Assessment of Active and Team-based Learning Techniques in a Transportation Engineering Introductory Course

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Abstract

Active and cooperative learning has shown significant benefits to students in STEM disciplines. Several active and cooperative learning techniques have been introduced to the Introduction to Transportation Engineering course throughout the last four semesters. This work presents a comparison of student learning in the two traditionally taught semesters compared to the two semesters that used active and team-based learning.

Introduction to Transportation Engineering is junior level introductory course in traffic engineering and covers vehicle dynamics, geometric design, traffic flow concepts, uninterrupted and interrupted flow analysis, quality of service assessment, and travel demand forecasting. This paper compares two semesters of traditional lecture format (Fall 2014 and Spring 2016) to two semesters using an active and team-based learning format (Spring 2017 and Spring 2018) and explores whether the implementation of active and team-based learning methods had an impact on student learning in the course. To answer this question, common exam questions between the four semesters (grouped into two groups: traditional vs. active/TBL) were compared. In addition, student surveys from the final semester provide insights into the student perception of active and team-based learning components.

Results showed a statistically significant improvement in 7/25 (28%) of the compared objectives, a statistically significant decline in 5/25 (20.0%) of compared objectives, and no change in 13/25 (52.0%) of objectives. The majority of the objectives that declined focused on concepts that were not covered in the in-class problems; the majority of objectives that improved were problem-solving type questions similar to the type of questions practiced with active learning. Student feedback showed satisfaction with the active and team-based format.

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 [1, 2]. This improvement has been seen across all STEM disciplines, course levels, and course sizes [2]. Cooperative learning is recommended to be used with active learning activities, and improves content retention, critical thinking and problem-solving skills [1].

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 [3-7]. TBL has been shown to be particularly effective for low-performers [8, 9]. 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 [10]. 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.

Several active and team-based learning techniques have been introduced to the Introduction to Transportation Engineering course during the last two semesters it was taught. This work will present a comparison of student learning in the two traditionally taught semesters compared to the two semesters that used active and team-based learning.

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 credit hour course and it is offered once per year, usually in the spring. This course is the only mandatory undergraduate course for Civil Engineering (CE) majors related to transportation engineering in our Department. CE majors account for approximately 50% of all students. Students in the architectural engineering or environmental engineering paths may also take this course as an elective, however, this percentage is typically low (1-2 students per year). Students generally take this course in their junior or 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.

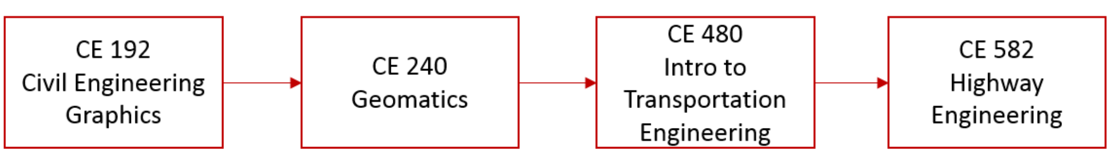

Figure 1. Course sequence for Introduction to Transportation Engineering

After completing this course, students are expected to:

(1) identify factors influencing road vehicle performance;
(2) calculate 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 is taught once per year under a variety of formats and by several instructors. The author took over the course in Fall 2014 and has been the only instructor since. In addition to the instructor, one graduate teaching assistant helps with the course by grading and providing support during in-class activities. The author taught the course in a traditional lecture format in Fall 2014 and Spring 2016. Beginning in Spring 2017, the course has shifted towards more active and team-based teaching methods.

The instructor's effort to shift the course was supported by a university-level initiative to move to evidence-based and student-centered teaching methods. During the past 6 years significant efforts have been made to move to these methods in undergraduate classes at the University, School, and Department level. Instructors have been provided with tools to facilitate these changes, such as new active learning classrooms, teaching workshops, teaching working groups, support for undergraduate teaching assistants, and a post-doctoral teaching fellow program. As such, students enrolled in the course are already familiar with this type of instruction and have similar past experiences from other courses.

Course Implementation

Fall 2014 and Spring 2016- Traditional Lecture

In Fall 2014 and Spring 2016 the course was taught as a lecture-based course, with limited active learning or team-based learning techniques. At the beginning of each class period, a short 4-5 question multiple-choice quiz was administered, based on the content that was covered during the previous class period. The instructor would present the material using PowerPoint slides to the students and provide the slides only after these were reviewed. 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 teams of two of their choosing and provide one submission per team. The students had to complete regular homework assignments; one set for each of the six chapters of the textbook that were covered. Three closed-book exams were given throughout the semester. 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. All three exams were non-comprehensive. The exams were reviewed in class after grading but were not returned to the students. The class size was 30 students in Fall 2014 and 38 students in Spring 2016. The grading scheme of the two semesters was similar, with the exception of the quizzes, which were graded as extra credit (up to 5%) in 2016.

Spring 2017 and Spring 2018- Active and Team-based

In 2017 several active learning techniques were introduced to the classroom. 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 period.

At the beginning of each class period, a short 4-5 question multiple-choice quiz was administered, based on the content that was given to review in advance. Next, the instructor would go over the quiz solutions and evaluate the students' performance. The instructor then briefly reviewed the PowerPoint slides and discussed any questions or comments raised by the students. Next, the class worked on in-class problems. Students would work on them initially, followed by assistance from the instructor with student input. These in-class problems were not submitted for grade. Extended problems solved in groups of two were conducted as well, similar to the previous semesters.

The students did not have to submit any homework assignments; instead, they reviewed the course lectures, came prepared for class to take the quizzes, and submitted the extended problems. The instructor provided recommended homework problems for students who wanted to practice solving textbook problems on their own. The answer keys were also provided as a guide to the students. Exams were also similar to the previous semesters, with difference being that the first part of the third exam was comprehensive. The class size was 40 students.

In Spring 2018, students were still responsible for studying from the lecture slides and/or the corresponding sections from the textbook prior to their arrival to class. New for Spring 2018, several aspects of TBL were implemented to get at the four essential principles of TBL [10]. These principles include thoughtful team formation and development, holding students accountable for both individual and group work, providing immediate feedback so teams can discuss outcomes, misunderstandings, and problems while content is fresh in their mind, and assignments that promote both learning and team development.

Teams were developed utilizing 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 order to hold students accountable, a two-stage quiz using i-clickers (https://www.iclicker.com/) was given at the beginning of each class period based on the content that was given to review in advance. 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 provide immediate feedback on their understanding. The use of i-clickers also helped the instructor quickly understand if there were misconceptions 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 when 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 submitted one extended problem per team.

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. 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. The exams were reviewed in class after grading but were not returned to the students. The class size was 39 students (one of which withdrew after the first exam). The grading scheme of the two semesters was different, due to the introduction of the in-class problems in 2018, and the lack of homework in 2017. A thorough comparison between the 2017 and 2018 semesters can be found in [11].

Table 1 summarizes the various active and team-based learning techniques that were used in the four semesters of the Introduction to Transportation Engineering.

Table 1. Comparison of course activities

	Fall 2014	Spring 2016	Spring 2017	Spring 2018
Preparation Activities	- None	- None	- Review course slides/textbook in advance	- Review course slides/textbook in advance
In-class Activities	- Quiz (hand-written) - Extended problems - Lecture	- Quiz (hand-written, extra credit) - Extended problems - Lecture	- 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	- Homework assignments (graded)	- Homework assignments (graded)	- Recommended homework (not graded)	- Homework assignments (graded)
Exams	- 3 exams	- 3 exams	- 3 exams	- 3 exams
Surveys	- None	- None	- None	- Mid-semester evaluation survey - CATME peer surveys

Results and Discussion

Learning Objective Comparison

For this analysis, data were analyzed in two groups: "traditional" semesters (Fall 2014 and Spring 2016), and "active-TBL" semesters (Spring 2017 and Spring 2018). To conduct this analysis, only the exam questions that were either the same or very similar (i.e., different numbers or slightly reworded) between the two semester groups and for which there were data for each of the four semesters were considered. This allowed comparison of 25/51 unit-level learning objectives. Since the instructor did not allow students to keep the exams after looking through them, but instead kept all exams, it was safe to assume that increased performance on a question was not because students had studied from old exams.

There were 25 comparable objectives across all semesters. Of these 25, 17 were "concept" type questions where results had discrete levels of scoring. In order to analyze group differences on frequencies of answers at each discrete level of correctness, a Chi-square test was done to determine statistically significant group differences. The Chi-square test is a non-parametric test so it does not require that the data are normally distributed [12]. A $p < .05$ was used for significance. Out of the 17 "concept" objectives, there was a significant difference among 7 of them, and no significant change in 10/17 (58.8%). There was a significant improvement in 3/17 (17.6%) and a significant decline in 4/17 (23.5%) of the concept objectives. These results are shown in Table 2. It is noted that there was a decline on more objectives than an increase in performance on these concept questions. This perhaps is due to the fact that these concept-based questions did not get attention during the active-learning portion of class, but instead the problem solving based questions were the focus. Students had more in-class, supported practice with the problem-solving questions than the concept-based questions.

Table 2. Results of Chi-Square test on Concept-based Questions

Objective	% Students who Answered Correctly		Chi-square
	Traditional	Active/TBL	P-value
1*	41.18%	21.79%	<.001
3	95.5%	88.5%	0.124
6*	57.4%	80.8%	0.002
7	86.6%	77.9%	0.179
9	58.8%	55.1%	0.653
10	70.6%	75.6%	0.491
14	72.6%	76.3%	0.14
25	71.9%	85.7%	0.643
26	88.2%	85.7%	0.653
30	71.6%	53.8%	0.113
32	76.5%	76.9%	0.061
34*	27.7%	11.5%	<.001
38	70.3%	65.4%	0.532
39*	76.1%	39.0%	<.001
40*	56.7%	90.8%	<.001
44*	48.5%	23.1%	0.001
46*	88.2%	97.4%	0.028

The remaining 8 objectives required problem solving that resulted in more continuous scores. Therefore these data were compared using the Mann Whitney U-test for independent samples [13]. 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. A $p < .05$ was used for significance. Figure 2 shows the results of this analysis. There was a statistically significant improvement on 4/8 (50%) of the objectives, and a significant decline in 1/8 (12.5%) of the objectives, and no significant change in 3/8 (37.5%) of the objectives. In general, students in the active learning semesters did perform better at exam questions that required computation and application of analytical processes that they had previously used in class.

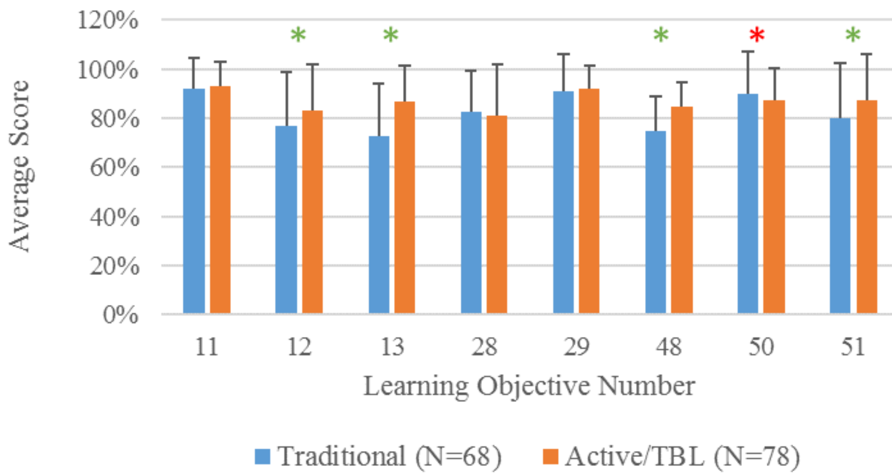

Figure 2. Scores on problem-solving exam questions in Traditional (blue) compared to Active/TBL (orange) semesters. *Indicates significance p< .05 by Mann-Whitney U test.

Overall, on all 25 comparable objectives (concept and problem-solving based) there was a statistically significant improvement in 7/25 (28%) of the compared objectives, a statistically significant decline in 5/25 (20.0%) of compared objectives, and no change in 13/25 (52.0%) of objectives. The learning objectives that were evaluated in the three exams cover a wide range of topics associated with transportation engineering. Table 2 presents a description of all learning objectives compared in the exams and the type of questions asked (concept or problem-solving).

Table 2. Learning Objectives by Exam *Indicates p < .05

Objective	Learning Objective	Concept or Problem	Statistical Inference*
	EXAM 1		
1	Define and calculate braking and stopping (theoretical and practical) distance	Concept	Decline
3	Define and calculate maximum tractive effort and engine-generated tractive effort	Concept	No change
6	Define and calculate maximum tractive effort and engine-generated tractive effort	Concept	Improvement
7	Design vertical crest curves	Concept	No change
9	Calculate rolling and aerodynamic resistances	Concept	No change
10	Define and calculate braking and stopping (theoretical and practical) distance	Concept	No change
11	Define and calculate engine torque and power	Problem	No change
12	Give stations and elevations of the lowest point, high point, PVI, and PVT of a vertical curve	Problem	Improvement
13	Describe the critical design features of horizontal curves. Calculate SSD for horizontal curves	Problem	Improvement
	EXAM 2		
14	Define traffic flow parameters	Concept	No change
25	Describe vehicle arrivals distribution and vehicle headways distribution	Concept	No change
26	Calculate analysis flow rate	Concept	No change
28	Define, calculate and illustrate queueing theory	Problem	No change
29	Apply the HCM basic freeway segments method and calculate LOS	Problem	No change
	EXAM 3		
30	Define and describe types of signal control	Concept	No change
32	Explain fundamental signal control characteristics and parameters	Concept	No change
34	Define LOS concepts	Concept	Decline
38	Describe trip distribution and mode choice of the Four Step Model	Concept	No change
39	Describe trip distribution and mode choice of the Four Step Model	Concept	Decline
40	Describe route choice step of the Four Step Model	Concept	Improvement
44	Explain fundamental signal control characteristics and parameters	Concept	Decline
46	Describe route choice step of the Four Step Model	Concept	Improvement
48	Develop and evaluate traffic signal phasing and timing plan	Problem	Improvement
50	Apply the trip generation process of the Four Step Model	Problem	Decline
51	Apply the route choice process of the Four Step Model	Problem	Improvement

Surveys

Three class surveys were introduced during the most recent semester (Spring 2018). 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?

The mid-semester evaluation survey had a 47% response rate (18 out of the 38 students responded). The overall results did not show any significant concern with respect to the course structure or the implemented teaching techniques. Figure 3 shows the survey results for questions 1 through 9. 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.

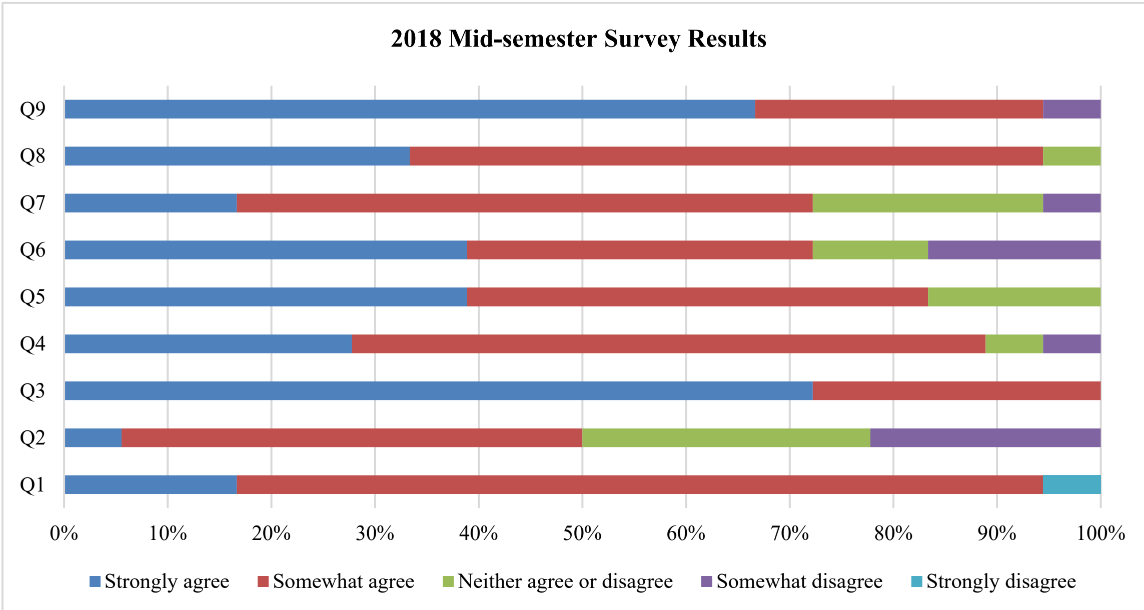

Figure 3. Mid-semester survey results for questions 1 through 9

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 there instead of the textbook, and also requested the teaching assistant to provide more feedback on their homework.

In addition to the surveys two peer-evaluation surveys were conducted towards the middle of the semester and towards the end of the 2018 semester. These two surveys were administered through the CATME software [14, 15] 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) [15]. Students rate themselves and each teammate on a 1-5 point scale, and also answer questions about team satisfaction among other aspects of teamwork. Team satisfaction scores were between 4 and 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 and enjoyed working with their teams.

Conclusions

This paper presented a comparison of student learning in an active and team-based format compared to traditional lecture.

In this case, the active and team-based learning format seemed to particularly benefit students in their ability to problem-solve on the exams. Exam problems that required the type of problem solving done during the in-class problems showed a significant improvement in scores. Exam problems requiring recalling of information or concepts presented only in the reading or PowerPoint slides showed a significant decline.

Students were generally satisfied with the flipped classroom and active learning environments. It was interesting to see that working in teams through the more formal TBL approach 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, but make more effective use of the "lecture" portion to strengthen the concept-related material.

One of the obstacles to wide-spread adoption of active learning is the time investment needed get started in a new format. Undoubtedly, the introduction of active learning and team-based learning techniques requires significant effort by the instructor (e.g., preparing new in-class problems, uploading material in advance, keeping track of all work done in-class through the quizzes and the problems, evaluating the group work, etc.). In this transformation, the graduate teaching assistant and post-doctoral teaching fellow assisted in the effort. Given the improvements in student learning already documented in the literature, as well as the improvement in student performance seen in problem-solving based questions in this study, the work of moving to an active learning based classroom seems well worth the effort. In addition to improved learning outcomes, students seem to be positively affected by this shift, as they are more actively engaged in course activities, and appear to enjoy class more. Students' comments based on the end-of-semester evaluation in the last two offerings have more positive tone than in the previous semesters. Lastly, the instructor enjoys the flipped environment more compared to traditional lecture, and feels more engaged with the students and more in touch with student learning.

Although this study revealed some important findings related to student learning, several limitations exist. The class demographics and background data such as average GPA, SAT scores, grade in prerequisite course, and ethnicity, were not available; therefore, it was not possible to either compare the groups on incoming academic statistics or to examine the effects of the transformation on under-represented groups. In addition, the sample size analyzed in this research is small (total number of students was 157), and only approximately half of the course learning objectives were able to be compared; therefore it is not possible to generalize the findings. Lastly, given the different grading schemes across the semesters, a comparison of the students' final grades or grade distribution does not inform this study. Future work includes investigating the effect of the course transformation on under-represented groups of students.

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