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Increased Problem Solving in Foundation Design through Inverting the Classroom

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Abstract

This paper summarizes the outcomes of inverting the classroom for Foundation Design, a senior technical elective in the Civil and Environmental Engineering (CEE) department that is offered each fall semester. The author taught Foundation Design for the first time in Fall 2018 and received feedback from teaching survey comments that 8 out of 24 (33%) students would like more time in class to go through examples. This is difficult to do in a traditional format because most example problems in foundation design are multi-step and require several charts and tables to solve, making it difficult to provide proper background material and sufficient time to solve these problems in a 75-minute class session. Based on this feedback, the instructor inverted the classroom in Fall 2019. To invert the classroom, lecture videos were recorded prior to class sessions and posted online for students to view and complete a short quiz on video understanding. Videos were approximately 10 minutes in length and usually one video was posted for each lecture session. New problem handouts were created for in-class problem solving sessions and more time was available for students to work on these problems in groups and as a class. Lessons learned from inverting the course and developing new problem handouts will be discussed. The outcomes of the project show that grades for the lower 50th percentile of the class increased. A significant increase was observed in homework grades, which potentially can be attributed to the inverted format that allowed for more time in class to work on example and homework problems. In addition to the increased performance in grades for the lower half of the class, positive feedback was received through comments on the teaching surveys. Overall, 17 of 34 comments (50%) cited that they enjoyed the inverted format or in-class problem solving sessions. These comments were unprompted and many comments did not include any reference to the class format.

Introduction

Inverted or “flipped” classrooms encourage active learning during class sessions and have been shown to be effective in engineering coursework [1] - [4]. In an inverted class structure, students typically watch lecture videos outside of classroom lecture time which allows for active learning, problem solving, and activities during class time traditionally used for lecturing. In recent years there has been increased interest and application of inverted classrooms in engineering coursework as a way to increase active learning and present course materials in a variety of formats, which can accommodate the various learning styles of students in the course [1] - [7]. Numerous studies have shown that student performance on exams has increased [1], [2], with the improved performance seen with the lower half of the students. This point shows that inverted classrooms can aid in creating a classroom environment that caters to all students, not just the top performing students. Additionally, students from inverted classrooms in engineering problem-based courses provided positive feedback in regards to the inverted classroom format, stating that they felt that the inverted classroom improved their overall learning ability to apply knowledge as well as their conceptual understanding of course materials [2], [7].

Motivation

Foundation Design is a senior technical elective in the Civil and Environmental Engineering (CEE) Department. The author taught Foundation Design for the first time in Fall 2018. Overall, the author's Course and Teacher Surveys (CATS) from Fall 2018 were positive and students indicated that they enjoyed the class; however, a common theme was present: students would like to go through more example problems at a slower pace during class sessions. Overall, 8 out of 24 students (33%) left unprompted comments on the CATS form indicating that they felt this way or similar (i.e., that the examples and notes could be restructured, with more examples and more time to work on those examples). This is likely due to the long, multi-step problems that are solved in Foundation Design. To address these issues, the author worked to invert the classroom for the course in Fall 2019.

The specific learning goals for this project were to: (1) Increase student learning and faculty-student interaction during class sessions by converting the course to an inverted format; (2) Incorporate more real-world examples and case-histories relevant to foundation engineering as part of the active learning classroom sessions to increase engineering judgement and problem-solving skills; and (3) Develop students' communication skills (written, oral, and graphical) through team-based problem-solving sessions in the classroom. It was proposed that assessment would be made on enhancement of student learning through evaluation of exam grades across multiple years (2018, 2019, 2020) and through CATS (specifically reflection from students on the inverted classroom experience). It was evident from the instructor's point of view that there was more problem-solving and in-class interaction with the inverted format.

Development

Foundation Design is a 3-credit course that is structured with two 75-minute class sessions each week. The enrollment for the course over the last three years has ranged from 44 to 45 students. Each year there was one course instructor and students were split between two course sections, with a maximum of 25 students in a single section. To invert the classroom, lecture videos were recorded prior to class sessions and posted online for students to view and complete a short quiz on video understanding. Videos were approximately 10 minutes in length and usually one video was posted for each lecture session. Previous studies have shown that shorter lecture videos are more effective [2]. The video lectures included brief introduction to theory and included relevant equations and figures needed for in-class problem solving. The goal of the video lectures was for students to understand background information before applying equations and figures to solve multi-step problems in class. New problem handouts were created for in-class problem solving sessions and more time was available for students to work on these problems in groups and as a class. Students often worked on problems in small groups of 2-3 before sharing with the class. Significant time was required to develop the new problem handouts, as handouts consisted of step-by-step procedures for the students to follow. Relevant charts and figures from lecture notes were inserted into the handout so that students only needed to bring the handout to class.

Lecture videos were required to be watched prior to class and video tracking statistics were captured using Mediasite. The percentage of the video that was watched by each student was recorded and accounted for 4% of each student's overall course grade. In addition to the lecture

video, a short quiz (1-2 questions) was posted on Blackboard and required to be completed prior to class sessions. These quizzes also accounted for 4% of each student's overall course grade.

Outcomes

Evaluation of student learning between the traditional lecture format and the inverted format was made by comparing grades on exams and homework assignments for the Fall 2018 (traditional lecture format), Fall 2019 (inverted format), and Fall 2020 (inverted format) course offerings. Some improvements to the inverted format were made between Fall 2019 and Fall 2020 based on student feedback and some lessons learned from the first inverted iteration. Figures 1 through 5 provide insight into student learning improvements from the Fall 2018 traditional lecture format to the Fall 2019 and Fall 2020 inverted lecture format. Figure 1 shows exam grades for midterm 1 with an increase in grades for Fall 2019 and Fall 2020 students in the bottom 40^{th} percentile. Similar results are shown for midterm 2 in Figure 2 for Fall 2019, where an increase was observed for the bottom 40^{th} percentile. Results of the final exam are shown in Figure 3 and show improvement in the bottom 10^{th} percentile for Fall 2020. It should be noted that the questions in midterm 1 and midterm 2 were not identical across the three years but were very similar. The final exam was essentially the same. The data for these exams only represents three years and should be considered preliminary, as other effects could be present over this short time period (e.g., different students, other exams and projects due at the same time, timing of the final exam during finals week, and the online course format of Fall 2020 due to COVID-19). Nonetheless, the inverted format provides encouraging results for increasing student performance in lower half of the class (below 50^{th} percentile). The exam grades for the upper percentiles remained essentially unchanged. These results are similar to previously published results of inverting structural design courses [2].

In addition to exam grades, homework assignment grades were also examined and plotted in Figure 4. An interesting result shows that homework grades showed significant improvement for students in the 60^{th} percentile or below in Fall 2019 and Fall 2020 compared to Fall 2018. This could potentially be attributed to the increased time spent in class working on problems, some of which included homework problems. This increase in performance for homework assignment grades (along with the slight increase in performance on exams) was reflected in course grades (as seen in Figure 5), where the bottom half of the class did significantly better in the Fall 2019 and Fall 2020 inverted format than the Fall 2018 traditional lecture format. To test the statistical significance of the data presented in Figures 1 through 5, Kolmogorov-Smirnov tests (using $\alpha = 0.05$) were performed to compare midterm 1, midterm 2, final exam, homework, and overall course grades between the inverted (Fall 2019 and Fall 2020) and traditional (Fall 2018) format. The only statistically significant change according to the Kolmogorov-Smirnov test was found for the homework grades. All other data did not show statistical significance between the inverted and traditional format; however, these data are only based on two years of data for the inverted format and should be considered preliminary. Additionally, the trends are encouraging and show improvement for the lower half of the class.

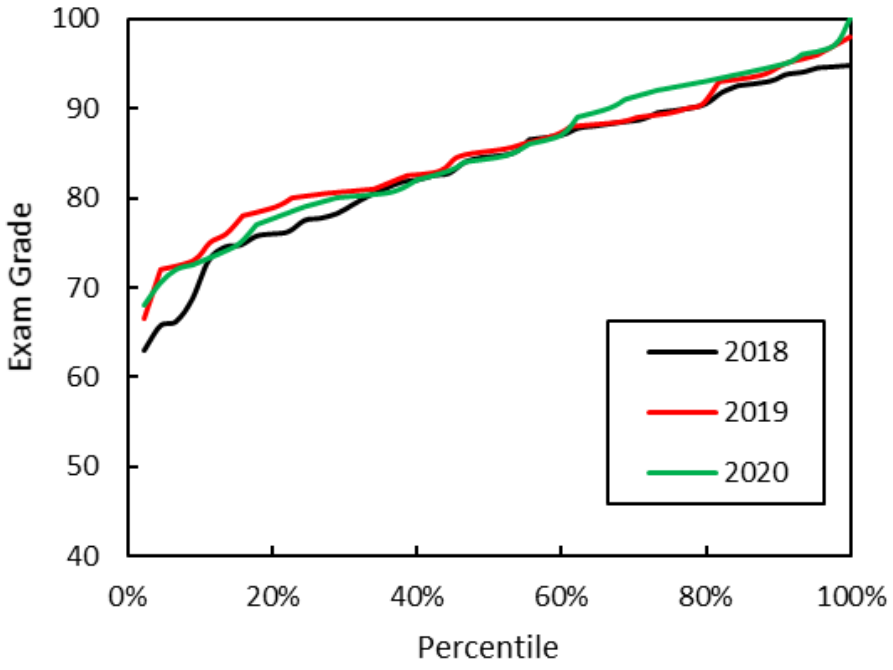

Figure 1. Distribution of Midterm 1 Grades for 2018, 2019, 2020

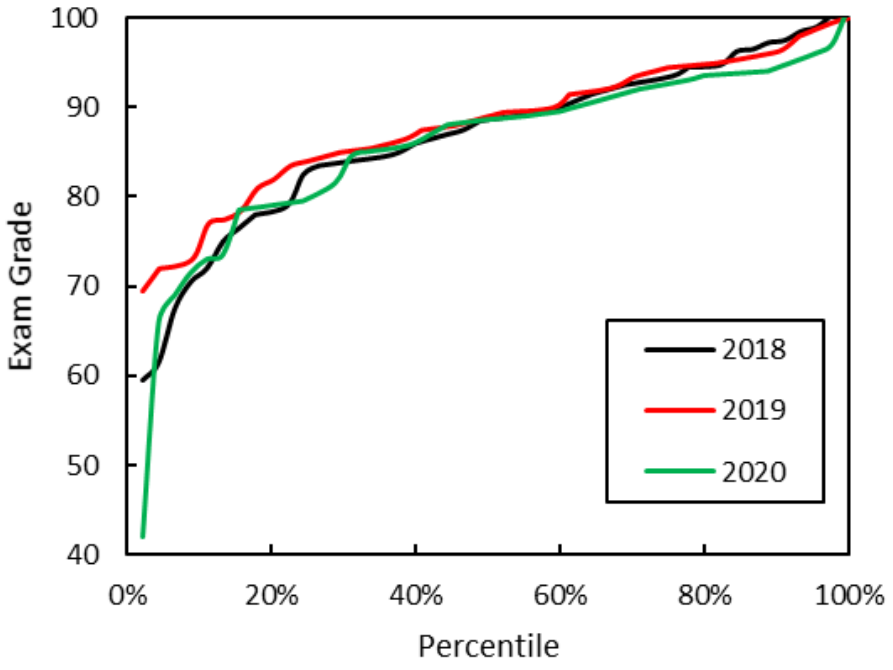

Figure 2. Distribution of Midterm 2 Grades for 2018, 2019, 2020

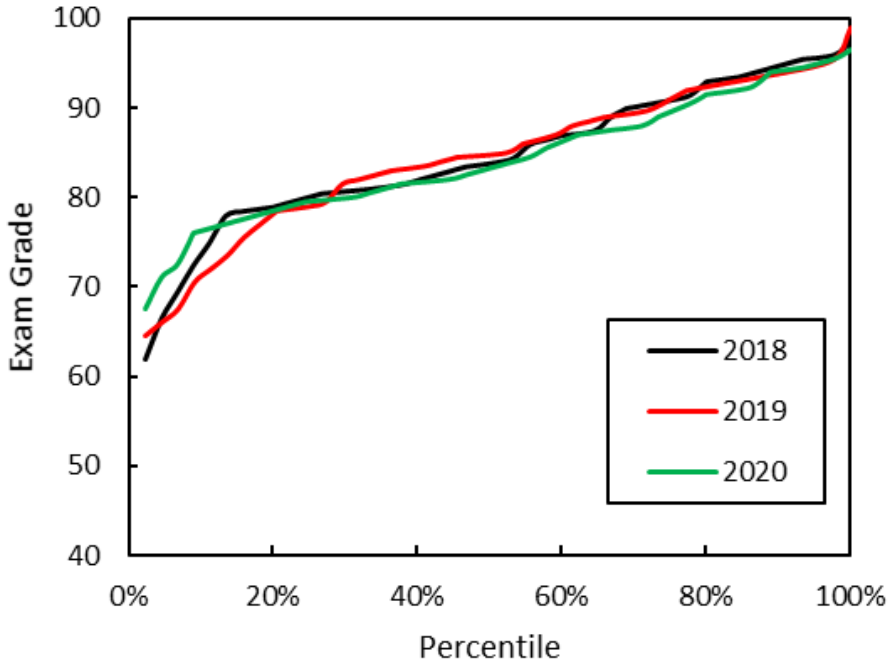

Figure 3. Distribution of Final Exam Grades for 2018, 2019, 2020

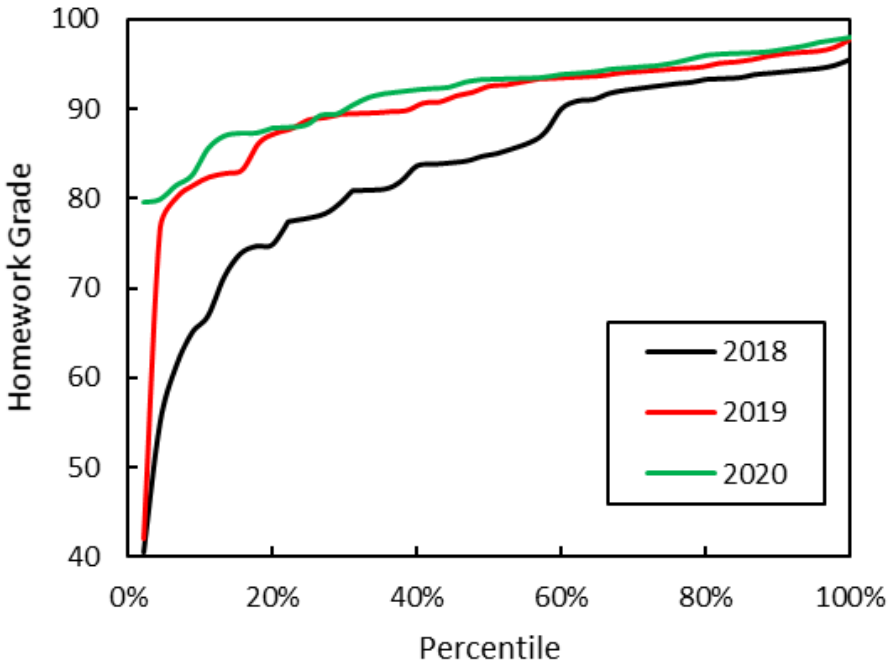

Figure 4. Distribution of Homework Grades for 2018, 2019, 2020

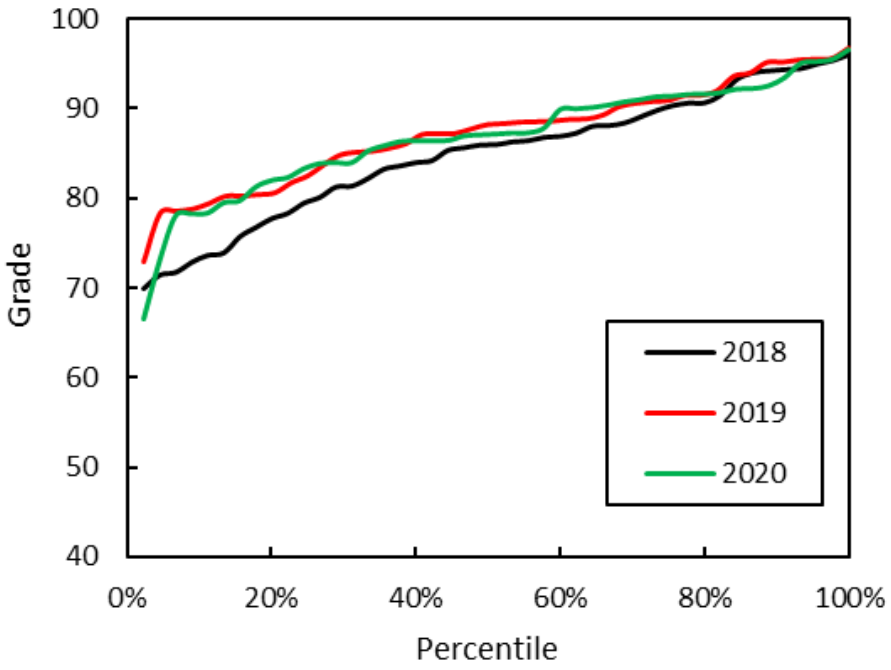

Figure 5. Distribution of Final Grades for 2018, 2019, 2020

In addition to the increased performance in grades for the lower half of the class, positive feedback was received through comments on the CATS. Overall, 17 of 34 comments (50%) cited that they enjoyed the inverted format or in-class problem solving sessions based on the Fall 2019 survey. Similar results were found for Fall 2020 surveys where 13 out of 27 comments (48%) enjoyed the course format or mentioned the value of in-class example problems. These comments were unprompted and therefore many comments did not include any reference to the class format. Only 1 of 32 comments (3%) had a negative view of the inverted format for Fall 2019 and only 1 of 23 comments (4%) had a negative view of the inverted format for Fall 2020.

Lessons Learned

There were several lessons that were learned based on inverting the course in Fall 2019 and Fall 2020. Inverting a course requires a significant amount of time to record videos and develop in-class activities. It was challenging at first to know how long these new in-class activities would take. When extra time was available at the end of class, it provided students with an opportunity to start their homework problems. This was a good way for students to have a few minutes to work together and ask the instructor any questions in class.

Another challenge was that some students felt that there was a disconnect between the video lectures and the in-class problems. A midterm survey was administered in Fall 2019 and many students suggested that a short recap of the video lecture material would be beneficial. Based on student feedback, short recaps were given in the beginning of class which the students seemed to appreciate.

In Foundation Design, charts and tables are often required to solve the example problems in class. The midterm survey administered in Fall 2020 revealed that students preferred for example problem worksheets to include any required tables and charts to minimize time spent flipping back and forth between the problem handout and the lecture notes. Based on the student feedback, in-class problem handouts were reworked to include all relevant tables and figures as well as step-by-step procedures. Students commented that it was much easier to follow along with the example problems in the new format.

Conclusions

Inverting a classroom can be a significant undertaking for a course instructor but was shown to improve student performance, specifically on homework assignments in a senior-level civil engineering technical elective course. Performance increases were observed for the lower 50^{th} percentile of the class, while the upper percentile performance on exams and homework remained the same as the traditional lecture format. These results are based on one year of traditional lecture format data and two years of inverted format class data. The inverted format consisted of 10-minute videos and short quizzes that were completed prior to class. New in-class problem handouts enabled for more active learning, problem-solving, and student participation. Student feedback on teaching surveys was positive and the instructor noted greater in-class engagement. Overall, the inverted format was shown to have a positive effect on student performance and participation while not receiving negative feedback for out of class lectures and quizzes.

Acknowledgments

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