Implementation of Flipped Classroom and Active Learning Techniques in a Transportation Engineering Introductory Course

Abstract
Active learning and cooperative learning have shown significant benefits to students in STEM disciplines. Several active-learning and cooperative learning techniques have been introduced to the Introduction to Transportation Engineering course at the University of Kansas, Civil, Environmental, and Architectural Engineering Department. This class is also taught as a flipped class. A comparison of student performance between two most recent semesters is offered in this paper. Results of the comparison, as well as students' responses to surveys conducted throughout this course are also offered.

Keywords: active learning, cooperative learning, flipped classroom, team-based learning.

Introduction

Active learning is beneficial to students and has repeatedly been shown to improve retention of content, achievement level, and success in courses (Felder, Woods et al. 2000, Freeman, Eddy et al. 2014). This improvement has been seen across all STEM disciplines, course levels, and course sizes (Freeman, Eddy et al. 2014). Cooperative learning is recommended to be used with active learning activities, and improves content retention, critical thinking and problem-solving skills (Felder, Woods et al. 2000).

Team-based learning (TBL) builds on cooperative learning by increasing the time teams spend together and the expectations of team integration and performance and has been shown to improve individual student learning and course satisfaction in a variety of disciplines (Mott and Peuker , Dana 2007, Anwar, Shaikh et al. 2012, Macke and Tapp 2012, McVey, Luchies et al. 2017). TBL has been shown to be particularly effective for low-performers (Conway, Johnson et al. 2010, Haidet, Kubitz et al. 2014). TBL is more structured than cooperative learning and includes careful team formation, opportunities for peer assessment, prompt feedback on individual and group performance, and an emphasis on group work (Michaelsen, Knight et al. 2002). Teams are recommended to consist of 5-7 people and stay together for the entire semester. Work done as a group should account for a significant portion of the course grade, immediate feedback should be given so teams can discuss outcomes, misunderstandings, and problems while content is fresh in their minds, and peer assessment should factor into the course grade. In order to take advantage of the benefits of TBL for students, the authors experimented with implementing several aspects of TBL in a junior level "Introduction to Transportation Engineering" course. We hypothesized that a shift to TBL would improve individual performance and learning in the course.

Course Description: Introduction to Transportation Engineering is an introductory course in traffic engineering covering vehicle dynamics, geometric design, traffic flow concepts,

uninterrupted and interrupted flow analysis, quality of service assessment, and travel demand forecasting. It is a three-hour (three credit) course and is offered in the Spring semesters. This course is the only mandatory undergraduate course for Civil Engineering (CE) majors related to transportation engineering. Environmental Engineering or Architectural Engineering students may also take this course as an elective. Students generally take this course in their junior/senior year, it is a pre-requisite for the advanced geometric design capstone class, and students should have completed the Geomatics course before enrolling in Transportation Engineering. Approximately forty students take this course every year. Figure 1 shows the course sequence in the Civil Engineering curriculum.

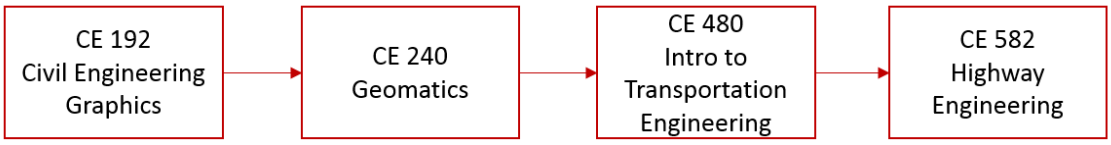

Figure 1. Course sequence for Introduction to Transportation Engineering

After completing this course, students are expected to:

(1) obtain an understanding of the factors influencing road vehicle performance;
(2) be familiar with elements involved in geometric design and the safety concerns that motivate vertical curve length and horizontal curve design;
(3) implement basic traffic flow and queuing principles and have the underlying basis for understanding complex queuing systems;
(4) conduct highway capacity and quality of service analysis at freeways and multilane highways,
(5) design signal timing and phasing plans at signalized intersections and perform quality of service assessment; and
(6) analyze traveler trip decisions, with respect to the modes and routes chosen by travelers.

Introduction to Transportation Engineering has been taught since the 2010-2011 academic year, under a variety of formats and by several instructors. Graduate teaching assistants have been utilized in the last three offerings of the course. The last semester that this class was taught as a typical “lecture-based” course was in 2014, and this was the first time the corresponding author of this paper taught this course at the University of Kansas. Since then, the course format has gradually shifted towards active-learning. This paper focuses on the last two offerings of the course: Spring 2017 and Spring 2018.

Course Implementation: In Spring 2017 several active-learning techniques were initiated in Introduction to Transportation Engineering. The class was taught in three 50-minute class periods each week. Students were given the lecture slides and the schedule of topics to be covered at each time period in advance. Students were responsible for studying from the lecture slides and/or the corresponding sections from the textbook prior to their arrival to class. The PowerPoint slides were posted on Blackboard approximately two days before each class.

In-class activities: At the beginning of each class period, a short 4-5 question multiple-choice quiz was administered, based on the content that was provided in advance. Next, the instructor reviewed quiz solutions and gauged with a show of hands the students' performance. Next the instructor briefly reviewed the PowerPoint slides and discussed any questions or comments raised by the students. Next, the class would work on in-class problems. Students would work on them initially, followed by assistance from the instructor, asking the students for input. These in-class problems were not submitted for grade. Upon completion of each chapter of the textbook, students would spend the entire class period solving an extended problem from that chapter. The students were free to work on the extended problem in pairs of their choosing and provide one submission per pair.

Homework: The students did not have to submit any homework; instead, they reviewed the course lectures, came to class prepared to take the quizzes, and submitted the extended problems. The instructor provided recommended homework problems for students who wanted to solve textbook problems on their own. The answer keys were also provided as a guide to the students.

Exams: Three closed-book exams were given throughout the semester. The students were allowed to use a calculator approved by the National Council of Examiners for Engineering and Surveying (NCEES) and an equation sheet provided by the instructor four days prior to the exam. The exams had two parts: the first one was the "concepts" part, which included 10-15 questions of multiple choice, or short answers. The second part included two to four problems. The first two exams were non-comprehensive. Only the first part of the final exam was comprehensive. Exam review sessions were conducted during the lecture prior to the scheduled exam. The students had the opportunity to raise questions and request solutions to specific problems from the textbook or from the extended problems. A quick recap of the course content was also performed during the exam review from the instructor.

In Spring 2018, several aspects of TBL were implemented. Similar to the first semester, students were responsible for studying from the lecture slides and/or the corresponding sections from the textbook prior to their arrival to class.

Team-based learning: A significant change from the first semester was the use of the web-based resource "Comprehensive Assessment of Team Member Effectiveness" (CATME, http://info.catme.org/) to form teams and to facilitate peer assessment. Through this system, an initial survey was first conducted, the results of which were used to form teams of 3-4 students that stayed together for the entire semester. Teams were smaller than typically recommended for TBL to be in line with the workload of the in-class activities. There were 10 teams in total. Two peer review surveys were conducted to gather students' assessment of their team members. Students had the opportunity to work with their teams during the in-class quizzes and the in-class problems, as discussed below.

In-class activities: At the beginning of each class period, students took a 2-3 question quiz based on the content that was given in advance. Two-stage quizzes using i-clickers (https://www.iclicker.com/) were implemented: in stage 1, students had 40 seconds to answer a quiz question individually, and in stage 2, students had 40 seconds to discuss the same quiz question with their team members and make the final selection. Each time, the class response

percentages were shown to help the students get an idea of the consensus. The use of the i-clickers helped the instructor understand the class performance and significantly reduced the amount of time required to administer the quizzes.

Similar to Spring 2017, the instructor briefly reviewed the PowerPoint slides in 10-15 minutes, and discussed any questions or comments raised by the students. The remaining period was dedicated to in-class problem solving in teams. The first in-class problem was designed for the students to solve with their teams in approximately 15 minutes, and was turned in and graded. The instructor and the graduate teaching assistant walked around the room and helped the teams as needed. After the completion of the first in-class problem, the instructor solved a second in-class problem of the same or greater difficulty as the first one. The instructor would also request help from the students to complete the solution. Detailed solutions of the second in-class problem were provided after class, through Blackboard. Solutions for the first in-class problem were not provided, as the teaching assistant provided feedback while grading. Upon completion of each chapter of the textbook, students spent the entire class period solving an extended problem from that chapter. Students worked in teams and would submit one extended problem per team.

Homework: Students submitted homework assignments; one set for each of the six chapters of the textbook. Six to seven problems were included in each homework set.

Exams: Three closed-book exams were given, in a similar format to Spring 2017. Most of the exam questions between the first and the second semester were similar, if not the same. It should be noted; however, that the second exam from 2018 was more challenging from the second exam of 2017, because it included an additional problem. Exams were not given back to students in either semester; rather the instructor returned them during class for review, and then picked them back up. Exam review sessions were conducted during the lecture prior to the scheduled exam. The students had the opportunity to raise questions and request solutions to specific problems from the textbook, homework, or from the extended problems. A quick recap of the course content was also performed during the exam review from the instructor.

Table 1 summarizes the various active-learning and flipped classroom techniques that were used in the two semesters of the Introduction to Transportation Engineering.

Table 1. Comparison of active learning implementation activities

	Spring 2017	Spring 2018
Preparation Activities	- Review course slides/textbook in advance	- Review course slides/textbook in advance
In-class Activities	- Quiz (hand-written) - Extended problems - In-class problems (not graded) - Lecture - Team-based work (self-selected, teams of 2)	- Quiz (i-clickers) - Extended problems - In-class problems (graded) - Lecture - Team-based work (CATME, teams of 3 or 4)
Homework	- Recommended homework (not graded)	- Homework assignments (graded)
Exams	- 3 exams	- 3 exams
Surveys	- None	- Mid-semester evaluation survey - CATME peer surveys

Evaluation

As described, the class underwent several changes during these two semesters. Although the flipped classroom style and several active-learning techniques were introduced during the first semester, the 2018 semester included components of TBL and the addition of homework. To determine the effectiveness of the changes in 2018, this paper presents an analysis of student performance on the same or similar exam questions across the two semesters and feedback received from the mid-semester and peer review surveys.

Exam Evaluation

The common exam questions for all three exams between the Spring 2017 and 2018 semesters were compared using the Mann Whitney U-test for independent samples. This is a nonparametric test, which is similar to the *t*-test but relaxes the assumption of normal distribution of the samples. This test determines whether two independent samples were selected from populations having the same distribution.

Surveys

Three class surveys were introduced during this semester. A mid-semester evaluation survey was conducted after the completion of the first exam. The mid-semester survey requested information on the components of the class, as well as on the students' preparation efforts. The first nine questions were targeted to gage their agreement on the following statements using a Likert scale (strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree):

- Q1: The “lecture” portion of the class (MWF 8 a.m.) is useful.
- Q2: The in-class quizzes are useful.
- Q3: The in-class problems are useful.
- Q4: The homework assignments are useful.
- Q5: The extended problem portion of the class is useful.
- Q6: I feel I have adequate support available to help me learn the content.
- Q7: I come to class prepared and ready to work on the in-class problems.
- Q8: The sequence of activities in class is appropriate (if you disagree, please share your suggestions for improving.)
- Q9: I am satisfied with my team.

Three additional questions were included in this survey:

- Q10: I prepare for the class by (check all that apply): reading textbooks, working examples from textbook, reviewing the PowerPoint slides, working homework problems, other.
- Q11: How much time do you spend preparing for class: none, less than 1 hour per class period, 1-2 hours per class period, 2-3 hours per class period, more than 3 hours per class period.
- Q12: How much time are you spending on homework each week: 2 hours or less, 2-4 hours, 4-6 hours, 6-8 hours, more than 8 hours.

Lastly, the survey concluded with the following two open-ended questions.

- Q13: What is something you think works well with this class?
- Q14: What is something you think should change about this class?

In addition, two peer-evaluation surveys were conducted towards the middle of the semester and towards the end of the semester. These two surveys were administered through the CATME software (Loughry, Ohland et al. 2007, Ohland, Loughry et al. 2012) which measures 29 types of team member contributions, and the short version groups team member contributions into five categories: contributing to the team’s work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities) (Ohland et al., 2012). Students rate themselves and each teammate on a 1-5 point scale.

Results and Discussion

In Exam 1 there were eight common exam questions and four common exam problems between the two semesters. Figure 2 shows the average score and standard deviation for each of the questions. Students performed significantly better on two questions (green *), and significantly worse on one question (red *).

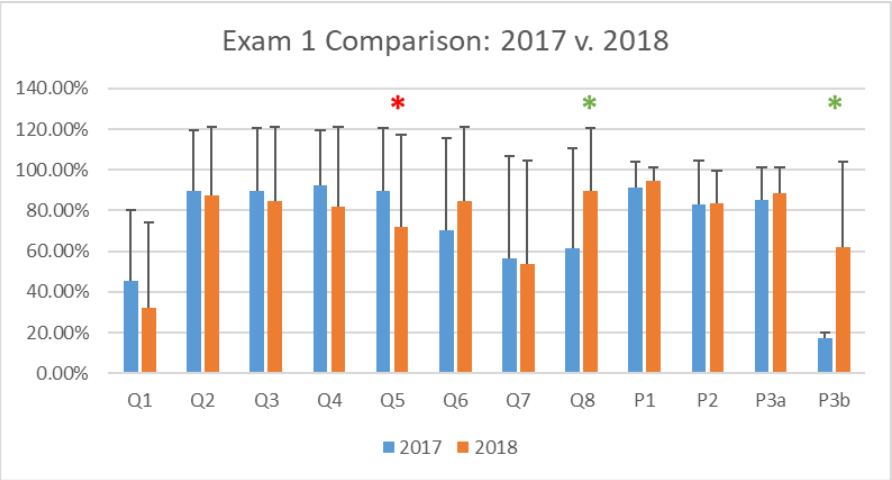

Figure 2. Exam 1 comparison

Exam 2 included nine common questions and two common problems between the two semesters. Figure 3 shows the average score and standard deviation for each of the questions. Students performed significantly better on three questions (green *), and significantly worse on one question (red *). It should be noted, that the 2018 exam was considerably more difficult than the 2017 exam, as it included an extra problem, which delayed the students and many did not have time to finish the exam.

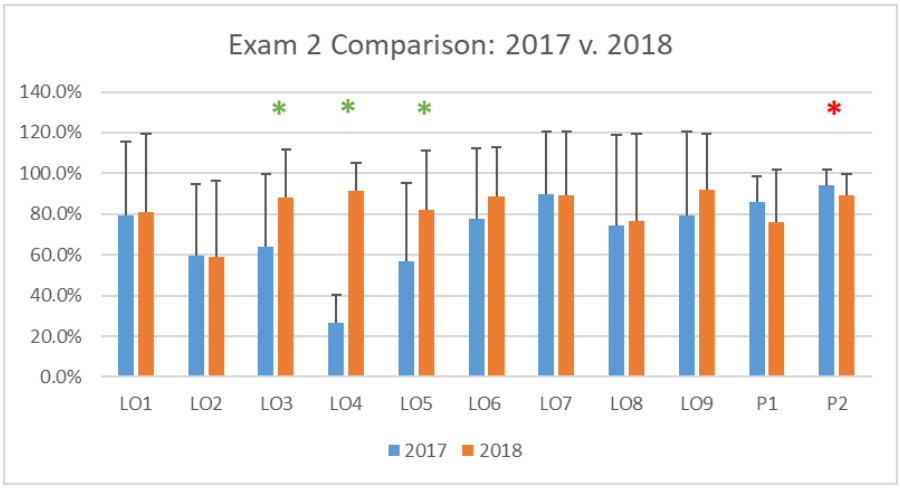

Figure 3. Exam 2 comparison

In their final exam (Exam 3) there were 13 common exam questions, four common multiple choice questions, and three common exam problems between the two semesters. Figure 4 shows the average score and standard deviation for each of the questions. Students performed significantly better on three questions (green *) and significantly worse on one question (red *). Their performance in the remaining questions was not found to vary significantly between the two semesters.

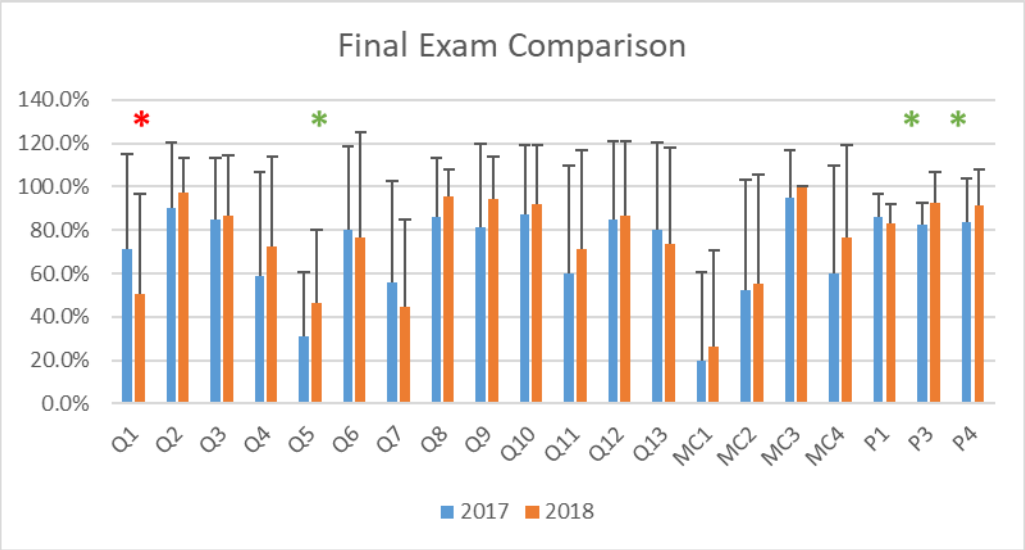

Figure 4. Final exam comparison

Overall, it can be concluded that students' performance slightly improved in the second semester. This improvement might be attributed to the additional in-class work that the students performed. It is also speculated that aspects of TBL improved student learning.

Mid-semester Evaluation

The mid-semester evaluation survey had a 47% response rate (18 out of the 28 students responded). The overall results did not show any significant concern with respect to the course structure or the implemented teaching techniques. Figure 5 shows the survey results for questions 1 through 9 presented in section 3.2.6. (page 5). Based on these results, it can be concluded that most of the students find the various components of the class (quizzes, in-class problems, lecture, extended problems, and homework) useful, and generally approve the course structure.

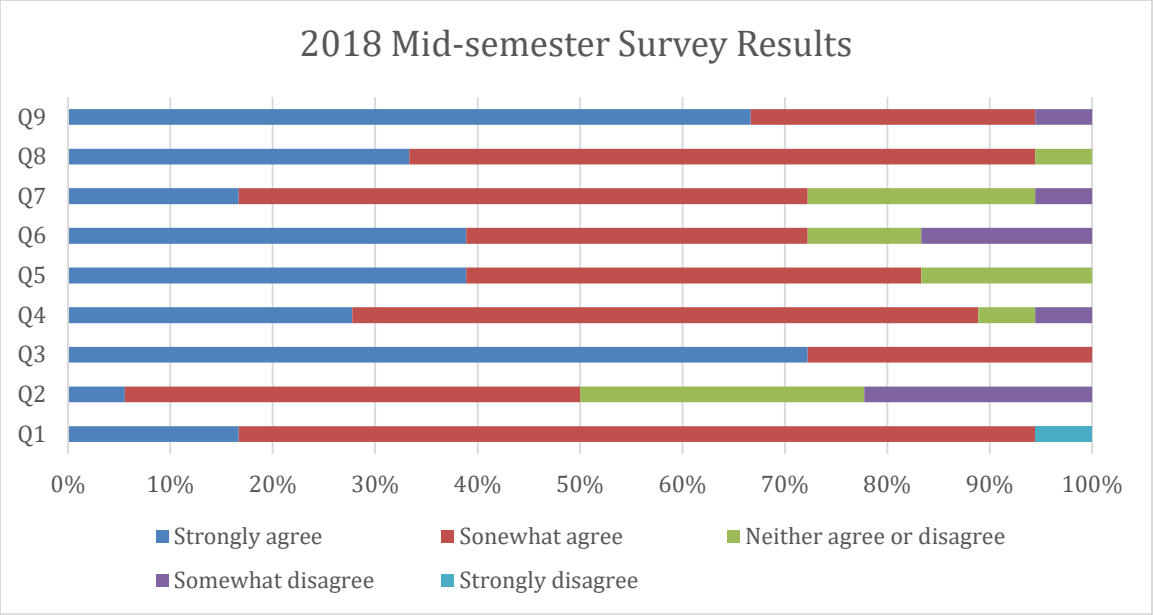

Figure 5. Mid-semester survey results for questions 1 through 9

In addition, regarding question 10 (how they prepare for class), 60% of the students reviewed the PowerPoint slides, 28% worked on homework problems, and 12% read from the textbook. In question 11 (how much time they spend preparing for class), 67% reported spending less than 1 hour, 17% reported spending 1-2 hours, 11% reported not spending any time, and 5% reported spending 2-3 hours. Lastly, with respect to question 12 (how much time they are spending on homework each week), 50% reported spending 2 hours or less, 33% reported spending 2-4 hours, and 17% reported spending 4-6 hours.

The two open-ended questions revealed some interesting responses. In the question "What is something you think works well about this class?" the students commented on the usefulness of the in-class problems, the extended problems, and working in teams. When asked about "What is something you think should change about the course?" the students suggested the following:

- discuss homework problems in class and provide the solutions;
- having quiz questions from the slides and not from the textbook, and making lecture slides more self-explanatory;
- have more in-class problems; and
- change the time period.

After discussing these results with the students, the instructor decided to alter the slides since students would primarily study from the slides instead of the textbook, and also requested the teaching assistant to provide more feedback on their homework.

CATME Evaluation

The results from the CATME peer evaluation was conducted twice over the 2018 semester; once in the middle of the semester, and once towards the end. The team satisfaction ratings were between 4-5 (five is the highest rating) on both evaluations for nine out of ten teams. Team satisfaction ratings did not change much between the mid semester and final evaluation. Students

were generally happy with and enjoyed working with their teams.

Conclusions

Both semesters discussed in this paper included flipped classroom and active learning components, although the use of these techniques became more organized during the second semester. Some of the key findings from this comparison are that students are becoming more accepting of the flipped classroom model, and prefer spending time actively solving problems in class instead of passively listening to lecture. It was also interesting to see that working in more formal teams through the CATME approach, and adopting a formal process of evaluating their team-based work through the surveys made the students more accountable for studying in advance and performing well for their peers. One of the challenges during both semesters was the time constraint to cover all in-class activities within the 50-minute class period. Moving forward, it is recommended to move the course to two 75-minute class periods per week. It is also recommended to continue implementing flipped classroom and active-learning techniques. As a next step, the researchers are also interested in looking into the effectiveness of flipped classroom and active learning compared to traditional lectures, as we speculate that such comparison would show much greater improvements in student learning.

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