Flipped Learning: a Hybrid Classroom Approach that Turns Construction and Engineering Education Upside Down

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Abstract

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[3]. 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) [1]. In the flipped model (see Figure 1 below) 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.

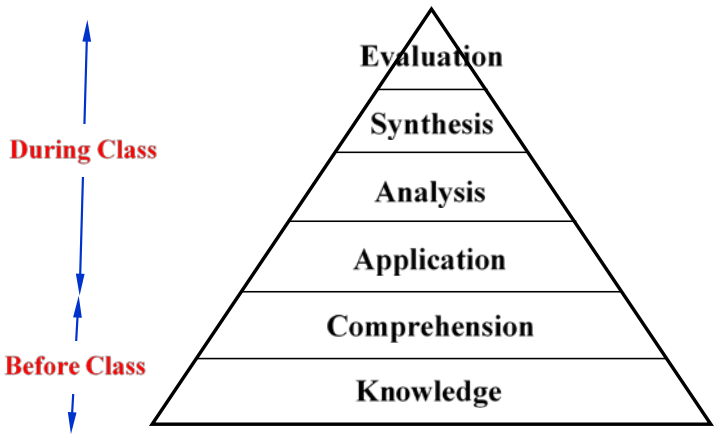

Figure 1. Bloom's Taxonomy as it relates to the Hybrid Courses

Project Motivation

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

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 2 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.

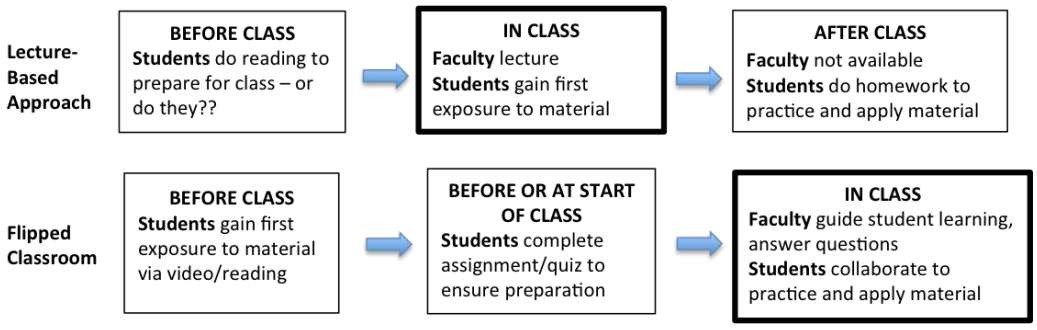

Figure 2. Comparison between a Traditional Lecture-Based Approach and a Flipped Classroom[8]

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 CECM department. One course was a freshman level "Introduction to Construction Management" 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 was two different sets of students in each course. Whereas the construction management course was selected due to its large amount of content (well-suited for online delivery) and its abundance of in-class activities requiring student-instructor interaction, the fluid mechanics course was chosen due to the sizeable amount of challenging technical topics that the instructor felt could be better addressed through more one-on-one interaction. 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[2, 3].

Flipped learning is a type of learner-centric model. The learner-centric model in America is mostly attributed to early progressive educator John Dewey. John Dewey 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 [4].

The authors believe that flipped learning is a form of active learning that focuses on the learner as the owner of the knowledge gained from participating in classroom activities. Thus the learner is required to use social and problem solving skills work on projects in the classroom. The learner in this model is responsible for gaining perquisite knowledge before coming to class, but is guided by the use of technology to create learning modules relevant to the content of the two courses.

The use of flipped classrooms is certainly not new to engineering education as can been seen when searching ASEE conference proceedings. A search using the terms "flipped classrooms" and "inverted classrooms" returns 90 articles for 2014 and 144 articles for 2015 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, Butler, and Laman[7]. 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[5] 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. Their assessment also included an end-of-semester survey that summarized student perspectives on the inverted model. 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[5], 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, such as pre and post implementation and assessment, while also highlighting the notable differences as to how each instructor the approach in their course. These differences were directly related to the differences in course content, academic levels, and instructor teaching styles.

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” (video from Aaron Sams highlighting his experience) [6] and ‘What is a flipped class? (University of Texas at Austin)[9]. While there is an abundance of videos available online that demonstrate the flipped classroom approach, 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 represent a representative sample of the comments received 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 college.
- This is a good idea since this is how a real-world work environment will be.
- I was skeptical at first, but now I think it will work.
- 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.
   - Minimizes boring the whole class while explaining something to one student.
   - I like having the teacher more involved.
   - Great idea, would like every class to be taught this way.
   - Teacher does more work outside of classroom and hands-on training during class.
   - Should eliminate issues when I spend hours stuck on one problem.
   - Helps with the whole "small feel" culture of our university with more one-on-one time with instructor.
   - It could be good or bad, depending on how well the teacher communicates in the online and in-class sessions.

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.
   - It will definitely help me because I struggle to take notes while also understanding the material (allows me to focus on one task).
   - It might be difficult adjusting from our normal habits.
   - I better put forth the effort before class.
   - It will actually make me review the material.
   - Seems like the pre-class work (lectures) is a base layer of knowledge and the in-class exercises build on that.

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.
   - How will this affect my grade?
   - 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. The next section details how the flipped classroom approach was implemented in each course, highlighting the variances from the "one size fits all" approach to address differences in course size, content, and design.

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 assignment (ticket) is also posted online. Most of the questions within the assignment 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 2, holding students accountable for doing the necessary pre-class is a key component in the flipped classroom approach. As such, 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. As the tickets are collected, each is evaluated for completeness and originality (i.e. making sure that no two tickets are direct copies of each other). Students identified has having copied tickets are not given credit for attending that day's 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, Butler, and Laman whose literature review identified that typical student attention spans range from 5-15 minutes[7]. The remainder of the class time is devoted to problem solving. Working in teams of two (which the instructor changes periodically) 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, and common questions are addressed on the board. As opportunities surface, the instructor makes a concerted effort to extend the class content to the synthesis and evaluation levels within Bloom's Taxonomy by posing questions and initiating class discussions that explore design applications/alternatives or having students defend their problem solving approach.

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. For student teams willing to accept another challenge, the instructor provides an extra credit "special problem" that requires the students to explore the topic in greater detail. As an example, when covering a lesson addressing buoyancy force, the "special problem" required students to analyze how buoyancy force is applied to the design of a tension-leg platform (a common offshore structure)

Course: Introduction to Construction Management

Students in the Introduction to Construction Management 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.

In the case of the Introduction to Construction Management Course the "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 class was more fun compared to the PowerPoint lectures.
    - The productivity of the class.
    - Knowing what I was going to do before class.
    - 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?*

    - One student may receive more attention than others. Teacher may not have time to get to all students.
    - I didn't like the amount of work outside the classroom.
    - Not being able ask questions while doing the out of class work.
    - The work you had to do at home.
    - 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).
    - Start this approach at the beginning of the semester.
    - Make the in-class groups smaller for more one-on-one time with the professor.
    - Shorter videos.
    - Switch partners more frequently.
    - Use on-line quizzes for the tickets.

4. *It what ways has the "flipped" learning environment helped you learn this semester?*

    - The class is more productive.
    - 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.
    - If forced me to apply myself more.
    - 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?*

    - In no way did it not help me.
    - It helped me to learn.
    - It was amazing!
    - 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.

<u>Performance Based Measures</u>

As a measure of student performance during both the traditional and flipped classroom portions of the hybrid Fluid Mechanics course, the instructor evaluated homework scores from the 22 students enrolled in the course for assignments 1~3 (traditional classroom portion) and assignments 4~7 (flipped classroom 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 for the traditional part of the course and assignments 3 & 4 in the flipped portion as shown in Table 2.

Table 1. Comparison of the Homework Scores taken for Traditional and Flipped Classroom Portions of the Fluid Mechanics Course

Measures	Assignments - Traditional Classroom Approach			Assignments - Flipped-Classroom Approach			
	Assignment #1	Assignment #2	Assignment #3	Assignment #4	Assignment #5	Assignment #6	Assignment #7
Low Score	12.0%	30.0%	28.0%	73.3%	70.0%	75.0%	88.5%
Average 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 Approach		Assignments - Flipped-Classroom Approach	
	Assignment #1	Assignment #2	Assignment #3	Assignment #4
Low Score	57.6%	58.8%	80.0%	80.0%
Average Score	73.5%	67.6%	89.7%	94.7%
High Score	88.0%	100.0%	94.0%	100.0%

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. Recognizing that an analysis of exam grades would provide further insight regarding any improvement in student performance with the flipped classroom approach, the authors plan on collecting exam data for the next course offerings and reporting on their findings a future publication.

As an additional 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.

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, making the course more accessible to those students who with the fast pace of a traditional classroom.
- 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.
- Engaging students in the learning process (which Swartz, Butler, and Laman define as active learning[6]) leads to a deeper level of thinking and cultivates students that are more creative and motivated.

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 working in collaborative problem solving 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. This is especially true for instructors that evaluate student work in class.
- 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. This in turn can lead to more opportunities for faculty to work with students in both undergraduate and graduate research projects.

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.

Both instructors feel that integrating flipped elements into their classroom is a gradual process.

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. Given the challenges and concerns the authors believe that flipped learning is a worthwhile endeavor and plan to integrate more flipped content into their courses in future course offerings. Moreover, the success of this project has spurred interest from several faculty both within the Department and the College to incorporate a flipped learning approach in their courses as well.

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