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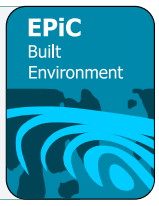

Exploring the Flipped Classroom Model in Construction Engineering and Management Education: A Case Study

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With the advancement of web technology, the flipped classroom model has become a frequently discussed topic in academic circles at all levels. However, there are only a few research articles available for measuring the effectiveness of the flipped teaching model. This paper reports a feasibility study of implementing the flipped classroom approach in construction engineering and management (CEM) education. For this study, the authors designed the flipped classroom course modules and carried out the case study experiment. Also, a survey was performed for this study to observe the students' perceptions on the reversed teaching model in CEM education. This study found that the flipped classroom may have more benefits than the conventional classroom model. The survey confirmed that students may accept the reversed teaching model to learn course content in CEM education. The authors believe that this study makes a contribution to the existing body of knowledge by providing evidence to promote a larger, more controlled study to further investigate the efficacy of the flipped classroom approach.

Key Words: Construction Education, Teaching, Pedagogy, Flipped Classroom

Introduction

Nowadays, many instructors use open educational resources via YouTube and Creative Commons for their teaching courses. They also use some web tools including WebEx, Microsoft Teams, Blackboard Collaborate, wiki software, and podcasts for their teaching and to connect with students more efficiently. Furthermore, students use mobile technology every day for communication and information searching. Without a doubt, technology has continued to change the process of teaching and learning. Lee (2014) argues that the conventional teaching model is not fully capable of providing the opportunities for Construction Engineering and Management (CEM) students to explore real-world problems. McCabe et al. (2000) also asserted that the pedagogical approach in CEM education mainly focuses on teaching the principles of construction engineering and management. Hence, CEM students may encounter difficulties in applying theoretical principles to authentic practices. To overcome this issue, CEM educators have made efforts at integrating authentic learning

activities into their courses. Furthermore, the importance of hands-on learning cannot be overemphasized for authentic practices within the CEM curriculum (Davis & Cline, 2009; Hegazy et al., 2013). Thus, it would be necessary to investigate an alternative pedagogical model to deliver CEM contents effectively.

Literature Review

Web technologies have a large influence on alternative teaching models (Cole, 2000). Several open educational resources (e.g., YouTube) have led to the extension of students' learning experience (Mishra, 2017). Students, as long as they are motivated, can be self-directed and active learners with the support of technology in their learning process. With the advance of mobile technologies, the reversed teaching model has been in the spotlight as an alternative pedagogical approach to facilitating student learning in academic circles at all levels. In this pedagogical theme, students can watch and listen to video lectures outside of the classroom as many times as they need. Precious class time can be utilized for the application modules, where students apply the knowledge to hands-on activities, including collaborative projects, interactive assessments, real-world case studies, or student-facilitated workshops, under supervision of the course instructor. Given these circumstances, the flipped classroom model could become a prevalent alternative approach to capturing the attention of today's student and facilitating active learning in CEM education (Lee et al., 2016).

Baker (2000) advocates the use of web-based instructional materials to free classroom time for active learning and a shift in classroom pedagogy from instructor-centered instruction to a learner-centered model. Zappe et al. (2009) assessed the flipped classroom model in a larger, undergraduate architectural engineering class. They found that, from their experiment, the reversed teaching model had a generally positive reaction from the students in the architectural engineering program. In addition, Bishop and Verleger (2013) performed a comprehensive survey of prior and ongoing research of the reversed classroom. Their study concurred that student perceptions of the flipped classroom model are positive in general. More recently, there have been several publications regarding the flipped classroom model. Mojtahedi et al. (2020) emphasize the importance of collaborations and interactions between students in the reversed classroom to improve their learning experience. Cleary (2020) applied the flipped classroom model to a structural analysis course. His study found that the flipped classroom model had positive effect on student success. Ling and Gan (2020) investigated the extent to which the flipped classroom is effective in students' learning of fundamental concepts in cost engineering. Their study found that students achieved mastery of fundamental concepts regardless of whether the teaching mode is the traditional or flipped classroom. Ling and Gan (2020) recommend that instructors use technology in the reversed classroom to help students understand online learning materials.

Based on the previous studies' findings, the authors believe that the flipped classroom model would be an alternative pedagogical approach to promote more active and collaborative learning environments for CEM students. The reversed teaching model will be able to allow instructors to incorporate more active learning strategies and draw students' engagement in their learning process.

Although the flipped classroom has become a popular topic in academic circles at all levels, there are only a few research articles available for measuring the effectiveness of the reversed classroom approach. For instance, Hotle and Garrow (2016) compared the traditional and reversed classrooms in an undergraduate civil engineering course. They found that student performance was not significantly different from the two different groups. Therefore, this study is trying to measure the effects of the flipped classroom model focusing on the students' ability to understand the online materials.

Methodology

Research Objective and Questions

This study aims at probing the feasibility of implementing the flipped classroom model in CEM education. The hypotheses in the study is that the reversed teaching model would be feasible to deliver CEM contents effectively. To accomplish this objective, the following questions were addressed:

- Does the reversed teaching model have the potential for improving students' understanding of the course contents in CEM education?
- What are students' perceptions on the flipped classroom in CEM education?

To address the first question, an experimental study was carried out in a construction estimating course to investigate the potential of the reversed teaching model in CEM education. To address the second question, a survey instrument was used at the end of this case study experiment to observe the students' perceptions on the flipped classroom in the construction estimating course.

Design and Implementation of the Experimental Study

For this experimental study, the lecture and application modules of an upper-level construction estimating course were developed for the reversed teaching model to teach quantity surveying techniques for the course topics of "sitework" and "concrete". Three sections of the construction estimating course utilized the lecture-based classroom model and the other three sections utilized the reversed teaching model to investigate which pedagogical approach is more effective than the other. Students' performance data on pre- and post-tests were collected from the six different sections of the course.

For the flipped classroom modules, six lecture videos and podcasts were created first to cover key concepts of quantity takeoff processes for sitework and concrete and provide students with practical examples. The length of each video was less than twenty-five minutes. Outside-of-class learning materials including the six lecture videos, PowerPoint presentations, and several links to access open educational resources for assigned readings were posted to Blackboard. Students were supposed to watch and review them before class to complete homework assignments. For the assignments, students were required to submit a summary of their learning as well as questions they had about the outside-of-class learning materials. The comprehension and retention of the outside-of-class learning components is then gauged by means of quizzes or class discussions at the beginning of the class. Any misunderstandings or unclear subjects were discussed through additional explanations or examples, and questions that students had about the materials were addressed prior to the application sessions in class. The remainder of class time was used for the application modules, where students applied the knowledge from their outside-of-class learning to scenario-based group projects in order to create quantity takeoff sheets on sitework and concrete under supervision of the course instructor. The instructor provided individual guidance and feedback on their work performance.

To measure the effects of the two different teaching models, one hundred and eighteen undergraduate CEM students from the Fall 2013 semester to the Spring 2017 semester were assigned randomly to two groups: Group A learned with the lecture-based classroom model and Group B learned with the flipped classroom model. The students included one hundred and nine males and nine females, juniors (N=63) and seniors (N=55).

In this study, the groups were assumed to be nonequivalent. Any differences observed in this study might have been due to pre-existing differences rather than the intervention. Thus, this study used a pretest-posttest design with switching replication, where both control and experimental groups are pre-tested and post-tested. The students in the experimental group were learned with the flipped classroom model whereas the students in the control group were learned with the lecture-based classroom model. All the students in each group were required to take both the pretest and the posttest so as to measure their performance capabilities. The scores on each test ranged from 0 to 15.

In examining the effectiveness of the two different models (lecture-based classroom model vs. flipped classroom model) to teaching construction estimating, the independent variable was the instructional methods which were utilized separately from each other. The dependent variable was the students' change scores (i.e., students' performance capabilities) before and after the intervention, which represent the effects of each instructional method. In other words, to measure the dependent variable, the frequency distributions of each group's "change" score which is the difference between the posttest and the pretest scores were compared.

For this study, the null hypothesis was stated as follows: *The means of the change scores of the two groups are not different statistically.*

Results of the Experimental Study

To identify pre-existing differences, pretest scores in each group were measured at the beginning of this study. Then, posttest scores were measured to determine the effects of the two different teaching models. Table 1 presents descriptive statistics for pretest score and posttest score of the two different groups. As shown in Table 1, it seems that the reversed teaching model produced a greater change in test scores. Table 2 shows the descriptive statistics for the means of the change scores in each group.

Table 1

Descriptive statistics for the pretest and posttest scores

	Group A (N=58) Lecture-Based Classroom Model		***Group B*** (N=60) Flipped Classroom Model	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Range	1-7	3-14	1-8	4-15
Mean	4.12	8.36	4.05	9.43
S.D.	1.88	2.88	1.75	2.85

Table 2

Descriptive statistics for the means of the change scores

	Group A (N=58) Lecture-Based Classroom Model	***Group B*** (N=60) Flipped Classroom Model
Range	1-8	1-9
Mean	4.24	5.38
S.D.	1.78	2.06

Figure 1 shows frequency distributions in percentages, compared to the change scores, which indicate the effects of the instructional methods. As illustrated in Figure 1, 53.33% (N=32) of students in Group B have a change score of 6 or more whereas only 24.14% (N=14) of students have the same in Group A.

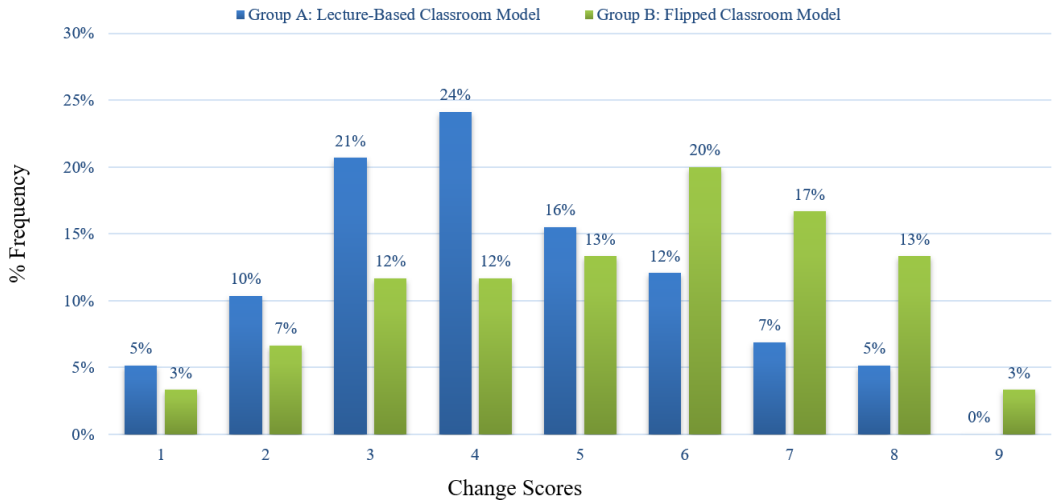

Figure 1. Frequency distributions of the change scores

An independent-sample t-test was conducted to compare the means of the change scores of two independent groups and to assess if any differences in the mean scores between the two groups of students are statistically significant or if they happened purely by chance. Table 3 summarizes the numerical results of the t-test.

Table 3

Numerical results of the t-test

df	115
t Stat	-3.226
P(T<=t) two-tail	0.002
t Critical two-tail	1.981

As shown in Table 3, the absolute value of the t-statistic is 3.226, which is greater than the corresponding critical value of 1.981. This result implies a statistically significant difference between the mean scores of the two groups of students at the $p<0.05$ significance level. Therefore, the null hypothesis was rejected, which indicates that the flipped classroom model made a difference in the students' performance capabilities in CEM education.

Student Opinion Survey on the Flipped Classroom Model

A survey was performed for this study to observe the students' perceptions on the flipped classroom in CEM education. Target individuals for this survey were the students who were taught using the

reversed teaching model. They all had learned the concepts and principles of "sitework" and "concrete" estimating through the flipped classroom settings. The questions were carefully developed for this survey, focusing on measuring the students' perceptions on the reversed teaching model in CEM education. The questionnaire was distributed to the students in class. It was voluntary for the students to participate in this survey.

The survey was divided into three main categories. The first category was designed to evaluate the online lecture modules, the second category focused on the in-class application modules, and the third category was designed to collect the students' overall perceptions on the flipped classroom experience.

Survey Results

Among the sixty students who were taught by the flipped classroom model, thirty-four students responded to the survey. The analysis of the survey results is a vital part in investigating the feasibility of the flipped classroom model in CEM education. The students were asked to answer a series of questions by using a response scale of 1 to 5 where 5 is 'strongly agree' and 1 is 'strongly disagree'.

Online Lecture Modules

The first question was "the flipped classroom model made it easier to learn the quantity surveying techniques of the subjects." 26.4% (N=9) of the respondents agreed and 35.3% (N=12) disagreed with the statement. Two of the students who disagreed commented, "It was not easy to understand online materials on my own." and "I know it is not your fault, but many of us just came to class without reviewing online materials." In fact, 41.2% (N=14) of the students did not think that the online modules were beneficial in preparing for the class activities. This result may be associated with the students' comments mentioned above.

In-Class Application Modules

52.9% (N=18) of the students positively responded to the question, "the flipped classroom model helped me learn more than the lecture-based classroom model would have." One student noted, "The class time was used for actual work. I was not just sitting in the back, listening." Furthermore, 61.7% (N=21) agreed that the in-class work helped them to learn more about the course subjects. Surprisingly, a majority of the students (85.3%, N=29) mentioned that it was helpful to do the in-class work when other students and the instructor were around to help.

Overall Perceptions

Only 23.5% (N=8) of the students preferred the lecture-based classroom model in learning course contents to the flipped classroom model. On the last question, the students were asked to rate their experience of the flipped classroom on a scale of 1 to 5 where 5 is the highest and 1 is the lowest. A frequency distribution of the rates was depicted in Figure 2. The mode of the distribution is 3; the mean of the rates is 3.12; and, the standard deviation is 1.12.

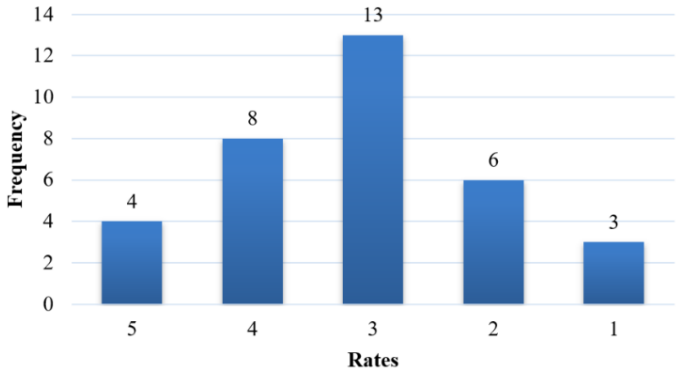

Figure 2. Frequency distribution of students' flipped classroom experience

Based on the results of the student opinion survey, the students' perceptions on the online lecture modules were not positive as shown in Table 4. On the survey, there was an open-ended question of "*what did you like the least about the flipped classroom model?*". Some of the students who answered this question noted, "*learning things on my own before class*", "*I had to read something I completely didn't know about*", and "*It was not easy to learn the quantity takeoff from online materials*." After reviewing these students' comments, the authors found that students in the flipped classroom need to be self-directed and active in their learning. This generates a research question for further study, "*how to lead students to self-motivated and active learners*". Without being self-motivated and active in their learning, students can easily give up reviewing online materials or just come to class with no preparation.

Table 4

Results of the student opinion survey

Online Lecture Modules	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The flipped classroom model made it easier to learn the quantity surveying techniques of the subjects.	2.94%	23.53%	38.24%	29.41%	5.88%
The online modules were beneficial in preparing for the class activities.	8.82%	20.59%	29.41%	29.41%	11.76%
In-Class Application Modules					
The flipped classroom model helped me learn more than the regular class approach would have.	14.71%	38.24%	32.35%	14.71%	0.00%
The in-class work helped me to learn more about the course subjects.	23.53%	38.24%	26.47%	11.76%	0.00%
It was helpful to do the in-class work when other students and the instructor are around so that I can ask for help.	32.35%	52.94%	14.71%	0.00%	0.00%
Overall Perceptions					
I prefer learning course contents this way compared to regular classes.	11.76%	32.35%	32.35%	14.71%	8.82%

The students' perceptions on the in-class application modules were considerably positive as shown in Table 4. Most of the students enjoyed the in-class work and highly rated the helpfulness of the in-

class application modules. Some students added the following comments on the survey: "*Having the instructor and other students nearby in class was very helpful*."; "*I learned the most by asking questions and getting answers during class activities*."; and, "*I enjoyed doing more practical exercises."* In addition to these positive comments, there was constructive criticism on the in-class application modules: "*Sometimes, very distracting and hard to keep up with*." and "*Sometimes, things get a little confusing*."

Discussion

The reversed teaching model is an instructional strategy using the support of web technology to deliver course content to students. The flipped classroom model blends online learning for lecture modules and active and collaborative learning for application modules. In the reversed teaching model, learning environments are designed to be student-centered, where students are encouraged to construct knowledge from their own learning experience. The instructor's main role can be shifted to that of a guide and facilitator to share information with students, support creativity, promote interactions among students to solve a problem, and respond to students' cognitive needs and development. The instructor can be a collaborative and cooperative contributor to students' learning process. The authors noted through the experimental study that the success of the reversed teaching model depends on to what extent the course instructions have been clearly designed to support student-engaged active learning under supervision of the course instructor. More importantly, the careful preparation of the out-of-class materials is extremely significant for the effective implementation of the flipped classroom.

Summary and Conclusion

The main objective of this study is to probe the feasibility of implementing the flipped classroom model in CEM education. For the experimental study, the authors designed the reversed teaching modules and the authors carried out the case study experiment. The results of this experimental study suggest the flipped classroom may have more benefits than the conventional classroom model. Also, a survey was performed for this study to observe the students' perceptions on the reversed teaching model in CEM education. The results of this survey suggest that students may accept the flipped classroom model to learn course content in CEM education.

Based on the findings of this study, it can be concluded that the reversed teaching model would be feasible to deliver CEM contents effectively. The flipped classroom model can provide CEM students with collaborative, interactive, adaptive, inquiry-based learning environments. However, this study only provides evidence to promote a larger, more controlled study to further investigate the efficacy of the flipped classroom model. The authors would like to comment that the flipped classroom model may give different results based on the course topic as well as class level. Further studies would be necessary to measure the applicability and usability of the flipped classroom model in CEM education. Additionally, some students may lack access to the necessary technology at home which was noticed due to the COVID-19 pandemic, or struggle in an environment that requires them to learn independently without the instructor and peers (Baily, 2020).

In conclusion, the successful implementation of the reversed teaching model heavily hinges on available technologies, university supports, instructor's commitments, and student motivation, and a willingness, by all parties, to learn and adapt the flipped classroom model.

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