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Building a Better Classroom and Learning Experience in Construction Management Courses through Flipped Learning

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Concern that increasing student enrollments and larger class sizes are impacting student learning motivated faculty at a 4-year public university in the Southeastern USA to perform a mixed-method study to examine the effect of a Flipped Classroom Model (FCM) on required course within a Construction Management program. The study targeted 120 students enrolled in both on-campus (45 students) and online (75 students) classrooms. While the online students were taught asynchronously using a traditional lecture-based classroom model, the on-campus students were taught using an FCM. Thus, the online students served as a control group, while the on-campus students served as a study group. Both online and on-campus students were taught by the same instructor using the same materials and assessments. Student academic performance was measured using several assignments, with additional qualitative data collected through both pre-implementation and post-implementation surveys. Data show a significant improvement in both the distribution and average assignments scores in the study group. The study also reveals several interesting trends regarding student reactions to flipped learning, the importance of self-directed learning, and the role of technology in strengthening student learning and problem-solving abilities.

Key Words: Flipped classroom, critical thinking, construction

Introduction

Flipped Classroom Model

In a traditional classroom model (TCM), students are first exposed to a lesson through a classroom lecture. They then try to learn the content through activities after class. The FCM challenges this idea, shifting the first exposure to outside of class through a pre-class element (typically utilizing online sources) so that class time can be allocated for active-learning activities such as problem solving, computer software applications, and class discussions. The primary goal of this approach is to move away from the traditional one-way knowledge flow from teacher to student into an environment that encourages student engagement with the instructor. This in turn leads to opportunities for

students to engage in advanced concepts, deep thinking, and collaborative learning (McNalley et al., 2017).

Flipped classrooms (also known as inverted classrooms) have been in existence for some time. There are numerous definitions for the flipped classroom ranging from Lage, Platt, and Treglia (2000) “events that traditionally taken place inside the classroom now take place outside and vice versa” to “an educational technique that consists of two-parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom” (Bishop & Verleger, 2013). Although recent literature differentiates between a flipped classroom and flipped learning (Chen, Wang, & Chen, 2014), for the purpose of this manuscript, a flipped classroom is defined as “using time outside of class to read and view online lectures, while class time can be spent on hands-on learning, group discussion, and question/answers sessions” (Gerstein, 2012).

The effects of a FCM on student learning (as measured by academic performance) have been evaluated in many courses including nursing (Missildine, Fountain, Summers, & Gosselin, 2013), statistics (Wilson, 2013), human-computer interaction (Day & Foley, 2006), biology (Moravec, Williams, Aguilar-Roca, & O’Dowdal, 2010), chemistry (Fitzgerald & Li, 2015) and basic pharmaceuticals (McLaughlin et al., 2014). Although research has shown that the FCM nurtures and enhances student cognitive skills (Gomez-Lanier, 2018), results regarding the impact of FCM on student performance in the classroom are mixed. Whereas some studies report an increase in student academic performance on exams and/or assignments (Chen et al., 2014; Tune, Sturek, & Basile, 2013) other studies report no significant difference in student achievement between a FCM and a TCM (Lage et al., 2014; Johnson & Renner, 2012; Strayer, 2007; Davies, Dean, & Ball, 2013).

Student perceptions of FCM have also been quite varied. Lage et al. (2000) identified that most students have a positive perception of the flipped model, although some students invariably disliked it and perceived the increased expectations for personal responsibility in learning as unfair or unreasonable (Wilson, 2013). Students reported experiencing more innovation and cooperation in a flipped classroom but were less satisfied with their preparation (Strayer, 2007), the web-based instruction (Frederickson, Reed, & Clifford, 2005), and required more support and facilitation from the instructor (Kim, Kim, Khera, & Getman, 2014). The FCM had a positive impact on students’ attitudes toward a class (Wilson, 2013), improved perceptions of the learning environment (Baepler, Walker, & Driessen, 2014) and the perception that the flipped classroom greatly enhanced their learning (Zappe, Leicht, Messner, & Litzinger, 2009). Students also reported a more student-centered approach and increased engagement (Goodwin & Miller, 2013) in the flipped model. Conversely, studies by Davies et al. (2013), Butt (2014), and Sengel (2016) indicate that students often view flipped classrooms negatively since they perceive flipped classrooms as requiring greater amounts of work and preparation.

Course Context

The current study targeted Construction Management undergraduate students enrolled in a Statics and Strengths of Materials course at a 4-year public university in Southeastern USA. Statics and Strengths of Materials is a required course in the Construction Management curriculum usually taken during the second semester of the sophomore year. The course has both on-campus (45 students) and online (75 students) sections. The purpose of the course is to improve students’ understanding of structures and their numerous applications in the construction industry. Students in this course learn to apply fundamental concepts including coplanar force systems, analysis of trusses and frames, centroids and moment of inertia, stresses and strains, properties of materials, bending, shear, and deflections in

beams. These topics have numerous applications within the field of Construction Management and directly relate to the design and construction of commercial, heavy civil (bridges, dams, etc.) industrial, and residential infrastructure.

On-Campus Course Format and Organization

Before Class. Prior to attending class, students are required to review an online lesson which contains a combination of PowerPoint slides (providing terminology, fundamental concepts, derivations, etc.), internet-based videos illustrating real-life applications of the lesson topics, and Lightboard videos demonstrating example computations. Detailed information regarding the use of Lightboard videos can be found at Rogers & Botnaru, 2019. Pre-class preparation in FCM is important for the quality of the in-class discussion. For this reason, students were required to complete on-line quizzes before every class (quizzes were turned off 30 minutes prior to class). Each online quiz contained questions covering several fundamental concepts and computational-based questions, which require students to rework examples covered within the online lesson (with different variables). The completion rates for the online quizzes were 91.8%.

During Class. Each class started with a 10~15 minute lesson overview in which the instructor highlighted the concepts covered in the online lesson. In doing so, the instructor addressed the concepts addressed within the quiz, while also emphasizing how the lesson's content related to previous and/or upcoming lessons, the course, and the profession. The remainder of the class time was devoted to in-class assignments that included problem solving sessions, computer-based activities with commonly used software including Bridge Designer, Microsoft Excel, and SkyCiv (structural Analysis and Design software). Assignments were assigned and collected at each class as shown in Table 1. Eighteen of the twenty assignments (all but assignments 10a and 10b which require software) were performed on an individual basis.

Online Course Format and Organization.

While the instructor offers the the students the opportunity to take the course synchronously (together, on a set day and time), very few of the online students opt for this opportunity. Most of the online students taking the Statics and Strengths of Materials course do so as an asynchronous class since this option is more flexible and better suits the program's online students who generally work during the day.

The course is taught by having the instructor record the synchronous course, in which he goes through the online content provided to the on-campus students (PowerPoint slides, internet-based videos, Lightboard recordings), but answers any questions posed by the synchronous students. To provide the online students with opportunities to seek assistance and interact with the instructor, the instructor offered two hours of "virtual office hours" every week (using Zoom) and was also available for private Zoom-based help sessions. All weekly assignments are collected on an individual basis.

Methodology

This was a mixed-method study carried out during the Spring 2023 semester. To assess any differences in academic performance between the control group (online students) and the study group (on-campus students) both groups of students were given identical homework assignments. Whereas the on-campus received the first half of each assignment (Assignment 1a, etc.) on Tuesday and the

second half on Thursdays (Assignment 1b, etc.) , the online students received the entire assignment (Assignment 1, etc.) on a weekly basis (due Sunday at midnight). Table 1 shows weekly assignment schedule for both the online (control) and on-campus (study) groups throughout the semester.

In addition to quantitative data collected on the students' performance on assignments, two anonymous surveys were administered to the study group (on-campus students) at the beginning and end of the semester. Both surveys were completed in class (voluntarily) with no incentives offered for their completion. The first survey (start-of-semester survey) was given to the students after providing them with an orientation to the FCM which consisted of a PowerPoint presentation and an online video. The survey contained four open-ended, short answer questions relating to the students' initial perceptions about the FCM. The second survey (end-of-semester survey) contained seven open-ended, short answer questions which addressed the students' overall experience with the FCM and how the FCM impacted their learning.

Information collected from the initial survey provided the researchers with important information regarding the students' initial perceptions of the FCM and how it would be implemented within the course. The following provides a representative sample of the comments received from the initial survey:

Having watched the videos introducing the "flipped classroom" approach, what are your perceptions regarding the student's role?

- Students will have no choice but to take a more active role in their learning.
- It gives students the opportunity to learn at their own pace.
- It should reduce the amount of time (and stress) spent on applying concepts.
- I like that our class time will be more devoted to hands-on learning.

What are your opinions regarding the teacher's role in the flipped (inverted) classroom approach?

- The teacher's role is more effective since they act like a learning coach/mentor.
- There is less pressure on the teacher because students will have to teach themselves.
- This allows the teacher to really focus on students on an individual basis.
- It's critical that the information provided to the students before class is accurate and clear.

How might or might not the "flipped classroom" help you to better learn the material for the course?

- It will force me to review the material before the lecture.
- I'm going to feel less overwhelmed since I'll have less busy work outside of class.
- I'm concerned that I won't be able to teach myself the material (I struggle with textbook learning).
- Seems like the classroom will be more interactive (more questions etc.), which I like.

Do you have any concerns regarding the instructor's use of the "flipped classroom" approach for a portion of this course?

- I'm concerned that some people may not attend class and fall behind.
- I worry about the amount of time needed to review the lessons, videos, etc.
- It's important that the videos and online lessons used for the class are good.
- I'm a little concerned about the quizzes which are due before class.

Table 1.

Weekly Assignment Schedule for the Online and On-Campus Courses

Week No.	Course Topics	Online Course (Control group) Assignment	On-Campus Course (Study group) Assignments
2	Force Characteristics (Forces Systems), Resultants, Vector addition, Moments, Varignon's Theorem, Couples	Assignment 1	Assignments 1a, 1b
3	Equilibrium of a particle, Free Body Diagrams, Loads and Supports	Assignment 2	Assignments 2a, 2b
4	Equilibrium: application to cables, simple beams with distributed loads	Assignment 3	Assignments 3a, 3b
7	Methods of Sections, Zero-force members, Pinned frames, Three-hinged arches	Assignment 4	Assignments 4a, 4b
8	Load paths, Tributary areas, Span directions, Lateral Stability, Simple stress, Axial Strain, Deformation	Assignment 5	Assignments 5a, 5b
10	Material properties, Elastic modulus, Stress-Strain Curves	Assignment 6	Assignments 6a, 6b
11	Excel Applications - Material Properties Center of Gravity and Centroids	Assignment 7	Assignments 7a, 7b
12	Moment of Inertia (MOI), MOI of Composite Areas	Assignment 8	Assignments 8a, 8b
13	Classification of beams and loads, Shear and bending moment, Relationship between Load, Shear, and Bending Moment	Assignment 9	Assignments 9a, 9b
14	Computer Exercise - Using Software to Create Shear and Bending Moment Diagrams , Flexural (Bending) Strain and Bending Stress	Assignment 10	Assignments 10a, 10b

Results

Quantitative Data Analyses

Table 2 and Figure 1 summarize student performance on same assignments between the online (control group) and the on-campus (study group) classes. In gathering the statistics, scores from the two weekly assignments for the study group (example: Assignments 1a, 1b) were combined to have the same point total as the one weekly assignment (example: Assignment 1) for the control group. The table shows that the average assignment scores for the control group ranged from 72.50% to

93.4% with a mean of 83.2%. Conversely, the overall performance for the study group was stronger, with average assignment scores varying from 82.2% to 95.2% with a mean of 90.7%. Whereas the range between the low and high scores on assignments for the online class (control group) was 20.9%, this range for the on-campus (study group) was 13.0%. As shown in Figure 1, the study group had higher scores on eight out of the ten assignments. Aside from the contrasts in assignment performance between the online and on-campus classes, an equally important measure relates to the variance of the low scores. Figure 2 shows an important trend: the scores of the lowest performing students in the control group were significantly lower in nine of the ten assignments of the lowest performing students in the focus group. Moreover, the average low score (taken across all ten assignments) for the control group is 33.2% lower than the average low scores (taken across all ten assignments) for the focus group. This means that even the lowest performing students in the focus group performed much stronger than the lowest performing students in the control group.

Table 2.

Comparison of the Average Assignment Scores

Class Type	Assignment Number									
	1	2	3	4	5	6	7	8	9	10
Online (Control Group)										
Min (%)	26.7	36.7	55.0	10.0	20.0	53.3	40.0	26.7	16.7	36.7
Ave (%)	84.9	87.7	90.0	72.5	81.2	93.4	81.1	79.4	72.8	89.5
On-Campus (Study Group)										
Min (%)	63.3	56.7	65.0	50.0	73.3	53.3	80.0	81.7	73.3	56.7
Ave (%)	94.6	82.2	91.9	82.8	92.4	88.3	95.2	92.7	93.8	92.9

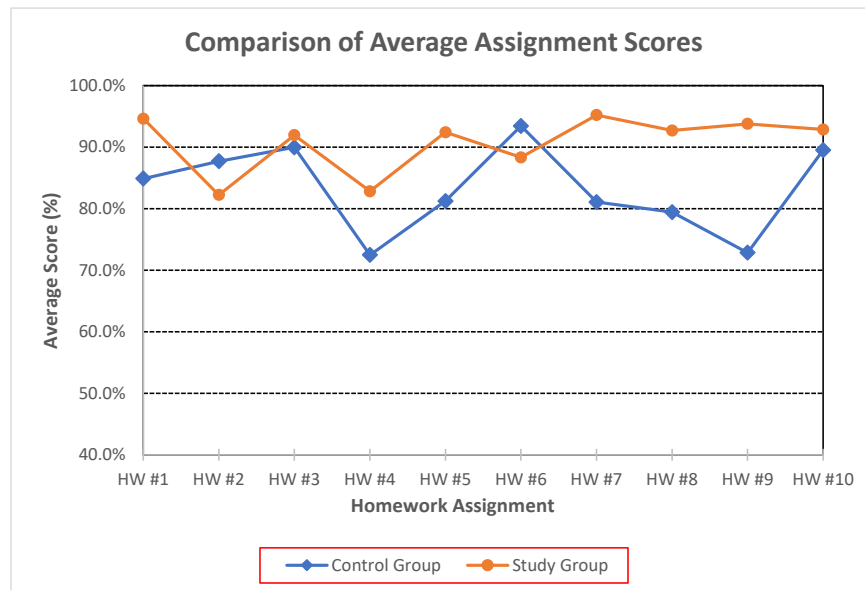


Figure 1. Comparison of Average Assignment Scores between the Control and the and On-Campus Classes

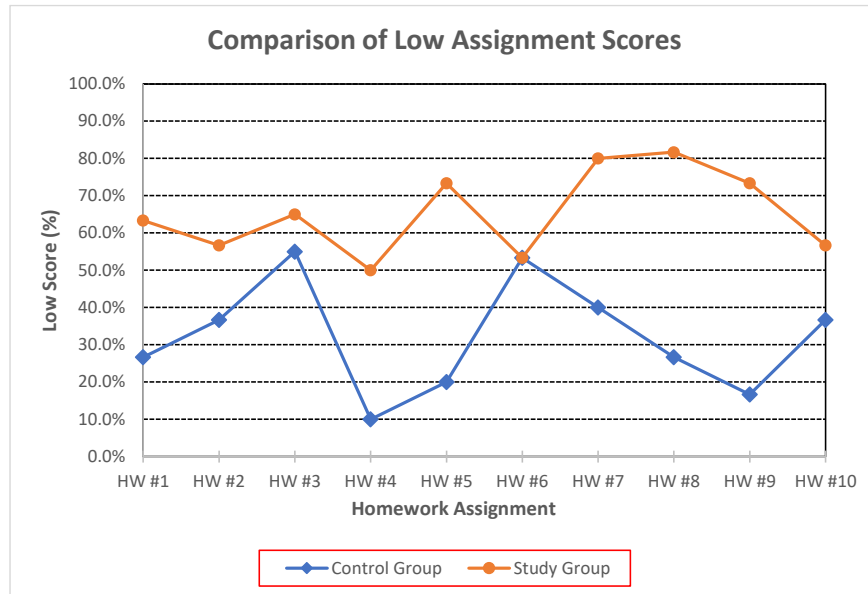


Figure 2. Comparison of the Low Assignment Scores between the Online (Control Group) and On-Campus (Study Group) Classes

Qualitative Data Analyses

At the completion of the course, students from the study group completed the end-of-semester survey which included short answer questions relating to their overall experience with the flipped classroom and how the FCM impacted their learning. The following provides a representative sample of the comments received from this survey:

What did you like most about the "flipped classroom" approach used for this course?

- The class had a lot of graded events (quizzes, homework) that helped me keep on track.
- I liked the flexibility of completing the online work based on my time schedule.
- I enjoyed working during class and having the instructor available for assistance.
- This approach helps us learn to collaborate with others.

Was there anything about the "flipped classroom" that you did not like?

- At times I felt overloaded with the amount of work.
- Sometimes you have classmates that aren't prepared and take up all the instructor's time to help others.
- I didn't like submitting the computer assignment on a group basis (versus individually).
- I didn't like having to look through the material before class.

If you could offer one suggestion to improve the flipped learning experience, what would it be?

- Use more randomized groups.

- Make sure students are reviewing the material before class.
- Maybe combine flipped with traditional lectures.
- Perhaps slow down a bit.

Do you feel that the in-class activities (problem sessions, computer labs, etc.) helped you learn the class material?

- Yes, they helped a lot.
- Having a chance to apply the concepts (right after learning them) was useful.
- I prefer solving problems in class, where the teacher is available to help.
- I particularly liked the computer-related classes.

Did the in-class activities provide you with opportunities to reflect (with teammates and/or the instructor) on how (assumptions, approach, etc.) you arrived at your answers and the answer itself?

- Often, I came up with a different (but correct) approach which built my confidence.
- Yes, the computer assignment required me to collaborate with my group.
- I learned a lot bouncing ideas from my instructor and classmates.
- I found myself having to defend my reasoning (often I learned I was wrong).

In what ways has the "flipped classroom" learning environment helped you learn this semester?

- I felt like I was in control of my own learning.
- It was nice to have the instructor available for help on the problems sessions, etc.
- I learned a lot working on the assignment in class (while the content was fresh).
- The flipped class lightened my workload by forcing me to take bite-size pieces on a frequent basis.

In what ways did the "flipped classroom" learning environment not help you to learn this semester?

- There were some weeks where it seemed like a lot.
- I often didn't ask questions of the professor because I was embarrassed.
- I often felt rushed due to the time limits of the class.
- I like to wrestle with problems by myself on my own time frame (rather than during class).

Discussion

The quantitative data from this study clearly shows an improvement in academic performance between the study group (students that used the flipped model classroom) and the control group (students that used a traditional classroom model). Qualitative data collected from the two anonymous surveys indicated that most students had a positive experience with the flipped learning environment. These surveys also provide valuable insight as to the numerous advantages that the flipped (inverted) classroom approach offers 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.
- Having the course content online allows students to review lesson material at their own pace.
- Empowering students to take a more active role in their learning helps them develop self-directed learning skills which are critical for construction managers that depend heavily on "on the spot" problem solving.
- Students receiving support from a learning community of peers and faculty are more likely to stay in their program of study and graduate.
- Flipped learning provides students with opportunities to "dive into" topics at a deeper level. This strengthens their interest in the topic(s) and stimulates their creativity.

Advantages for instructors:

- Inverted classrooms allow programs to offer larger class sections without compromising student teacher interaction and engagement.
- Instructors wanting to have the "best of two worlds" can combine a traditional lecture-based approach for lessons not conducive to online methods with a flipped classroom approach for lessons 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.

Despite 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 implementation of a course:

- Flipped classrooms rely heavily on student participation prior to the class. While the instructor used online quizzes to hold students accountable for their pre-class preparation, there was no way to guarantee that students fully and independently participated in their 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 ensuring that the course content is integrated from lesson to lesson.
- Flipped learning relies on technology to augment and enhance student learning outside of the classroom. Not all students have access to computers while away from campus.

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.

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