Improve Engineering Student Engagement through In-Class and Out-Class Interactions

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ABSTRACT

Analysis and Design of Control Systems is a core course in most Electrical Engineering programs in the United States. This course is also an important component in some mechanical engineering and aerospace engineering programs. It serves as a gate-keeper course to prepare sophomores for senior level courses. This course also provides systemic analysis approaches to electrical, mechanical, and aerospace engineering students for real-world applications. However, for years a high rate of D and F grades and withdrawal (DFW) has been observed in this course at the University of Texas at San Antonio. This DFW rate has been associated with low attendance rates and engagement levels. The goal of this study is to integrate multiple interactive activities into the course instructions and followed with online quizzes after classes.

The in-class interactions include 1) a series of mini-lectures on time-management, note-taking, exam preparation, and critical thinking skills; 2) 5-20 minutes in-class quizzes or group practices every week; 3) peer-tutoring on specific questions assigned before a class; and 4) in-class MATLAB simulations and animations on chosen topics. The follow-up out-class interactions were performed by 8 adaptively released on-line quizzes. If a student passes an online quiz with a score higher or equal to 70, the solution of the quiz will be released. Otherwise, a video lecture with respect to each knowledge point the student missed will be released and a 2nd online quiz will be assigned to the students to examine the knowledge points again. If the student cannot pass the 2nd quiz with a score above 70, an appointment will be scheduled between the student and the instructor during recitation or office hour to help the students. Study groups were also formed to promote peer-tutoring and out-class interactions.

Evaluation of the new components was conducted based on classroom attendance rate, two student surveys through the semester, three classroom observations, teaching evaluations, and students'

performance for two years for a total of 61 students. The results were also compared against a control group (33 students) who had the course without these course components in the previous semesters. Our results illustrated significant improvements in classroom attendance rates, teaching evaluation, and students' performance (GPA) with the combined in- and out-class interactions.

Introduction

Analysis and Design of Control Systems is a core course in most Electrical Engineering programs in the United States. This course is also an important component in some mechanical engineering and aerospace engineering programs. This course provides systemic analysis approaches to engineering students for real-world applications and serves as a gate-keeper course to well prepare students for senior level curriculum. The course is math-heavy since it needs understanding and application of knowledge from pre-calculus, calculus, physics, and linear algebra. A high rate of D and F grades and withdrawal (DFW) for this course has been observed at the University of Texas at San Antonio. This high DFW has been partially due to low student engagement levels during the past, evidenced by low class-attendance rate, low students' visit in office hours, and low student interest and enrollment in senior level control classes.

Evaluation of our previous teaching-learning pattern illustrated that our lecture time is mainly used for content delivering and practices of knowledge points are performed outside the classroom. This passive knowledge transmitting-acquisition style has an obvious defect. Students may understand the knowledge during the class but forget partially or completely when they practice after the class and proper help may not be available while students practice. To improve our teaching-learning efficiency, we re-designed this course based on constructive practice-based teaching-learning model and established a web-based feedback mechanism for this course to increase our student engagement for the course and thus to reduce DFW rate.

As the understanding of cognition, learning, and teaching gets deeper and better, teaching-learning model with a constructivist perspective has gained more attention during the past two decades.[1, 2] In a constructivist viewpoint, learning is to actively construct students' understanding, and teaching is to guide students' learning process and understand students' thinking.[3-7] The researches all point to the importance of student engagement in engineering education. Specifically, Zepke and colleagues have proposed possible actions to improve student engagement. [8]

Course Design and Delivery

To promote students' habit of active learning and improve students' engagement in the class, we modified our lecture components for student-focused teaching practice and significantly increased students' practices during class time. Our redesign can be classified into in-class interactions and out-class interaction including web-based adaptive-release feedbacks and study-group formation.

In-class Interactions

The in-class interactions include 1) a series of mini-lectures on time-management, note-taking, exam preparation, and critical thinking skills; 2) 5-20minutes in-class quizzes or group practices every week; 3) peer-tutoring on specific questions assigned before a class; and 4) in-class MATLAB simulations and animations on chosen topics.

To illustrate our mini-lectures, course modules of time-management skills were presented here. Time-management skills were introduced at the beginning of the semester. The ***goal*** of time management lecturer is to help students find a ***balance*** among the things they ***need to do*** and the things they ***want*** *to do*. Our time-management skill lectures include:

Lecture 1: Students self-evaluation

Students were asked to answer the following question in 10 minutes.

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Fall 2018 Semester Calendar

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday / Sunday
Week One: Aug 20-26	20 Roadrunner Day	21 1st Day of Class	22	23	24	25 / 26
Week Two: Aug 27-Sep 2	27	28	29	30	31	1-Sep / 2
Week Three: Sep 3-9	3 Labor Day No classes	4	5 EXAM 1	6	7	8 / 9
Week Four: Sep 10-16	10 Lab Report 1	11	12	13 TEST 1	14	15 / 16
Week Five: Sep 17-23	17	18	19	20	21 EXAM 1	22 / 23
Week Six: Sep 24-30	24	25	26 EXAM 2	27	28 Lab Report 2	29 / 30
Week Seven: Oct 1-7	1-Oct	2	3	4 ESSAY 1	5	6 / 7
Week Eight: Oct 8-14	8	9	10	11	12 Presentation	13 / 14
Week Nine: Oct 15-21	15	16	17 EXAM 3	18 TEST 2	19 EXAM 2	20 / 21
Week Ten: Oct 22-28	22	23	24 Lab Report 3	25	26	27 / 28
Week Eleven: Oct 29- Nov 4	29	30 ESSAY 2	31	1-Nov	2	3 / 4
Week Twelve: Nov 5-11	5	6	7	8 Project	9	10 / 11
Week Thirteen: Nov 12-18	12 Lab Report 4	13	14 EXAM 4	15	16 EXAM 3	17 / 18
Week Fourteen: Nov 19-25	19	20	21	22 Thanksgiving	23 Holiday	24 / 25
Week Fifteen: Nov 26-Dec 2	26 Group Project	27 TEST 3	28	29	30	1-Dec / 2
Week Sixteen: Dec 3-9	3	4	5 Lab Report 4	6 Study	7 Days	8 / 9
Week Seventeen: Dec 10-16	10 Circuits Final	11	12 Control Final	13	14 Lab Final	15 / 16

Figure 1: Big picture on time planning for the whole semester.

1. Do you know how much time you need to spend on activities each week?
2. Do you set aside time for planning and scheduling?
3. Do you write and keep track of a daily "to do" list?
4. Do you include extra time in your schedule to deal with things that come up unexpectedly?
5. Do you set goals to determine what you should focus on?
6. Do you prioritize tasks so you can complete the most important things first?
7. Do you complete assignments before the due date?

This lecture series allows students to assess how well they manage their time.

Lecture 2: Planning Study Time

There are three steps for students to follow and practice.

1. Big Picture: Mark all important deadlines in each week for the whole ***semester*** as shown in Figure 1.
2. Break it down: break the schedule into hours for each ***week*** based on the big picture and list tasks for each hour as shown in Figure 2.
3. Follow through: A ***daily*** to-do list is requested for students to highlight the priority of tasks, revise for emerging issues, and check it up each night.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
6:00AM							
7:00AM							
8:00AM		Electrical and Computer Engineering Lab 1		Electrical and Computer Engineering Lab 1		Engineering Ambassadors	
9:00AM	Work Study		Work Study		Work Study		
10:00AM							
11:00AM		Analysis & Design of Control Systems		Analysis & Design of Control Systems			
12:00PM							
1:00PM							
2:00PM			Math in Signals and Systems				
3:00PM	Math in Signals and Systems		Math in Signals and Systems		Math in Signals and Systems		
4:00PM	Meeting With Advisor	Circuits II	Analysis & Design of Control Systems	Circuits II	Lab Electrical and Computer Engineering Lab 1		
5:00PM							
6:00PM		Electronic Devices	IEEE	Electronic Devices			
7:00PM							
8:00PM							
9:00PM							
10:00PM							

Figure 2: An example of weekly schedule in hours.

Lecture 3: Mobile Apps to Manage Calendar

Three students were invited to show how to use calendars such as Fantastical, Outlook, and Google, with their mobile devices.

Through these three mini-lectures, students learned how to manage time efficiently, and the three invited student's talks ignited their interests in attending the class.

In our note-taking mini-lecture, a retention figure attracted lots of attention from students (Figure 3). They knew that just 1 hour after the lecture, they might only remember 50% of lecture material and two days later they might only remember 10% of class material. Since our lecture series were scheduled on Tuesdays and Thursdays, it was essential to review the lecture every day after the class and put this in their daily task list established during the time-management mini-lectures.

Since our mini-lectures were arranged at the beginning of each class, a significant decrease of late students' arrivals was observed. In addition, due to student involvement in these mini-lectures, the interactive class climate was established and students were more willing to raise questions in the following technical lecture part.

We also scheduled a 5-20minutes of in-class practice every week. These in-class practices were group practice during the first half of the semester and gradually evolved into independent practice at the end of the semester. We also integrated our in-class practice with the peer-tutoring mechanism.[9, 10]Peer tutoring consists of students teaching other students of the same or different age, either in a one-on-one setting or involving one tutor working with two or more students at the same time.

Students were invited to demonstrate their practices to gain extra credit. By this way, any mistakes they made on the blackboard were observed by other students. In addition, other students were encouraged to share the mistakes they made during their practices. With these in-class practices, students learned not only the correct way to apply their new knowledge but also potential mistakes or challenges they might face when they practiced independently after the class.

Out-class Interactions

The out-class interactions include two major activities: web-based adaptive-release feedbacks and study group formation.

1. Web-based adaptive-release feedback

The out-class interactions were performed by eight adaptively released on-line quizzes. If a student passes an online quiz with a score higher or equal to 70, the solution of the quiz will be released. Otherwise, a video lecture with respect to each knowledge point the student missed will be released and a 2nd online quiz will be assigned to the student to examine the knowledge points again. If the student cannot pass the 2nd quiz with a score above 70, an appointment will be scheduled between the student and the instructor during recitation or office hours to help the student. Details about this adaptive-release feedback mechanism have been reported previously.[11]

2. Study-group formation

Group-studying is one of the most recognized approaches to achieve academic success in a team-spirited higher education environment and increase persistence in STEM curriculum.[10, 12] Group-studying offers students an opportunity to engage in a more in-depth discussion with peers with no concerns for their professors/instructors. Group-studying also motivates the persistency of study. Besides the student-initiated study group, the instructor and teaching assistant also organized a special study group to help students to prepare for their exams and solve homework problems. Specifically, students were encouraged to attend an international mathematical contest in modeling (https://www.comap.com/undergraduate/contests/mcm/), one of the most welcomed and joined contests for control students.

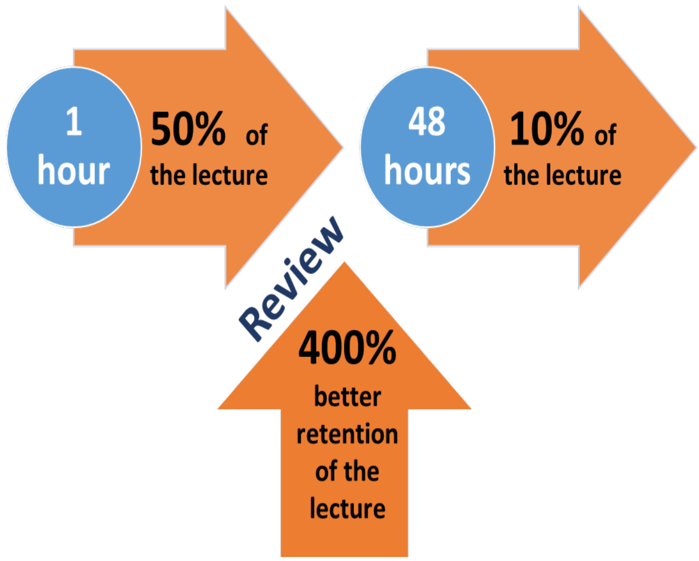

Figure 3: Retention of memory decreased significantly with time and a daily review increased retention 400%.

Other Activities

We have two surveys, three classroom observations, and course evaluation conducted during the semester. The two surveys were conducted at week 4 and 8 to collect feedback for our mini-lectures, in-class interactions, and out-class interactions. The three classroom observations were conducted from week 8-week 12 to quantify the class time usage including lecture, group work, interactions, and administrative tasks. The course evaluation was performed at the end of the semester.

Evaluation

Student Enrollment

A total of 94 students were enrolled in this study. Sixty-three students registered in the course with in-class and out-class interactions for the engagement-improving group and 33 students were in the control group without such interaction. A summary of student characteristics is shown in Table

1. No significant difference in students' demographics and performance was observed between the engagement-improving group and control group.

Outcome Measures

Outcomes measured in the study include students' study habits, academic performance, interest in engineering, and persistence in the study. These outcomes were measured using the following criteria:

1) Study habits and persistence: study habits were evaluated by Surveys 1 and 2 and classroom activities.

2) Academic success was assessed using grades in this class.

3) Interest in engineering: changes in engineering interest were measured using surveys at the beginning and middle of the semester.

4) Persistence in the study: attendance rate during the semester and DFW rate of the course.

Table 1. Characters of students in this study

	Engagement-improving group	Control group
Number of Students	61	33
Number of Males	50	29
Number of Females	11	4
Average ± SD of overall GPA	3.08±0.35	3.05±0.48

Statistical Analysis

A one-tailed t-test was performed with unequal variances to assess the changes in students' performance between the training group and the control group. Statistical significance was established with a p-value less than 0.05. Academic performance was evaluated based on the average grades in the two student groups gathering a p-value about 0.03.

Results

Study Habits Assessment

The engagement-improving group demonstrated a significant improvement in study habits gained from our mini-lectures through our two surveys. Our students' surveys also showed strong agreement on the effectiveness of 3 most helpful skills: time management, note taking, and group studies from the mini-lecture series. Students who attended study group regularly have demonstrated an average score of 84/100, which is much better than the average score (68/100) of students who did not join any study group.

Impact of Engagement-Improving on Student Performance

The average grade of the course was 2.89/4 in the engagement-improving group compared to an average of 2.39/4 from the control group as shown in Table 2. This elevated average score was accompanied by a reduced DFW rate, 18% in the control group and 13% in the engagement-improving group.

Persistence in Study

The attendance rates collected during the 16 weeks were averaged. A higher attendance rate of 85% in the engagement-improving group was compared to 76% in the control group. A better student-instructor interaction and student-student interaction was demonstrated in the three classroom observations.

Table 2. Students' performance in the engagement-improving and control groups

	Training Group	Control Group
Average ± SD Course Grading	2.89±0.82	2.39±0.85
DFW Rate	13%	18%
Average attendance rate	87%	76%

Percentages of student's activity (orange) and instructor's activity (green) were shown in Figure 4 in one classroom observation. In Figure 4, the instructor guiding student work accounted for 46% of class time and a reduced instructor presenting time (85%) was recorded. In addition, students receiving, talking to class (student discussion, peer-tutoring), and hands-on working time were 87%, 49%, and 3%, respectively. With the guided student work, in-class interactions, it was much easier for students to understand the knowledge points and apply the newly acquired knowledge to problem-solving.

In addition, in the following semester, two teams (6 students) were formed to attend the mathematical contest in modeling, suggesting an increased interest in pursuing advanced studies in control.

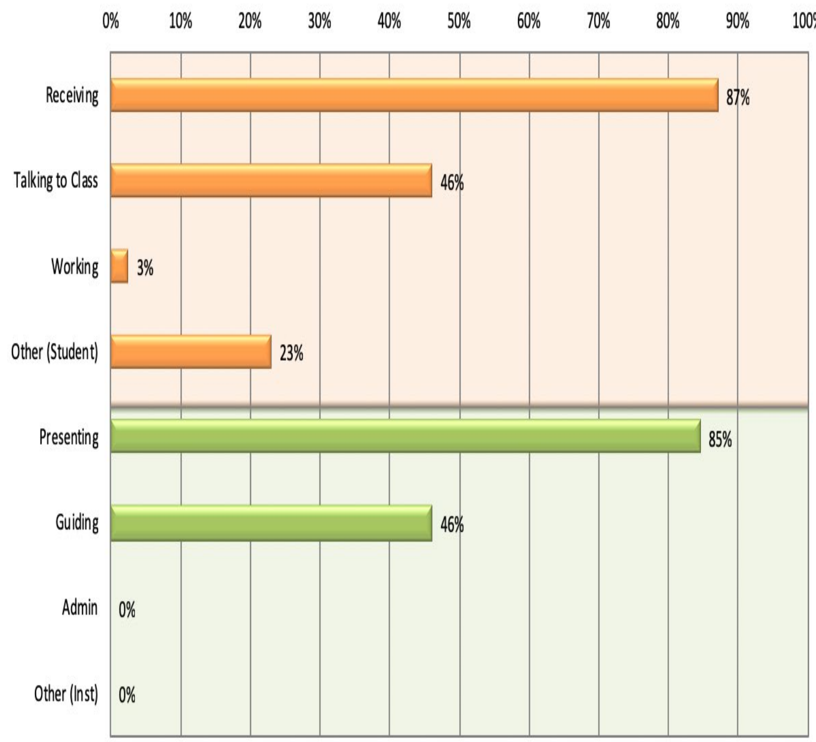

Figure 4: Students' (orange) and instructor's (green) activities (percentage of class time) are shown.

Conclusion

With this project, a series of in-class and out-class activities were integrated into our course modules to improve students' engagement in an Electrical Engineering core course:

Analysis and Design of Control Systems. Course outcomes illustrated an improvement of classroom performance, better study habits, and improved students' engagement based on average grades for the engagement-improving group against the control group. In addition, an enhanced engagement in the course was also suggested by frequent students' visits to the instructor's office and the reduced DFW rate.

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