

Using an Inverted Classroom Approach to Promote Active Learning in Construction Management and Engineering Courses

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Concern that larger class sizes are reducing student-instructor interaction and impacting student learning has motivated educators to look for innovative teaching and classroom management techniques. One approach involves using a "flipped classroom" in which students gain the necessary knowledge outside the classroom (online) and then spend class time working on hands-on learning activities. The flipped classroom shifts instruction from a traditional lecturer-centered model, where the instructor passes on his/her knowledge to the student by lecturing, to a learner-centered model in which students take an active role in their learning and instructors serve as learning facilitators. This paper summarizes the results of a project in which a hybrid flipped-traditional classroom model was used for two required courses. The outcomes revealed several interesting results regarding student reactions, the role of a collaborative classroom environment in creating a learning community, and how increased student-instructor interaction improved student critical thinking and problem solving abilities.

Keywords: Hybrid, flipped classroom, learner-centered

Introduction

This section addresses the primary motivations for initiating the project and provides a brief history of the evolution and common applications of flipped (inverted) classrooms. Flipped classrooms change learning from a teacher-centric lecture model to a learner-centric blended or virtual model (Bergmann & Sams, 2014). Students are able to view lecture material at their own pace and use class time for problem solving with the help of peers and the course instructor. In a traditional lecture-based classroom students perform lower level cognitive tasks (Bloom's taxonomy levels 1 & 2: knowledge and comprehension) during the lecture and are expected to perform higher level cognition on assignments and tests (Bloom's taxonomy levels 3, 4, 5 and sometimes 6: application, analysis, synthesis, and sometimes evaluation) (Anderson & Krathwohl, 2001). In the flipped model lower level cognition is done on the students' time, usually via online lectures and reading material, and higher level cognitive tasks are done in the classroom with the help of peers and the course instructor.

Project Motivation

In response to increasing student enrollments and larger class sizes, faculty within the Civil Engineering and Construction (CEC) department are looking for alternative approaches to increase student-instructor interaction, foster critical thinking, and improve the overall student learning experience (Gross & Musselman, 2015).

One such approach involves the development of a hybrid flipped-traditional classroom which combines the attributes of a flipped approach (increased hands-on activities) with the attributes of a traditional approach (material presentation by an expert). The basis of the flipped-classroom approach is that students review lesson content outside of the classroom (online) and then spend class time applying concepts and exploring topics in greater detail through collaboration with peers and face-to-face interaction with instructors (see Figure 1 below). The basis of this approach is to shift the classroom from a lecturer-centered model to a learner-centered model, encouraging students take a more active role in their learning. The hybrid approach provided instructors with the flexibility to alternate between lecture-based and flipped classroom approaches depending on which approach was most appropriate.

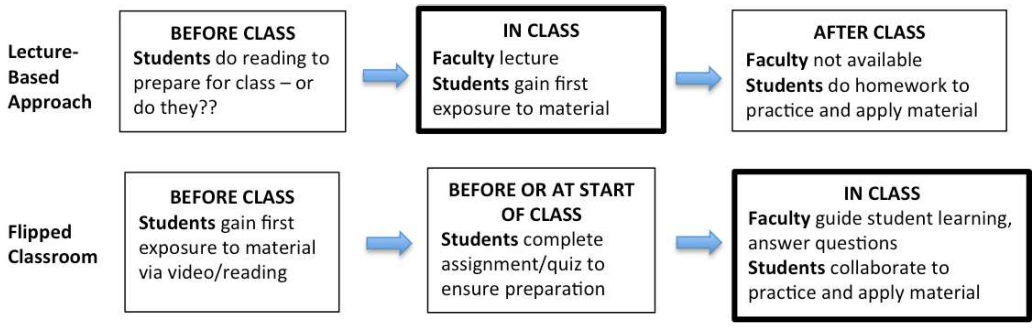

Figure 1. Comparison between a Traditional Lecture-Based Approach and a Flipped Classroom (University of Michigan, 2015)

The purpose of this project was to develop and apply a hybrid flipped-traditional classroom model in two different required courses (taught by two different faculty) within the CEC department. One course was a freshman level "Introduction to Construction Management" course and the other was a junior level course in Fluid Mechanics. Since the courses are from two different programs (Construction Management and Civil Engineering), there were two different sets of students in each course. The hybrid approach provided the faculty with the flexibility to alternate between lecture-based and flipped-classroom approaches depending on which approach was most appropriate for that point in the course. Having taught the courses several times in the past, both instructors were keenly aware of which topics would be most suitable for each approach.

Evolution of the Flipped-Classroom Approach

Flipped learning arguably was pioneered by two high school science teachers, Jon Bergmann and Aaron Sams, in the spring of 2007. Both Bergmann and Sams were chemistry teachers at Woodland Park High School in Woodland, Park Colorado. The first flipped classroom sessions used software to voice record over PowerPoint lectures. At the time, students who attended Woodland Park High School would often miss class to attend school sponsored extra-curricular events. The first recorded lectures were used as a way to teach students who could not attend all class sessions due to scheduling conflicts. After both teachers began using the model they noticed how flipping improved student interaction both among peers and with the teacher (Bergman & Sams 2014, 2015).

Flipped learning is a type of learner-centric model. The learner-centric model in America is mostly attributed to early progressive educator John Dewey who suggested that the process of learning was more important than goals or predetermined learning outcomes. Further he suggested that if learning is to be successful it requires the learner to take an active role in that process (Dewey, 2009). The authors believe that flipped learning is a form of active learning that puts the learner as the owner of the knowledge gained from participating in classroom activities. The learner in this model is responsible for gaining perquisite knowledge before coming to class, but is guided by the use of technology.

The use of flipped classrooms is certainly not new to engineering education as can been seen when searching American Society for Engineering Education (ASEE) conference proceedings. A search using the terms "flipped classrooms" and "inverted classrooms" returns 170 articles for 2017 and 184 articles for 2018 across multiple disciplines. As expected, there is a lot of variance regarding the content of the articles. Whereas some articles focus on identifying the "lessons learned" from case studies in which inverted classrooms were used for various types of courses at different academic levels, others spotlight instructor and student observations pertaining to benefits and limitations of the approach. Other articles address pedagogical-based strategies for improving its implementation. One such paper that contains many of these topics and was used in the design and implementation of our hybrid classroom came from Swartz, Velegol, and Laman (2014). In this paper the authors report on the use of a flipped classroom in three Civil Engineering courses taken at three different academic levels (sophomore, junior, senior). While their paper did not address a method for direct assessment, it did provide valuable insight regarding the merits and challenges associated with inverted classrooms as well as practical strategies and insights for its application. In a similar study by Gross and Musselman (2015) involving the use of a flipped classroom approach in several courses related to structural design, the authors used courses taught in the same department which is similar to this study, but

also included assessment results taken from quizzes, problem sets, and design projects. A flipped classroom model was recently used by in a multi-year study that examined student performance for a large (800 student) Introductory Programming course through quantitative and qualitative measures (Marasco, Moshirpour, & Moussavi, 2017). Our study differs from the aforementioned studies in two areas: i) our courses came from two distinct programs (civil engineering and construction management) and ii) our assessment involved *both* a pre-implementation survey (addressing student perspectives prior to applying an inverted classroom structure) and a post-implementation survey (providing insight as to how the approach impacted their learning and how its implementation could be improved). Similar to the report by Gross and Musselman (2015), and others identified in the literature review, our project also included direct assessment through the evaluation of homework assignments.

Methodology

This section provides detailed information as to how the hybrid classroom model was implemented in each of the two courses. In doing so, it identifies the components of the flipped classroom component common for each course, while also highlighting the notable differences as to how each instructor applied the hybrid model to their course.

Pre-implementation Assessment

Prior to implementing the flipped-classroom portion of the course, both instructors provided their students with a brief orientation to this teaching technique through the use of two short videos: "The Flipped Classroom" (Sams, 2012) and "What is a flipped class?" (University of Texas at Austin, 2015). Students were also provided with an informed consent form notifying them of the study. While there are numerous videos available online explaining the flipped classrooms, these videos were selected based on their quality and clarity. Following the orientation, the instructors used a questionnaire to assess the students' opinions regarding the use of the flipped classroom approach and how it might impact their learning. The following shows a representative sample of the student comments taken directly from the questionnaire:

1. *Having watched the videos introducing the "flipped classroom" approach, what are your perceptions regarding the student's role?*
   - I like the idea of covering the theory and reading at home where I have ample time to understand the process and work through the math.
   - It looks like I've have more responsibility but ultimately less frustration.
   - It might be difficult to adjust to since it's not done elsewhere in our college.
   - It puts larger role on student for preparing, but seems more productive.

2. *What are your opinions regarding the teacher's role in the flipped (inverted) classroom approach?*
   - We can learn most everything online but really need the professors help in applying the material.
   - The professor can actually help us with difficulties and questions.
   - Teacher does more work outside of classroom and hands-on training during class.
   - Should eliminate issues when I spend hours stuck on one problem.

3. *How might or might not the "flipped classroom" help you to better learn the material for the course?*
   - When I leave class, I now that I will understand the material and be able to answer any questions.
   - This way helps me get the extra help I need since I don't have to visit during office hours.
   - I better put forth the effort before class.
   - It will actually make me review the material.

4. *Do you have any concerns regarding the instructor's use of the "flipped classroom" approach for a portion of this course?*
   - I'm concerned about the difficulty of the online material.
   - Not concerned – did this in my Calculus II course.
   - Now I have to participate during class (rather than day dreaming).
   - Sounds like it could be a game changer in the engineering students' world.

The information collected from the questionnaire was not only useful in understanding student perceptions and concerns relating to the flipped classroom approach, but in helping the instructors design and implement strategies aimed at improving student learning while also addressing the students' concerns.

Implementation

Course: Fluid Mechanics. As students arrive for class, the instructor collects a "ticket" from each student which contains a lesson-specific assignment used to measure their understanding of the key concepts covered in the online lesson. Like the lesson itself, the ticket is also posted online. Most of the questions within the ticket are short answer, addressing knowledge and comprehension levels within Bloom's Taxonomy. However, usually there is a computational-based question requiring students to rework an example from the online lesson (with different variables) or a similar problem addressing the application and analysis levels within Bloom's. As shown in Figure 1, holding students accountable for doing the necessary pre-class preparation is a key component in the flipped classroom approach. Students entering the classroom without their completed ticket are considered absent for the class (counting against their attendance grade) but are allowed to participate in the problem solving portion of the class.

Having collected the tickets, each class starts with a 10~15 minute lesson overview in which the instructor highlights the concepts covered in the online lesson. In doing so, he addresses the concepts addressed within the ticket while also emphasizing how the lesson's content relates to previous and/or upcoming lessons, the course, and the profession. The instructor intentionally limits the lesson overview to 15 minutes based on the finding from Swartz et al. (2014) whose literature review identified that typical student attention spans range from 5-15 minutes. The remainder of the class time is devoted to problem solving. Working in teams of two, the students use class time solving problems in a collaborative environment in which students share ideas, the instructor moves from group to group answering questions and posing questions that require critical thinking. As each student team completes the assignment, the assignment is graded in their presence. This provides the instructor another opportunity to interact with the students, identifying any deficiencies and reemphasizing critical concepts.

Course: Introduction to Construction Management. Students in this course were instructed to work through online learning modules. One such module included a detailed PowerPoint that introduced construction estimating along with five instructional videos that prepared students to use Microsoft Excel. Students were then required to complete an out of class exercise that demonstrated their ability to use spreadsheets. The assignment was the "ticket" to get into class for the in-class exercise. This ticket was worth 20% of the total project grade with the in-class project consisting of the other 80%. The ticket was submitted electronically the day before class and a printed copy was required to get credit for attending the course.

At the beginning of class the instructor also spent around 10~15 minutes reviewing the modules contents and collecting tickets. The remainder of class was spent with students working on problem solving. Each student was required to work with a peer, but each student was responsible for submitting their own original work. Working with peers allowed students to ask each other questions and to stimulate questions. During this time the instructor walked around the room helping students who had questions that could not be answered by their peer partners.

Results

This section addresses how well the flipped classroom portion of each course functioned both in terms of student opinions and actual class performance.

Post-implementation Assessment

After completing the flipped classroom portion of each course, the students completed a post-implementation questionnaire in order to gage their opinions regarding the flipped classroom approach and evaluate how it impacted their learning. As was the case of the pre-implementation survey, the following represent a representative sample of the comments received from the questionnaire:

1. *What did you like most about the format of the "flipped" portion of the course?*
   - It was more interactive than the traditional format.
   - More personal help. I could spend more or less time on specific subjects depending on my needs.
   - The extra help you get while in class is priceless and well needed.
   - The liked the focus on problem solving and not just on theory.

2. *Was there anything about the "flipped" portion of the course that you did not like?*
   - Not being able ask questions while doing the out of class work.
   - I'm an auditory learner so learning the material beforehand was slightly difficult.
   - At times I didn't like the partner system (when my partner didn't help).
   - If you miss one day of class, you get thrown off.

3. *If you could offer one suggestion to improve the inverted (flipped) learning experience, what would it be?*
   - More open discussion as a group before class begins.
   - More help on the homework (ticket).
   - Make the in-class groups smaller for more one-on-one time with the professor.
   - Use on-line quizzes for the tickets.

4. *It what ways has the "flipped" learning environment helped you learn this semester?*
   - Taught me to be responsible for my own learning.
   - Helped me to manage my time.
   - It's given me more time to learn on my own the skills I'll apply in the classroom.
   - It helps me grasp the concepts in class rather than going home and Googling the answers.

5. *It what ways did the "flipped" learning environment not help you to learn this semester?*
   - It helped me to learn.
   - There wasn't as much teaching, it was mostly learn on your own and ask questions.
   - It has been very helpful to me in every way.
   - I have nothing bad to say, I love it and the group work is a plus.

Performance Based Measures

As a measure of student performance during both the traditional and flipped classroom portions of the Fluid Mechanics course, the instructor evaluated homework scores from the 24 students enrolled in the course for assignments 1~3 (traditional portion) and assignments 4~7 (flipped portion) as shown in Table 1. The instructor for the Introduction to Construction Management course evaluated homework scores from the 77 students enrolled in the course for assignments 1and 2 (traditional portion) and assignments 3 and 4 (flipped portion) as shown in Table 2 below.

Table 1 indicates an average score of 71.6% for the assignments evaluated during the traditional classroom portion of the course compared to 93.2% during the flipped-classroom portion. The difference with regard to the low scores was even more dramatic; with low scores averages changing from 23.3% (traditional classroom) to 76.7% (flipped classroom) respectively. Table 2 indicates an average score of 70.6% for the assignments evaluated during the traditional portion of the course compared to 92.2% during the flipped portion. The difference for the low scores was a similar shift in the Introduction to Construction course with low scores for the traditional portion at 58.2% and 80.0% for the flipped course. Whereas the authors anticipated higher scores during the flipped classroom portion of the course due to their increased availability to answer questions and opportunities for collaboration among students, nonetheless the difference in performance is significant and clearly illustrates that flipped classroom approach improved student performance and learning.

Table 1

Comparison of the Homework Scores taken for Traditional and Flipped Classroom Portions of the Fluid Mechanics Course

Measures	Assignments – Traditional Classroom			Assignments – Flipped Classroom			
	Assign. #1	Assign. #2	Assign. #3	Assign. #4	Assign. #5	Assign. #6	Assign. #7
Low Score	12.0%	30.0%	28.0%	73.3%	70.0%	75.0%	88.5%
Ave. Score	74.6%	78.7%	65.3%	94.0%	91.3%	93.5%	93.9%
High Score	100.0%	100.0%	90.0%	100.0%	100.0%	100.0%	100.0%

Table 2

Comparison of the Homework Scores taken for Traditional and Flipped Classroom Portions of the Introduction to Construction Course

Measures	Assignments – Traditional Classroom		Assignments – Flipped Classroom	
	Assign. #1	Assign. #2	Assign. #3	Assign. #4
Low Score	57.6%	58.8%	80.0%	80.0%
Ave. Score	73.5%	67.6%	89.7%	94.7%
High Score	88.0%	100.0%	94.0%	100.0%

As an additional measure, the instructor for the Fluid Mechanics compared the performance of midterm exam #1 taken from the Fall 2017 semester (in which all the content had been delivered using a traditional classroom approach) with the *same* midterm exam taken during the Spring 2018 semester in which all the content was delivered using only a flipped classroom approach. As shown in Table 3 below, the average exam grade from the flipped class was 3.8% higher.

Table 3

Comparison of Exams Scores for the Fluid Mechanics Course taken Traditional (Fall 2017) and Flipped (Spring 2018) Classrooms

Measures	Mid-Term Exam #1 Scores	
	Fall 2017 – Traditional Classroom	Spring 2018 – Flipped Classroom
Low Score	48.3%	61.0%
Ave. Score	76.1%	80.9%
High Score	100.0%	97.2%

Moreover, a comparison of distribution of grades (Figure 2) shows that the percentage of students achieving a score of 70% or better increased from 71.4% for the traditional classroom to 82.4% for the flipped classroom. Equally importantly, whereas 14.1% of the students failed the exam in the Fall 2017 semester (traditional classroom), nobody failed the exam during the Spring 2018 semester (flipped classroom) which highlights the effectiveness of flipped classrooms in keeping students engaged. Essentially, the regimen of in-class activities help students from falling behind. As a final testimonial of how the flipped classroom impacted student learning, upon completion of the scheduled flipped classroom track of each course, many students from both courses requested that the instructors

continue to apply the approach throughout the remaining weeks of the course and in other courses within the CECM department.

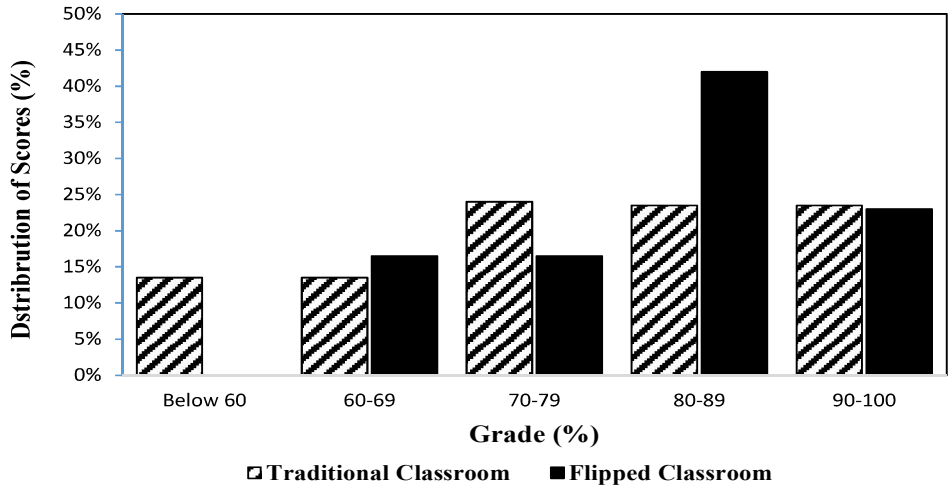

Figure 2. Distribution of Exam Scores for the Fluid Mechanics Course taken Traditional (Fall 2017) and Flipped (Spring 2018) Classrooms

Discussion

For academic programs facing increased students enrollments, pressure to increase research/scholarship productivity, and diminishing resources, the "flipped" (inverted) classroom approach offers many noteworthy advantages for both students and instructors.

Advantages for students:

- Providing students with a collaborative classroom environment to apply course material provides a more positive learning experience than the traditional method of using homework assignments as a student's first exposure to problem solving.
- The online environment allows students to review lesson material at their own pace.
- Transitioning students from passive to active participants in the learning process empowers them to take responsibility for their learning while also developing self-directed learning skills. This skill is vital in both the civil engineering and construction management professions that depend heavily on autonomous problem solving and continuous learning.
- Students receiving support from a learning community of peers and faculty are more likely to stay in their program of study and graduate (Fishman, Ludgate, & Tutak, 2017).
- Engaging students in the learning process leads to a deeper level of thinking and cultivates students that are more creative and motivated (Swartz et al., 2014).

Advantages for instructors:

- Inverted classrooms allow programs to offer larger class sections without compromising student teacher interaction and engagement.
- Combining traditional and flipped classroom approaches within in a single hybrid course allows the instructors the flexibility to apply a lecture-based approach for lessons not conducive to online methods and a flipped classroom approach in cases in which students would benefit collaborating in groups.
- Having the instructor assist students with their assignments during class time minimizes the need for office hours and frees up time for instructor to work on other tasks.

- The flipped classroom approach provides an environment that fosters creativity and allows instructors to use class time for more challenging and engaging activities. This provides opportunities to expand the class beyond the original learning outcomes while sparking student interest in their major.

In spite of the abundance of advantages, both instructors also observed several disadvantages associated with the inverted portion of each class that need to be addressed both in the design and implement of the course:

- Flipped classrooms rely heavily on student participation prior to the class. While both instructors attempted to hold students accountable through the use of "tickets" and quizzes, there was no way to guarantee that students fully and independently participated in their pre-class preparations.
- Implementing a flipped classroom requires extra effort for instructors in preparing the online content, creating hands-on classroom activities that stimulate and motivate students to want to learn, while also making sure all of the content integrates from lesson to lesson.

The flipped learning environment provides students with a learning environment in which they are able to take ownership of their learning. While it might be suitable for some classes, it does have limitations. Flipped learning relies on technology to augment and enhance student learning outside of the classroom. Not all students have access to the computers while away from campus.

For the authors, this was the first step towards integrating technology to enhance the in class experience using flipped learning. We chose to use a hybrid flipped model to see how students responded to the experience versus the traditional classroom approach. The survey data collected from this study indicated that the students had positive feelings about the flipped learning environment and improved scores on assignments. Some students were concerned with the workload outside of class and the authors were concerned about the time it took to prepare material for the flipped environment. While the results from this study are specific to these course, the authors believe that flipped learning is a worthwhile endeavor and could yield positive results in similar programs.

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