learning in several cases [12], [13], [14].

A flipped classroom can be defined as “an educational technique that consists of two parts: “Interactive group learning activities inside the classroom and direct computer-based individual instruction outside the classroom” [15]. In a flipped classroom, the student takes responsibility for viewing content ahead of the lecture. Subsequently, class time is re-purposed to provide the students opportunities to work more examples, peer learn, and engage directly with the instructor. The pre-lecture is typically delivered via video content and may be combined with an evaluation tool (e.g., embedded or post quiz) that keeps students focused. Students are able to
control the pace of the lecture and can re-watch if necessary to increase comprehension. They become an active participant in the learning process. Most importantly, the student is provided the time necessary to digest the material before class, unlike a conventional classroom.

Some authors have reported their early efforts to flip engineering classrooms [16], [17], [18], but this instructional model gained popularity in more recent years, and methods have been described in the literature [15], [19], [20], [21]. However, many of these methods vary between studies. It is important to standardize methods and establish fundamentals for successful implementation. Generally, flipped classroom models make effective use of time, technology, and accommodate various learning styles [16], [22], [23]. They also help students become self-directed learners [11], [22], foster collaborative learning and personalized learning [16], [24], increase classroom engagement and student-faculty interaction [11], [23], [24], [25], and have been shown to improve student performance [16], [22], [26], [27], [28], [29].

Given the accumulating evidence regarding the positive benefits of this pedagogy, it is important to differentiate the aspects of the methodology that are successful from those that have not worked well. Students in a study conducted by Stickel et al. [25] appreciated the ability to re-watch videos and have direct interaction with the instructor during class. In a study conducted by Love et al. [27], student scores were higher, they liked having the ability to re-watch the lecture videos, and they had more positive perceptions of how the material was relevant to their career. Lape et al. [29] reported that students rated the workload as “well distributed” and also liked the instructor interaction. Students from a study conducted by Toto and Nguyen [30] reported that they benefited from the re-purposed class time used to work additional problems and activities. Mason et al. [22] were able to cover more material over the same period of time. While students in this study were initially frustrated by the flipped method, they were able to complete more practice problems, and they performed significantly better on matched quiz/exam problems across several topics in comparison to the control group. Students generally had positive perceptions, reported that class time was used more effectively, and rated the videos as stronger contributors to learning in comparison to homework assignments. Hereid and Schiller [21] highlighted their ability to customize classroom activities based on student struggles and learning styles.

However, there are mixed reviews reported in the literature. For example, while Amresh et al. [28] reported higher average scores on assignments and exams, students in this study thought the videos were boring and did not see the value in the flipped approach. Similarly, Helmke [9] found significant increases in pre-/post-test scores and higher performance on the final exam compared to control group, but student participants reported lack of engagement with the provided resources, they felt intimidated to ask questions in class, and they expressed a lack of preparation for in-person class. Some authors highlight the importance of individual differences in student learning and personality characteristics. While Stickel et al. [25] reported higher scores and greater improvement in analytical problem-solving capabilities, their analyses concludes that self-efficacy and learning styles contributed to final grades beyond the contribution of increased teacher interactions. According to Lape et al. [29], while all students improved from pre- to post test, they did not observe significant differences in outcomes between the groups. These authors contend that success may depend on individual differences including study habits, persistence, preparedness, commitment to course, aptitude, etc. At the conclusion
of a study involving the review of 24 flipped classrooms by Bishop and Verleger [15], the authors encouraged future research to include performance measures and controlled study designs.

Establishing organized structure of these activities is critical to achieve higher levels of learning [31], which is an objective of this study. Only select studies have highlighted the use of flipped technology to achieve high-order learning. Redekopp and Ragusa [24] reported that the active learning techniques helped students achieve higher-order learning outcomes. In their study, students in the flipped classroom performed better than those in the control group on the course projects that involved a deeper evaluation of the material and, therefore, higher-order learning. They found little differences in performance involving lower-order learning outcomes, but valued the fact that flipped models always provided students with increased time to interact and discuss. Gross and Musselman [31] reported that flipped classes can increase student comprehension of fundamental knowledge (lower level learning), and improve their ability to apply that knowledge in application-based engineering classes. Their students were better prepared to apply knowledge during class time. These authors suggest that the variation in results found in the literature can be attributed to the methodologies and structure provided during the class time.

Based on the preliminary feedback from the students surveyed in this study and in the literature, increased exposure to material, the ability to start and stop a video that is available for review anytime, the ability to work additional problems, the ability to take responsibility for the learning and work with peers, and the ability to directly engage with the instructor in a group setting improves the learning environment. However, it is important to carefully plan and execute the effort. To accomplish this, it is critical that the pre-lecture technology, in-class activities, and the instructor are effective and able to keep the students engaged.

**Research Design**

This study investigates the impacts of a Partially Flipped Classroom (PFC) instructional model in a junior level geotechnical engineering course required for an undergraduate Civil Engineering degree. A control group was conducted during the fall 2018 semester and a treatment group is currently being assessed during the spring 2019 semester. This paper is a work in progress that will be completed by end of May 2019. This section outlines the extensive research design, and subsequent sections of this paper compare the data acquired from the control and treatment groups for the first two content modules (Test 1 and Test 2 material).

The course notes, the amount of material covered, the learning objectives/expectations, and the evaluation instruments are identical for both groups. The delivery style and access to additional video resources and practice problems will differ for the treatment group for a subset of lectures, and the impacts will be evaluated as described in this paper. In general, the goal of this study is to 1) determine if the PFC instructional model can increase student engagement and motivation in the classroom, 2) measure differences in student performance between control and treatment groups, 3) determine if and how the PFC model enables students to reach higher-order cognitive skills, 4) evaluate student perceptions of the new model, and 5) identify and overcome challenges associated with implementing a PFC model during this study and in future classrooms. More
specifically, the control group design and treatment group design are described in the following paragraphs.

**Control Group**

In general, the instructor taught the control group using standard lecture format with supplemental examples as time permitted. The instructor utilizes partially completed course notes that contain the backbone of the lecture with blank spaces throughout the notes to fill in important information, stress important concepts, and work examples. The students are required to print the notes prior to class. While the instructor lectured at the front of a traditional classroom, the course notes were displayed on a document camera, and notes/examples were completed while class discussion took place. In addition to the delivery of the lecture material, there was typically time to work a few examples and/or use simple class props to increase comprehension of the concepts. While purchasing the textbook is highly recommended, a student can successfully complete this course without the textbook due to the extensive course notes and resources provided in the class. Additionally, the instructor has found from past experience that required use of the textbook does not ensure successful comprehension in geotechnical engineering. Independent use of a textbook in a geotechnical engineering course can be difficult for students since the material is not intuitive.

Once a topic is covered, students typically complete a short daily quiz on that topic during the subsequent class (instead of the class it is introduced in) to allow students time to digest the material. The quiz questions include short multiple choice, fill in the blank, or simple calculation style questions that typically stay within Blooms level 1 and 2, but also ask the students to ‘apply’ concepts in a simple way (level 3). The high frequency of the short quizzes encourages students to keep up with the material and remain engaged with their own notes. They also provide an immediate assessment of comprehension. Homework is assigned for each topic to enable the students to practice the fundamental concepts on their own time and at their own pace. Tests 1-4 cover the four content modules in the course (i.e., soil structure, seepage and soil stress, consolidation, and shear strength, respectively), and the final exam is comprehensive. Table 1 summarizes the course topics by lecture. Additionally, 12 volunteer participants provided detailed qualitative feedback through focus groups interviews organized by the study evaluator. A description of the focus group volunteers is provided in the Participants section of this paper. At select times during the semester, the control group was asked to submit qualitative feedback via survey regarding their comprehension of the material and their opinions on course delivery and pace. This paper focuses on the quantitative data acquired to date with some highlights from qualitative findings.

**Treatment Group**

With the exception of the four flipped topics (starred in Table 1), everything that was delivered to the control group remains the same for the treatment group. Treatment group students printed course notes, took daily quizzes, completed four tests and a final comprehensive exam, participated in focus groups, and provided qualitative survey feedback. However, for the four flipped topics displayed in Table 1, students were required to watch a video prior to class so they
would be prepared for the subsequent flipped class activities. Treatment group participants were also asked to provide survey feedback on their experience.

Table 1. Lecture Number by Course Topic

<table>
<thead>
<tr>
<th>Content Module</th>
<th>Lecture</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2</td>
<td>Phase Diagram Relationships</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Soil Structure and Composition</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Soil Classification (USCS and AASHTO)</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Compaction Fundamentals*</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Site Exploration</td>
</tr>
<tr>
<td>2</td>
<td>7,8</td>
<td>1D Seepage</td>
</tr>
<tr>
<td></td>
<td>9,10</td>
<td>2D Seepage*</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Soil Stress Concepts and Stress Distribution</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Total and Effective Stress</td>
</tr>
<tr>
<td>3</td>
<td>13,14,15</td>
<td>Soil Consolidation*</td>
</tr>
<tr>
<td></td>
<td>16,17</td>
<td>Rate of Soil Consolidation</td>
</tr>
<tr>
<td>4</td>
<td>18,19,20</td>
<td>Shear Strength Fundamentals and Testing*</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Introduction to Lateral Earth Pressures</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>Introduction to Slope Stability</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>Introduction to Bearing Capacity</td>
</tr>
</tbody>
</table>

*Flip Topic

This study focusses on a ‘partial flip’ to prevent overwhelming the students with too much out of classroom content initially before evaluating the effectiveness of this method. For this reason, one flip topic from each of the four content modules displayed in Table 1 was selected to distribute the flipped content throughout the semester and avoid overwhelming the students with too much video content at one time. The instructor selected a topic having concepts that students struggle with based on student performance in previous years. Based on those criteria, the instructor selected 1) compaction fundamentals, 2) 2D seepage, 3) soil consolidation fundamentals and calculations, and 4) shear strength fundamentals and testing. Table 1 displays the lecture topics contained within each content module, the number of lecture periods associated with each topic, and the placement of each flip topic. The data collected from this study will help the instructor determine if there is value in adding additional flipped lectures and/or digital resources in the future.

Each video was designed to focus on the key concepts for the flipped lecture topic. The quality of the videos improved during the semester as a result of student feedback. For example, during the first video, a Kaltura recording with screen capture of a PowerPoint that paralleled the course notes was utilized. The students indicated that they wanted to see the instructor writing things down like in class. For the second video, the instructor positioned a camera on a tripod looking down on a table so that the instructor could write directly on the course notes. While this method worked for a quick fix, the video and zoom quality were substandard for this application. The third and fourth video were professionally recorded and edited by the Academic Multimedia
Production Team on campus using high quality video and audio equipment. Student feedback suggests a significant improvement in the final videos.

In all cases, quiz questions were embedded into the videos using a Kaltura quiz editor. During each video, students were required to print out and fill in the course notes as if they were sitting in the classroom. The videos were 30 minutes or less in length, and students received quiz credit for full participation prior to the lecture period. The video enabled students to process and archive the material at their own pace and re-visit parts of the video as needed to strengthen their understanding of the material.

The class immediately following the required video content was then utilized to 1) answer immediate questions from the video, 2) reinforce the most important concepts with a mini lecture, 3) work a short example problem, and 3) have students work problems either individually and/or in groups of two as the instructor rotated around the classroom to answer questions and provide guidance for the class. The instructor utilized formative feedback to improve the flipped classroom during the semester.

**Participants**

Participants of this study include the instructor of the course and 97 consenting undergraduate students enrolled in two semesters of a required geotechnical engineering course at UNC Charlotte, which is a southeastern urban research university in the United States. There were 44 control group participants (97.8% of registered students) during the first semester, and 53 treatment group participants (98.1% of registered students) during the second semester. Of the 99 students that registered during these two semesters, approximately 98% elected to participate in this study. There were 39 male and 5 female students participating in the control group, and there were 35 male and 18 female students participating in the treatment group. The distribution of age was approximately normal (M = 22.45 years, SD = 3.72 years). Figure 1 displays the average GPA of all consenting student participants in the study by group (control and treatment) at the beginning of each semester. With the exception of 1 post-baccalaureate student, all participants in this class are in their first or second semester of their junior year within the BSCE curriculum so there are minimal differences in their civil engineering preparation for this course. The critical path and required pre-requisites in the curriculum ensure this to be true. Table 2 summarizes all participant information.

Based on a one-way analysis of variance (ANOVA), there is a significant difference in gender distribution between the control and treatment groups ($F(1, 95) = 7.148, p = .009$). However, there are no significant differences in GPA ($F(1, 92) = .411, p = .523$) or ethnicity ($F(1, 93) = .002, p = .969$). The data indicate that 88.6% and 11.3% of the control group are male and female, respectively, and 66% and 34% are male and female, respectively, in the treatment group. While there is a statistically significant difference in gender distribution between groups, one could argue that the analysis associated with student GPA minimizes differences in student potential if you assume GPA level is an indicator of student capability and motivation to do well in academic coursework. As a result, this study assumes the overall intellect of the students is equivalent across student samples and, therefore, comparable when analyzed as a control group versus a treatment group.
This study was designed to have four focus groups each semester (one during each content module listed in Table 1), and each focus group had three participants. Focus group participants volunteer during the consent process, and groups are created based on volunteer availability. The volunteer participants are compensated for their time with a Starbucks gift card. In general, the average GPA for the focus group participants (Table 2) are slightly higher than the averages for each group. Within the control group interviewees, 66.7% and 33.3% are male and female, respectively. In the treatment group, 18.2% and 81.8% are male and female, respectively. While Figure 1 displays the variation of GPA for all participants in this study by student number, this figure also displays the control and treatment group focus group volunteers, segregated on the right side of this figure as student number 55 and student number 60, respectively.

Table 2. Student Participant Information

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Participants</td>
<td>44</td>
<td>53</td>
</tr>
<tr>
<td>Male</td>
<td>88.6%</td>
<td>66.0%</td>
</tr>
<tr>
<td>Female</td>
<td>11.3%</td>
<td>34.0%</td>
</tr>
<tr>
<td>Average GPA</td>
<td>2.92 ± 0.52</td>
<td>2.86 ± 0.48</td>
</tr>
<tr>
<td>Average GPA (Female)</td>
<td>3.11 ± 0.52</td>
<td>2.93 ± 0.45</td>
</tr>
<tr>
<td>Average GPA (Male)</td>
<td>2.90 ± 0.52</td>
<td>2.82 ± 0.50</td>
</tr>
<tr>
<td>Caucasian</td>
<td>66.7%</td>
<td>64.3%</td>
</tr>
<tr>
<td>African American</td>
<td>4.4%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>6.7%</td>
<td>10.7%</td>
</tr>
<tr>
<td>Other</td>
<td>15.6%</td>
<td>10.7%</td>
</tr>
</tbody>
</table>

Focus Group Participants

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>8</td>
<td>2’</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>9’</td>
</tr>
<tr>
<td>Average GPA</td>
<td>2.89 ± 0.41</td>
<td>3.53 ± 0.44</td>
</tr>
<tr>
<td>Average GPA (Female)</td>
<td>2.75 ± 0.41</td>
<td>3.07 ± 0.44</td>
</tr>
<tr>
<td>Average GPA (Male)</td>
<td>2.96 ± 0.42</td>
<td>3.26 ± 0.59</td>
</tr>
</tbody>
</table>

*One volunteer still needs to be identified*
Design Methodology and Evaluation Plan

A psychology graduate student specializing in quantitative analysis within the College of Education is serving as the program evaluator for this study under the guidance of a faculty member and education assessment expert from the College of Education at UNC Charlotte. The evaluation plan, which includes both quantitative and qualitative assessment instrumentation, was developed to evaluate the educational impacts of flipping specific geotechnical engineering lectures. This study uses “comparison (cross-sectional) group design” methods. The skills, perceptions, and gains developed by student participants in a control group will be compared to the same data collected from the treatment group. All quantitative instrumentation questions on quizzes and tests are identical for the control and treatment groups.

Quantitative Instrumentation

The quantitative instrumentation utilized during both semesters includes: 1) a 15 question pre-quiz that serves as a baseline measure, 2) daily short-answer quizzes that evaluate the students understanding of concepts presented in the previous class, 3) four content module tests throughout the semester (T1, T2, T3, and T4), and 4) the final comprehensive exam. While homework counts towards their course grade, it is not utilized as an assessment tool in this study since it is impossible to know the source of their information (e.g., individual or shared work). The goal of the homework is to provide the students with an opportunity to engage the material independently outside of class. Each quantitative assessment instrument is described in more detail below. All quantitative data from the criteria-based assessments are analyzed using statistical procedures.

Figure 1. Average GPA for all Student Participants.
- **Baseline Pre-Quiz:** The 15 point multiple choice pre-quiz covers material from all four content modules, and is conducted at the beginning of each semester to assess prior knowledge for each student participant. Each question is coded with a difficulty level in accordance with Bloom’s Taxonomy [1]. It is expected that the students have little to no prior knowledge of the subject matter since most students are taking this course for the first time. Exceptions could include students who have had internships, participated in research experiences, or have taken this course before. While this type of personal data was collected to account for any variations attributable to unique experiences, the pre-quiz results for all students indicate that students have the same baseline measure.

- **Daily Short Quizzes:** There are typically three questions on a daily quiz that are parallel in type and difficulty to the questions presented on the pre-quiz and the short-answer questions on each test and the final exam. Each question is coded with a difficulty level in accordance with Bloom’s Taxonomy. These questions typically fall within Blooms level 1 and 2, but some questions also ask the student to solve problems on a simple level (level 3). Questions are either multiple choice, true-false, fill in the blank, or require a simple calculation. Daily quizzes are completed during the class that follows the lecture to allow students to digest the material on their own.

- **Tests 1 - 4:** A test is conducted at the end of each content module displayed in Table 1. Exactly 20% of each test includes short answer questions that are parallel in type and difficulty to the questions presented on the pre-quiz and daily quizzes. The remaining 80% of each test includes longer workout engineering problems, which require students to tap into the ‘apply’ and ‘analyze’ levels of Bloom’s Taxonomy.

- **Final Comprehensive Exam:** At the completion of the semester, students are required to complete a final comprehensive exam covering 10 topic areas. Each topic has both short answer and workout type problems, parallel in format and difficulty to question on other assessment tools.

Using the topic of consolidation as an example (content module 3), Figure 2 displays an example of a typical short-answer question and a typical workout problem for the same topic. In this paper the quantitative data are analyzed to accomplish and report on two important goals of this study: 1) compare the control group performance to the treatment group performance, and 2) determine if the proposed instructional method enables students to reach higher order cognitive skills. It is important to note that the number of points and the grading rubric for each problem is established ahead of time to minimize subjectivity during the grading process.
Qualitative Instrumentation

The qualitative instrumentation utilized during both semesters include: 1) student focus groups, 2) student surveys, and 3) student records. While a description of the qualitative data collection is summarized in this paper, a full evaluation of these data is beyond the scope of this paper. This in-progress paper focuses on the comparison of quantitative data collected for the control and treatment groups during the first two content modules to evaluate the efficacy of the PFC instructional model. Each qualitative assessment is described in more detail below.

- **Student Focus Groups:** Student focus group interviews are conducted by the project evaluator four times each semester with approximately three students in each group. A focus group is conducted after each flip topic listed in Table 1. The evaluator systematically asks questions from a focus group guide, enabling 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 are analyzed using a constant comparison method.
from grounded theory where statements are grouped by common themes. The emerging themes are adapted during the data analysis procedure.

- **Student Surveys:** Students are surveyed at the beginning and end of the semester to collect information and student perceptions related to their previous employment and/or research experiences, comfort level with the use of technology in a course, experiences with flipped classes, preferred learning styles, effectiveness of various teaching/delivery methods, and preferred study/preparation methods. Students are surveyed regularly throughout the semester to collect feedback on clarity of instruction, perceived knowledge gains and/or comprehension of material, their level of engagement during class, instructional pace, quality of interactions with the instructor, enthusiasm for classroom activities, etc. Additional treatment group questions collect feedback specific to the required video content associated with the flipped classes (e.g., quality, length, engagement, etc.), and their opinion of the instructional pace and level of engagement during the class that follows the video. The goal is to determine if there are significant differences in the feedback and perceptions recorded by the control group in comparison to the treatment group.

- **Student Records:** Student records are utilized to collect demographic and academic information including credit hours completed and GPA information.

**Preliminary Quantitative Data: Comparing Control and Treatment Data**

This section compares the performance of the control group to the treatment group using (1) daily quiz grades, (2) short answer test questions, and (3) workout test problems from assessment instruments in content modules 1 and 2. The following sections provide data and discussion for each assessment. For all figures and discussion, the topics covered in this course are identified by the lecture numbers in Table 1.

**Daily Quiz Performance Comparison**

Daily quizzes are normally conducted during the subsequent lecture period (instead of the lecture that it is introduced in) to enable students to digest the material before they are quizzed. They typically have three questions, one point each. Figure 3 displays the combined mean scores of the quizzes taken by both participant groups during content module 1 and 2 (topics listed in Table 1). Daily quizzes 5 (QL5) and 10 (QL10) were associated with the flip topics as indicated on this figure. The treatment group scores tended to be higher than the control group scores in all cases with the exception of Lecture 7 (1D Seepage). A one-way analysis of variance (ANOVA) was completed on the quiz data and there were significant differences in the daily quiz performances on Lecture 3 - Soil Structure and Composition ($F(1, 93) = 7.397, p = .008$, partial $\eta^2 = .074$) and Lecture 10 - 2D Seepage ($F(1, 92) = 14.23, p < .001$, partial $\eta^2 = .134$) with the treatment group scoring significantly higher on average. Please note that significant differences are indicated in Figure 3 and all subsequent figures with a star near the axis for easy reference.

While there was no significant difference in daily quiz performance on the first flip topic *(Compaction – QL5)*, there was a significant difference in daily quiz performance between the control and treatment for the second flip topic *(2D Seepage – QL10)*. While both daily quizzes have problems coded Blooms level 1, 2, and 3, the 2D seepage quiz questions coded level 2 and 3 are more difficult and calculation intensive in comparison to the compaction quiz questions.
with the same coding. For example, on the L5 quiz, the level 3 question reads, *If a standard proctor test was performed on the field soil and optimum conditions coincided with a value equal to 104 pcf, the relative compaction value would be (something less than/greater than 100%) if the field conditions were measured to be 112 pcf.* In comparison, the L10 level 3 question reads, *Given the above flownet, assume the datum is at the bottom of the headwater. If a piezometer were installed a point B, what would it read?* The 2D seepage question requires the student to evaluate a figure and dive deeper in concept. As a result, the significant difference reported on the L10 data is promising.

![Figure 3. Daily Short Quiz Performance Comparison](image)

For the treatment class, the instructor also gave a daily quiz at the end of the flip class for the 2D seepage topic (see the white bar labeled *Flip Class* on Figure 3). Recall that all other quizzes are conducted during the subsequent lecture period. It should be noted that the performance of this quiz by the treatment group at the end of the first lecture period (the flip class), is higher than the performance of the control group that took their first daily quiz during subsequent lecture. In other words, it appears that the preliminary engagement with the video content prior to the flip class and the additional active learning engagement during the flip lecture enabled the treatment students to take the quiz one class earlier and score higher in comparison to the control group.

**Short Answer Test Question Performance Comparison**

Figure 4(a) and Figure 4(b) display the combined mean score for all short answer questions in Problem 1 of Test 1 and Test 2, respectively, for both the control and treatment groups. The last set of bars in each figure also display the total score for all short answer questions combined. The lecture number associated with each set of bars is reported at the top and the Blooms level is reported just above each set of bars to distinguish relative difficulty level of the short answer problem. For example, short answer questions 1.4, 1.5, and 1.6 cover lecture topic 3 and
associate with Bloom’s levels 1, 2, and 3, respectively. Subsequent figures will group analysis by Bloom’s level and topic.

For the data presented in Figure 4(a), a one-way analysis of variance (ANOVA) was completed on the short answer test data of Test 1. There was a significant increase in performance from control to treatment for question 1.4 ($F(1, 95) = 5.887, p = .017, \text{partial } \eta^2 = .058$), for question 1.10 ($F(1, 95) = 12.53, p = .001, \text{partial } \eta^2 = .117$), and question 1.18 ($F(1, 95) = 16.306, p < .001, \text{partial } \eta^2 = .146$). Alternatively, the control group performed significantly better on question 1.15 ($F(1, 95) = 7.780, p = .006, \text{partial } \eta^2 = .076$). While the treatment group had significant increases in performance on three questions out of 19 total questions, there does not appear to be a solid trend in performance of the short answer questions on Test 1.

For the data presented in Figure 4(b), a one-way analysis of variance (ANOVA) was completed on the short answer test data of Test 2. There were four problems that the treatment group performed significantly better on: question 1.9 ($F(1, 95) = 8.487, p = .004, \text{partial } \eta^2 = .082$), question 1.14 ($F(1, 95) = 4.331, p = .040, \text{partial } \eta^2 = .044$), question 1.16 ($F(1, 95) = 54.624, p < .001, \text{partial } \eta^2 = .365$), question 1.20 ($F(1, 95) = 6.039, p = .016, \text{partial } \eta^2 = .060$) and the total score ($F(1, 95) = 8.311, p = .005, \text{partial } \eta^2 = .080$). All problems that scored significant differences between groups are noted with a star near the axis labels in all figures. For Test 2, the treatment group short answer test data more frequently plotted above the control group in comparison to Test 1. Additionally, there was a statistically significant increase in treatment group performance on problem 1.9, which is associated with the content module 2 flip topic (2D seepage) and is coded a level 3 question. It should be further noted that the treatment group performed better on all level 3 questions on Test 2, and there was a significant improvement in the overall performance of the short answer questions on Test 2 from control to treatment groups. These data indicated improved overall performance resulting from the efforts of the PFC instructional model. Additionally, students are performing better on questions coded with a higher-order cognitive skill level.
Figure 4. Short Answer Test Question Performance for (a) Test 1 and (b) Test 2.

Figure 5 displays the combined mean score for all short answer questions in Problem 1 of Test 1 and Test 2, grouped by Blooms level, for both the control and treatment groups. In all cases, the treatment group scores were at or above the control group, but there is a significant difference in performance in the Blooms level 1 questions for Test 1 ($F(1, 96) = 7.603, p = .007$, partial $\eta^2 = .073$), Blooms level 1 for Test 2 ($F(1, 95) = 5.237, p = .024$, partial $\eta^2 = .052$), and Blooms level 3 for Test 2 ($F(1, 95) = 5.344, p = .023$, partial $\eta^2 = .053$). Significant differences are denoted using a star on the axis of each figure. The treatment group, on average, performed 11.91 points,
8.26 points, and 12.34 points (in percent) higher than the control group at these levels, respectively. Similar to results presented in Figure 3 and Figure 4(b), there appears to be a pattern of increased performance associated with higher level questions for content module 2 material.

![Figure 5. Short Answer Test Question Performance by Blooms Level for Test 1 and Test 2](image)

**Work-out Test Problem Performance Comparison**

Test 1 and Test 2 each had one workout problem associated with the flipped topics: compaction and 2D seepage, respectively. To assess the work-out problems associated with the flip topics in more depth, a special detailed rubric was created specifically for these problems, and Blooms levels were identified for each key evaluation step within the problem. Table 3 provides the detailed rubric for the compaction problem assessed. For each problem part in Table 3, the Blooms level, the assessment criteria, and the scale used are identified. For example, the compaction problem provides the student with a compaction curve, and requires the student to solve three parts to the problem: (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; (b) Assuming optimum moisture conditions, what is the maximum possible dry unit weight that can be achieved via compaction?; and (c) If the specifications require the water content to be within 2% of optimum, determine and shade in the full ‘acceptable range’ on the figure, showing all work necessary to identify the four coordinates of your range. Part (b) of the problem is assessed utilize six criteria evaluating four levels of Blooms Taxonomy. For each problem assessed using this method, the problems completed by the control and treatment groups are re-assessed at the same time to ensure consistency in the evaluation. A similar rubric was created for the 2D seepage test problem (content module 2).
Table 3. Assessment Rubric for the Compaction Workout Problem on Test 1

<table>
<thead>
<tr>
<th>Part</th>
<th>Blooms Level</th>
<th>Assessment Criteria</th>
<th>Likert Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>4</td>
<td>Examine correct equation ( \gamma_d^{\min} )</td>
<td>0 = No Work</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Interpret ( \gamma_d^{\max} )</td>
<td>1 = Method and/or understanding significantly off and below standard.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Execute the Equation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Report Units</td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td>4</td>
<td>Examine correct ZAV line equation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Remember to use ( G_s ) in Equation</td>
<td>2 = Touches on right method but significant errors in concept.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Interpret ( w_{\text{opt}} )</td>
<td>3 = Right method with minor errors in concept.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Identify ( S = 1.0 ) for ZAV line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Execute the Equation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Report Units</td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td>4</td>
<td>Differentiate Acceptable Range – all 4 borders</td>
<td>4 = Right method with simple mistakes but understands concept fully.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Interpret 2% of optimum</td>
<td>5 = 100% correct</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Calculate 4 coordinates</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 displays the combined mean score of the control group and treatment group for each assessment criteria listed in Table 3 (scores range from 0-5 in accordance with the Likert scale established on the rubric). The Blooms level is labeled at the top of each bar group. The treatment group scored higher on average for every criteria. The difference between control and treatment group performance appears to be larger for part (b) of the problem.
A one-way analysis of variance (ANOVA) was completed on the assessment data collected using the rubric in Table 3 for the compaction workout problem (content module 1 flip topic) and a similar rubric for the 2D seepage problem (content module 2 flip topic). While the findings from the 2D seepage workout test problem yielded no significant differences, the analysis performed on the compaction workout test problem resulted in significant differences when data were grouped by both Blooms levels 1-4 (Figure 7) and by general performance on parts (a), (b), and (c) of the compaction problem (Figure 8). Both Figure 7 and Figure 8 display the combined mean score (%) based on these groupings, respectively. In all cases, the treatment group scored higher on average in comparison to the control group. The ANOVA statistical results are displayed in Table 4. The follow-up analysis of covariance (ANCOVA) indicates that the treatment group is performing, on average, 9.2 points, 25.5 points, 12.9 points, and 12.3 points higher than the control group on the Remember (Level 1), Understand (Level 2), Apply (Level 3), and Analyze (Level 4) levels, respectively (Figure 7). Findings also indicate that the treatment group is performing, on average, 6.2 point and 22.6 points higher than the control group on parts (a) and (b) of the compaction problem, respectively (Figure 8). Again, statistically significant differences are denoted with a start on the axis of each figure. Similar to the observations reported from the data presented in Figure 4(b), there appears to be a trend indicating improved overall performance and increased level of learning resulting from the efforts of the PFC instructional model based on these data.

![Figure 7. Compaction Workout Test Problem Performance by Level of Learning](image-url)
Figure 8. Compaction Workout Test Problem Performance for each Part of the Problem

Table 4. Summary of Statistically Significant Results from the Compaction Test Problem.

<table>
<thead>
<tr>
<th>Grouped by Blooms Level (Figure 7)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Blooms Level 1: Remember</td>
<td>$F(1, 96) = 7.041$</td>
<td>$p = .009$</td>
</tr>
<tr>
<td>Blooms Level 2: Understand</td>
<td>$F(1, 96) = 11.231$</td>
<td>$p = .001$</td>
</tr>
<tr>
<td>Blooms Level 3: Apply</td>
<td>$F(1, 96) = 11.042$</td>
<td>$p = .001$</td>
</tr>
<tr>
<td>Blooms Level 4: Analyze</td>
<td>$F(1, 96) = 9.178$</td>
<td>$p = .003$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grouped by Part (Figure 8)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Part (a)</td>
<td>$F(1, 94) = 4.368$</td>
<td>$p = .039$</td>
</tr>
<tr>
<td>Part (b)</td>
<td>$F(1, 94) = 15.907$</td>
<td>$p &lt; .001$</td>
</tr>
</tbody>
</table>

Preliminary Qualitative Data: Comparing Control and Treatment Data

While this paper focuses mainly on the comparison of quantitative data for the control and treatment groups, this section attempts to summarize the key points from focus groups conducted. A more detailed analysis will be presented in a subsequent paper. To date, 17 students have been interviewed and the key points presented below are organized by ‘theme’.

Focus Group Feedback Summary by Theme

- **Course Notes:** Both groups generally agree that the course notes provided by the instructor are a good learning tool for class. They value the partially completed course notes provided by the instructor. Students like the structure of the notes and the resource that they provide. They feel that the notes keep them focused and enable them to cover the material effectively. Students appreciate having blank spaces to take notes and work examples in the critical, more challenging areas of the lecture. They “allow me to pay more attention to the instructor and what is being said instead of focusing on getting everything down on paper”.
Classroom Pace: All participants agreed that, due to the pace, they prioritized getting the information they needed into their notes over ensuring comprehension and understanding at a conceptual level inside the classroom. They reported that they focused on taking notes during the lecture, then worked on their conceptual understanding through the homework after class. Some students feel the pace is a little fast and others feel the pace is just right, but all students agree that the notes help students keep up with the material and provide a resource to refer to when working individually. One student states, “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.” Another student states, “If someone has a question, the instructor will slow down. The instructor knows exactly how much time to spend on each important topic.” Students generally have a positive attitude toward the traditional lectures and feel comfortable with the material presented inside the classroom during the lecture, but by the time they begin homework assignments on their own, they sometimes don’t know where to start. Oftentimes, having the notes handy remedied confusion during homework. For this reason, students want additional problems to work on their own in class.

Classroom Examples and Interactions: Students reported that they benefit from examples worked in class, but would like more opportunities for additional practice before attempting homework independently. “Lecture is not enough time for practice problems but it’s always nice to sit down with peers and solve a problem. Right now we only have the lecture material with a walked through sample problem, but it’s not us doing it together with peers.” All students like a mixture of interactions inside the classroom. They like when the instructor works a problem step by step, but they appreciate having the ability to work a problem on their own and then check in with their neighbor and/or ask the instructor questions. When asked about working in groups, most do not mind working with one other student but they want the opportunity to digest the material and give it a try on their own first. The instructor occasionally brings some kind of demonstration or visual to the lecture to show concepts and keep students engaged. Students mentioned that they appreciated these as it exemplified how the material is applied in the real world. When asked about other types of delivery, they unanimously commented on their dislike for PowerPoint.

Instructor Interactions: Students generally feel that the instructor is responsive to emails and questions both inside and outside of the classroom, but would take advantage of opportunities for extra contact. Students feel that the instructor’s high expectations and enthusiasm keep them motivated to do their best. One student states, “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 student states, “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.” Students unanimously favor activity and engagement in the classroom.

Time Management: All students in the control group, which aligned with the first semester following the schedule change described in this paper, mentioned that they would like to return to the MWF schedule that all core Civil Engineering classes had before the mandatory teaching schedule change was implemented by the University. They miss having the extra lecture period that served as a supplemental instruction period.

Suggested Improvements: When asked for suggested improvements, students unanimously want more example problems and opportunities for working problems on their own or in
small groups in class. One control group student suggested recording parts of the lecture or examples so that students could reference at a later time if needed.

Focus Group and Post-Video Survey Feedback Regarding Flipped Content

- **Video Quality and Format:** Treatment group students generally liked the concept of the videos but were not shy about providing feedback verbally and by survey for improvement. The instructor continues to apply their suggested changes related to video quality, audio quality, type of presentation, use of quiz questions, etc. The majority of the students requested quiz questions to be embedded inside the video to keep them focused and others wanted those quiz questions to be at the end of the video. Interestingly, the majority of students favored having a quiz with the video to keep them focused.

- **Video Benefits:** Based on student surveys and focus group interviews, students unanimously like the ability to stop, digest, and/or rewind the video in places where there is a need. One student stated, “I think that, as someone who has ADD or ADHD, it’s extremely important to be able to rewind back.” Students made comments about the conventional lecture, “once it is said, it is gone”, but the students overwhelmingly appreciated that the video content allows them to work at their own pace, and use it as a tool to study.

- **Video Length:** Most students (not all) were satisfied with the length of the video (typically 25-30 minutes) but would have appreciated a shorter video if possible. Students would definitely not support a video longer than 30 minutes. Participants mentioned that they would prefer a shorter video that hit on the most critical points, supplemented by some lecture in class. One participant noted that they would be fine with the length of the video if it was their only homework, but that the combination of the video with the other homework was overwhelming given their current course load. One student states, “if this class was my only worry, then I’d be like, yeah, the lecture video was a perfect length. If I had a lot more time to give to this class. But if you have six classes, it’s like.....it’s a lot of assignments due this week for one class.”

- **Flipped Classroom Environment:** Students unanimously prefer the classroom environment experienced in the lecture period following the video (the flipped classroom). They felt it was much more productive in comparison to the conventional delivery style, and it was helpful that they could ask the professor questions one-on-one. They felt more engaged, they valued the time to work examples with the instructor, and they enjoyed having the ability to work problems on their own and/or with a peer.

Summary and Preliminary Conclusions

A Partially Flipped Classroom (PFC) instructional model was introduced into a geotechnical engineering classroom as part of a SOTL grant to increase student engagement and motivation in the classroom, increase overall student performance in the course, enable students to reach high-order cognitive skills, evaluate changes in student perceptions and self-efficacy, and identify the challenges associated with implementing a PFC model. This paper focusses on the quantitative data from quiz and test questions to evaluate overall student performance and determine if higher order cognitive skills can be achieved using a PFC. Qualitative data from the focus group interviews are also summarized to highlight student perceptions and needs inside the course with and without the PFC model. This in-progress paper specifically compares control and treatment
group data for the first two content modules encompassing Test 1 and Test 2 material. While there is a significant difference in gender distribution between the control and treatment group in this study, there are no significant differences in GPA or ethnicity. Therefore, this study assumes the overall intellect of the students is equivalent and that the student samples are comparable.

Based on the quantitative data collected from the study to date (content modules 1 and 2 in Table 1 only), there appears to be a trend of improved overall student performance and there are some signs that this instructional model impacts the student’s ability to reach higher order cognitive skills. Highlights from the analysis are provided below:

1. The treatment group scored higher than the control group in four out of five of the daily quizzes that were conducted (Figure 3). There was a statistically significant increase in performance of the treatment group for daily quiz 10, which corresponds to the second flip topic (2D seepage). Quizzes are normally conducted during the subsequent lecture period to enable each student time to engage the newly learned concepts prior to the quiz. As a quick assessment, an additional daily quiz was conducted at the end of the lecture 10 flip class (the first in-person lecture for this topic). Treatment group participants who took this quiz (one class earlier than the norm) scored 36.4% higher than control group participants who took their quiz during subsequent lecture.

2. In Test 2, the treatment group short answer test data (20% of each test score) more frequently plotted above the control group (Figure 4). There was a statistically significant increase in treatment group performance on Problem 1.9, which is coded a Blooms level 3 problem and is associated with the flip topic for content module 2. Additionally, it can be concluded that the treatment group performed better on all questions coded Blooms level 3 on Test 2, and there was a statistically significant improvement in the overall performance of the short answer questions on Test 2 from control to treatment groups.

3. When short answer questions on Tests 1 and 2 were grouped by Blooms level, a statistically significant increase in performance from control to treatment was found in Level 1 questions for both Test 1 and Test 2 (Remember), and in Level 3 questions for Test 2 (Apply).

4. For the workout test problem associated with the flipped topic on Test 1 (compaction) and Test 2 (2D seepage), a detailed rubric that was designed to assess overall performance and performance based on cognitive levels of learning (Blooms Taxonomy) was utilized to assess these two problems. The analysis performed on the compaction workout test problem indicates statistically significant increases in treatment group results when data are grouped by both Blooms levels 1-4 (Figure 7) and by general performance on two of the three parts of the problem (Figure 8).

These findings, collectively, indicate that there is evidence of improved performance and higher levels of learning as a result of the PFC instructional model. Student feedback from the focus group interviews clearly expresses a need or desire for additional classroom time to work examples, engage the instructor, and work with peers to help digest the material before they practice on their own at home. Now that students are able to watch video content covering difficult material at their own pace, it is clear that students benefit from digesting the material prior to class, and then practicing the material inside of class where so they can get help before they practice independently at home. Based on this preliminary data, the process of having students watch effective video content ahead of the class appears to impact comprehension and
their ability to access higher order cognitive skills, ultimately improving overall performance in some areas. The instructor and students value the additional time and more relaxed and effective learning environment that takes place during the flipped classroom lecture. The formative feedback regarding the technology and use of time in the flipped classroom collected during this study has been invaluable to the continuous improvement process of this instructional model and the authors look forward to completing the analysis of the full data set in the near future.

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