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Post-Pandemic Student Reception of Flipped Classrooms in Civil Engineering Education

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Abstract

Before the COVID-19 SARS-COV pandemic of 2020, significant momentum had occurred in the engineering education community for use of flipped classrooms. For engineering educators seeking to develop more time and space in the classroom for active learning activities, flipped classrooms are an attractive pedagogical tool. The concept of a flipped classroom is to provide students with a pre-class video viewing and pre-class reading assignment to prime them for in-class interactive learning experiences. The engineering education literature has many positive examples of flipped classrooms. In our curricula, flipped classrooms were used to positive effect in geotechnical engineering courses within the Department of Civil and Environmental Engineering for several years, with student learning outcomes and student opinion surveys used to document the effectiveness and reception of the flipped classroom format. However, the COVID-19 pandemic provided a 2-year change in student learning unprecedented in recent memory. Instruction for much of the undergraduate curricula went online to at least some extent during the pandemic. Although there was a range of virtual learning tools used to varying effect over the pandemic, with different approaches utilized by faculty, students found themselves in a virtual environment for an extended period. In the aftermath of the pandemic, engineering educators have observed a markedly changed student reception of the flipped classroom concept. Despite not changing the tools and techniques utilized in the same classes pre- and post-pandemic, student reception of the flipped classroom format has decreased. Data collected from flipped classrooms post-pandemic are compared in this paper to data collected pre-pandemic. The results of this comparison of student feedback and learning outcomes has shown that the effects of the pandemic induced virtual campus experience has changed the landscape, perhaps just temporarily, and that students' post-pandemic are overwhelmingly desirous of in-class instruction with no videos. They are tired of videos and online modules! They want to interact face-to-face. This paper helps provide a balanced examination of the times and seasons for effective use of the flipped classroom format.

Introduction

Student acceptance of pedagogical tools and techniques varies in time and space. They will more or less favorably view different approaches used by the instructor based on their collective experience, shared history, and the comfortable familiarity of their past education. It may be hard to think now, but when the first use of internet-based video modules for augmenting classroom instruction were introduced in the 1990s, students struggled. In 2023, students are accustomed to video augmentation of learning. Likewise, when the first online quiz modules were given to students in the 1990s, it was a shock to them. We hear that in the 1890s students feasted intellectually on their textbooks. It has been many years since students broadly dug into their

textbooks voluntarily widely. It should not be a surprise to us then, that the tools and techniques which we have widely adopted and implemented across academia, and that students have used for years, may become less effective. In the aftermath of the COVID-19 SARS-2 pandemic, we are seeing some changes in the effectiveness of certain pedagogical methods, in particular the use of internet-based video instruction.

We have used the flipped classroom to varying degree since 2015, with widespread adoption of flipped classrooms in 2018. In the early years, we found the use of flipped classrooms to be novel, exciting, and freeing. The students responded warmly and strongly to the ability to have the lecture available at their leisure, with time in class spent in more interactive ways. Student athletes and non-traditional students who had to miss class more that their peers were strong early supporters of flipped classrooms in our department and on our campus. Being able to get a lecture while on the road for sponsored athletics or work greatly benefited those students, while helping the rest of the class with active learning in the classroom itself.

However, in March of 2020 the world shut down for an unprecedented global pandemic. Students were exclusively doing all of their coursework over the internet; with platforms such as Zoom becoming an hourly duty. New concepts such as Zoom fatigue became familiar foes for faculty and students alike. Particularly impacted were those in their last year of high school and first year of university studies, in the critical life transition. As we have progressed past the more active phases of the pandemic and return to normalcy on campus, we have seen changes to student response, acceptance, and efficacy of flipped classrooms. This trend has warranted an examination of the changes that we are observing in our classrooms and across our campus. Therefore, we have closely examined and evaluated the grades, exam scores, and student feedback that we have received pre-pandemic in a set of geotechnical engineering courses at the junior and senior level in the Department of Civil and Environmental Engineering, compared them to post-pandemic data for both flipped and conventional non-flipped classrooms. These observations do not include alternative instructors for the same courses over the same period, as there were not rigorous controls for uniformity to ensure that an even comparison could be made.

Our Flipped Classrooms

The flipped classroom approach has been well studied as a pedagogical tool since the mid-2000s [1-9], with many rigorous and observational studies published from faculty researchers and scholars a like from around the world. Although implementation and particulars of the flipped classroom format vary, the primary concepts generally accepted in the literature [1-9] are as follows for the engineering, and particularly civil engineering education community:

1. In contrast to conventional learning classrooms, which feature a lecture followed by working of examples, the flipped classroom moves the lecture outside of the classroom to a video that is viewed pre-class.

2. The video is watched by the students in the pre-class phase, often accompanied by a short reading assignment. In the conventional learning classroom, the assigned pre-reading is often substantial and may be accompanied by a pre-class quiz to encourage reading.
3. In class, the instructor has more time to work examples. Some instructors will work examples for the entirety of the class time working examples in a passive learning manner. Other instructors will leverage the time for active learning or similar interactive activities which are less formal than the conventional passive approach [10].
4. The degree of active learning varies by instructor, but often includes a brief walk-through of the concept, followed by an interactive activity in which students develop some solution on their own or in groups, trailed by a regrouping of the class for instructor feedback.
5. After class, in the post-class phase, the students are assigned some level of practice, usually in the form of a required homework. This may also be a quiz, an ungraded encouraged homework assignment, or set of optional practice problems.

The scholarship on active learning is rich [11-13] and shows remarkable versatility in the pedagogical method. In our classrooms we strongly embrace the active learning method for classroom instruction when paired with flipped classrooms. We also follow a partner, or complementary, pedagogical approach in some class sessions in the flipped paradigm, the productive failure method. The productive failure method [14-16], is like the active learning approach except the walkthrough of the concept is after the activity rather than before. In our implementation of flipped classrooms, we also have some class sessions that are more conventional in nature and a characterized by more passive instruction and working of examples. We differentiate the pre-class, in-class, and post-class portions of the flipped classroom approach and the conventional approach in Figure 1.

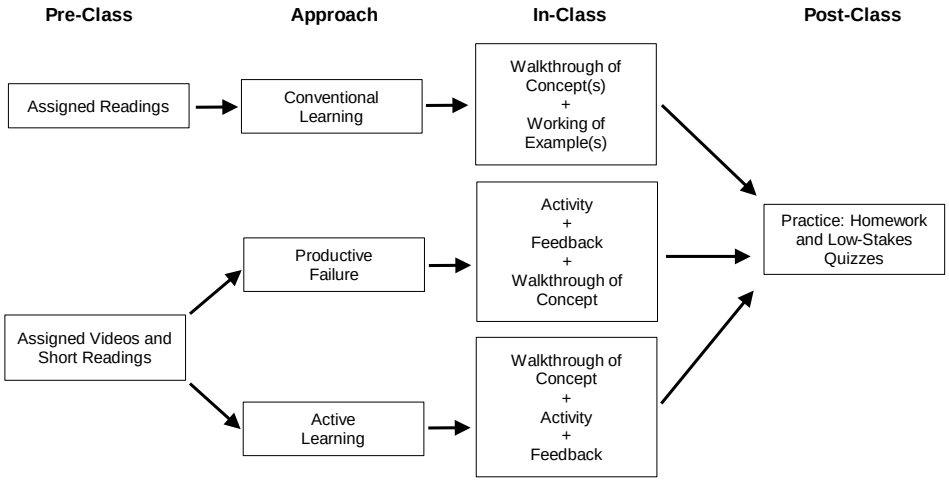

Figure 1. Concept between conventional learning and flipped classrooms pre-class through post-class as implemented herein. Flipped classrooms in our methodology employ both active learning and productive failure learning extensively, while conventional classrooms only occasionally employ the active learning.

Methodology

Since the fall of 2018, we have been using flipped classroom approaches in the geotechnical engineering undergraduate classroom. This has included two junior level soil mechanics classes and one senior level geotechnical design electives. The introductory soil mechanics course (GEO I) has 60 to 80 students in each instance it is taught, while GEO II has 30 to 50 students in each instance it is taught. The senior design elective has 18 to 30 students in each section. All three courses are completed over a 16-week semester that is decomposed into four modules of instruction over 12 weeks. Exams, holidays, and finals consume the rest of the semester. Prior to 2018 all three courses were taught conventionally. Running parallel to the three flipped courses, are two senior design electives that were taught in a more conventional manner after 2018. The majority of students are enrolled in at least 2 of the 5 courses, and this overlap is noted. Graduate students can co-enroll in the senior level courses but take additional rigor in their semester compared to the undergraduates. Key differences between the junior and senior level courses are that the senior level courses have less assigned homework and a semester-long term project. This semester-long term project includes two interim deliverables that are reviewed by the instructor and revised by the students into a final deliverable. These projects are group projects that are a nearly complete design of an engineered system such as the foundations for a large, big box store, using the actual site information for a real-world project, the actual structural loads from the actual building, and the constraints of the site known at the time of design.

As per the flipped classroom methodology listed previously, the course structure for the junior and senior level classes is shown in Table 1 for both the flipped classroom sections and conventional classroom sections. In Table 1, AL indicates the week is dedicated to active learning activities (see Figure 1), while PF indicates productive failure approaches are used that week. CL indicates a conventional lecture with worked examples (Figure 1). For the flipped class sections, there are three videos for the students to watch at the leisure pre-class, and an accompanying brief reading assignment. For the conventional sections, the pre-class phase is characterized by a longer reading assignment. In both the flipped sections and the conventional, pre-class work is encouraged by weekly quizzes that focus solely on the material found only in the pre-class assignment. Without these quizzes, the pre-class utilization of video and textbook resources is spotty for both flipped and conventional approaches.

Table 1. Structure of flipped classroom versus conventional classroom sections

Course Structure	Modules 1 and 2						Mid-Term	Modules 3 and 4						Final
Flipped Section	CL	AL	PF	AL	PF	AL		CL	AL	PF	AL	PF	AL	
Week / Topic	1	2	3	4	5	6	Exam	7	8	9	10	11	12	Exam
Conventional Section	CL	CL	PF	CL	CL	AL		CL	CL	PF	CL	CL	AL	

The instructor also collects feedback from students via class surveys. Student feedback on the ungraded approach from instructor administered blind surveys (using the campus learning management system that enables student confidentiality) and end of term campus administered

class evaluations were compiled and tabulated for 2018-2022. The grades, exam results, and student feedback were then aggregated and compared to the same aggregated data from semesters prior to implementation of the flipped classroom in the same courses in the years from 2015 through spring of 2018.

Grading of the sections varied over the course of the study. In an effort to encourage more active participation by students in the overall learning (and not just active learning activities in the classroom), the courses were graded under varying grading schema. Specifications grading [17-19], contract grading [20-22], mastery grading [23-25], and ungrading [26-34] were all attempted to various levels of success. These changes in grading schema are an acknowledged variable.

For reference on the approach to exam rigor and exam writing, all exams were devised and conceived under the assumptions of the “85% rule for optimal learning” concept [35-37]. This concept comes from the neuroscience literature that follows learning studies that have shown that optimal learning occurs when the average person in a cohort is being challenged at the edge of their competence – not so hard that they are discouraged, but not so easy that they get bored. This concept has been applied widely to machine learning and computer science. Exams are written so that the target is for an average student to complete 85% of the exam correctly.

Results

Exam scores at mid-term and final can be compared across cohorts and courses. As exams must change with time, in this study we compare only a subset of topics, items and problems of the larger exam that are held as similar as possible over time. Minor changes are needed in each new section due to changes in textbook, state of knowledge, and to prevent cheating with old exams. However, the set of items identified in 2015 as core “study items” has been held as constant as possible to allow comparisons over time and across cohorts. Table 2 presents the raw exam score means and standard deviations for all classes aggregated together. Figure 2 presents the midterm and final exam changes pre- and post-pandemic for the study items only. Also presented in Table 2 and Figure 2 are the aggregated favorability rankings of the students in all sections. All results in Table 2 and Figure 2 are out of a maximum of 100. A 5-point Likert Scale Survey was used for favorability towards the flipped classroom. The 5-point scale has two points on favorable, two points on unfavorable, and a neutral option. In Figure 5, both the moderately and strongly favorable data is combined across the pre- and post-pandemic timelines.

Table 2. Flipped classroom student acceptance and exam scores showing mean (standard deviation) pre- and post-pandemic.

		% Favorable View		Average Grade	
Condition	**N**	**Midterm**	**Final**	**Midterm**	**Final**
Pre-Pandemic	354	63	68	85.06 (20.86)	84.16 (15.54)
Post-Pandemic	362	47	44	66.67 (32.57)	76.67 (28.78)

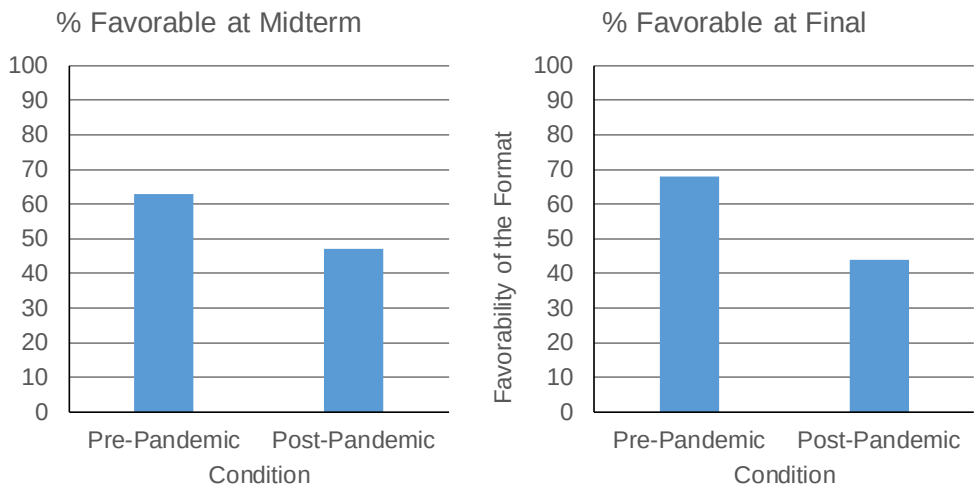

Figure 2. Summary of favorability of flipped classrooms pre- and post-pandemic for all courses, junior and senior.

Table 2 and Figure 2 show a pre- and post-pandemic comparative trend, with overall satisfaction and effectiveness amongst students declining. The surveys also included questions specific to the flipped classroom format, with questions and answers adding additional clarity to student acceptance and satisfaction with the flipped format. Additional results of the surveys found that:

- Pre-pandemic the rates of pre-class video viewing were stronger than post-pandemic.
- Pre-pandemic and post-pandemic rates of textbook reading pre-class were low but held approximately constant with both flipped and conventional classrooms.
- Favored video length was 20 minutes, with 15 and 25-minute videos favored over shorted or longer videos. Students felt that videos shorted than 15-minutes did not have time to develop the concepts, while videos longer than 30-minutes could become tedious.
- Flipped classrooms were more favorably viewed by higher ability students than lower ability student's pre-pandemic (ability estimated simply by ternary division of mid-term exam scores into three ability bins along 33 and 67th percentiles). Post-pandemic the higher ability student views on flipped classrooms have moved towards that of the other ability groups.
- Student comments showed that the majority of students post-pandemic preferred a class format with some video content, as supplemental material rather than required and central to the course. The majority of students in the post-pandemic surveys appreciated videos to help them review a concept they were unsure of, or for a missed class session. When asked if videos should be removed wholesale, they were strongly opposed.
- Student acceptance and satisfaction of active learning (and productive failure) was approximately equal to, or even less, than conventional lectures and conventional learning. Some students strongly supported active learning, while others yearned for

simpler and more constrained conventional lecture and problem-solving in class. In small group discussions with student's post-pandemic, a consensus view emerged that students preferred a mix of conventional, active, and productive failure learning rather than a strong preponderance of one or the other.

- Student acceptance and satisfaction of the flipped format was approximately equal to that of conventional classrooms pre-pandemic, while post-pandemic the favorable views of the conventional classroom increased significantly. Table 4 shows the comparison.

Table 4. Comparison of student acceptance and grades for conventional and flipped classrooms, pre- and post-pandemic.

		% Favorable View		Average Grade	
Condition	**N**	**Pre-Pandemic**	**Post-Pandemic**	**Pre-Pandemic**	**Post-Pandemic**
Conventional	572 / 90	64	84	84.27 (10.01)	86.02 (13.25)
Flipped Class	354 / 362	68	44	84.16 (15.54)	76.67 (28.78)

Lastly, student feedback and grades for undergraduates versus graduate students is separated and considered. Graduate students were slightly more accepting of flipped classrooms prior to the pandemic, while maintaining that level of acceptance post-pandemic. Graduate student grades were statistically unchanged by the pandemic. Table 5 presents these results.

Table 5. Student acceptance of the flipped classroom approach separating out graduate student and undergraduates enrolled in the senior electives.

		% Favorable View		Average Grade	
Condition	**N**	**Undergraduate**	**Graduate**	**Undergraduate**	**Graduate**
Pre-Pandemic	0	68	73	84.16 (15.54)	87.72 (7.23)
Post-Pandemic	0	44	69	76.67 (28.78)	86.33 (8.19)

Discussion

We find that there may be an optimized balance that can be struck between the conventional and flipped classroom. In Spring of 2023, the classes have been re-organized into a hybrid of conventional and flipped. The video lectures from previous years are available as resources for students interested in or needing supplemental explanations. With more in-class time needed for basic instruction and working of examples, there is less time for active learning or productive failure learning. Thus, only the most effective of the active learning and productive failure activities have been preserved in the Spring of 2023 course composition. Referring to Figure 1 and Table 1, the hybrid approach has two days each week as conventional learning, with one day a week in either the active or productive failure delivery mode. This was done due to the high demand from students in previous semesters to move away from a fully flipped format, but with their coincidental high demand for supplemental videos.

For students from marginalized identify groups, differing cognitive abilities, differing physical abilities, differing home or domestic situations, and non-traditional students we find some of the most enthusiastic acceptance of the flipped classroom; we find that these students can do quite well in a fully flipped classroom or one with supplemental video content. Non-traditional students are in particular effusive about the intentional inclusion of video content in the course. Many non-traditional students are raising families, returning from years of work experience, veterans, and working professionals. For these students, they are more likely to be impacted by needing to be absent from class. Whether it be a sick child, work schedule, illness, or jury duty, supplemental video lectures from a flipped class made available in a more conventional course are critically helpful. Many of these students, whether non-traditional students, have enormous capacity as engineers and wonderful potential, but may be held back by conventional or flipped classrooms that are overly dependent on the classroom experience.

The most helpful tool to help students read and watch videos regardless of the class format are the weekly quizzes. These quizzes are not overlong and are low stakes. With complete focus on the material in the textbook and/or video it provides incentives to take the pre-class time and invest in the background preparation for class. Background preparation is essential for robust discussions in active learning activities. Thus, effectiveness of the flipped format largely was contingent on the quizzes.

In terms of limitations and confounding factors to this paper, we were still using active learning and other pedagogical tools and techniques in the classroom. Those have not been removed from consideration in this paper. We have also changed grading schema, with an ungraded approach favored in the more recent semesters. We also note that instructional skill level has increased with time, and that instructional skill pre-2018 was not as honed as since implementation of the ungraded classrooms since 2018. Other instructors have taught these classes in other sections in the period of 2015-2022. We have not compared any data with their courses, as no rigorous controls were implemented to allow for comparison with courses from other instructors.

Conclusion

Before the COVID-19 SARS-COV pandemic acceptance of flipped classrooms by our students was quite favorable, with good learning outcomes. With additional time and space in the classroom for active learning activities, flipped classrooms are an attractive pedagogical tool for geotechnical engineering courses, which tend to have a significant learning curve for many students. However, the COVID-19 pandemic provided a 2-year change in student learning unprecedented in recent memory. Instruction for much of the undergraduate curricula went online to at least some extent during the pandemic. Although there was a range of virtual learning tools used to varying effect over the pandemic, with different approaches utilized by faculty, students found themselves in a virtual environment for an extended period. In the aftermath of the pandemic, we measure and observe a markedly changed student reception of the

flipped classroom concept. Despite not changing the teaching methods utilized in our classes pre- and post-pandemic, student reception of the flipped classroom format has significantly decreased. Data collected from flipped classrooms post-pandemic showed significant reductions in student favorability and performance. The results of this comparison and ongoing interactive collection of student feedback and learning outcomes has shown that the effects of the pandemic induced virtual campus experience has changed the landscape, perhaps just temporarily, and that student's post-pandemic are overwhelmingly desirous of in-class instruction with no videos. We find that our graduate students co-enrolled in senior design electives have been less affected by the pandemic in terms of acceptance of the flipped format. This gives hope that the effects of the pandemic on the student experience with flipped classrooms will be temporary. However, it is a reminder that student acceptance of pedagogical tools does vary in time, and that instructors should be nimble in being able to respond to the needs of an individual cohort.

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