Evaluation of Online Learning in a First-year Engineering Design Course

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ABSTRACT

This evidence based practice paper evaluates an online project-based design engineering course. Because of increasing enrollments in engineering courses, class facilities on campus cannot accommodate for additional students. Adding to this problem is that universities may simply not have enough instructors to offer additional course sections to accommodate class growth. Therefore, online learning may be one pathway to address this problem. We examined a first-year engineering course, which consisted of both lecture and lab sections. In this course, students designed, built and tested a remote controlled and an autonomous device over the duration of two quarters. The online course used pre-recorded lectures and covered all theoretical content related to the design project. A traditional/in-person lecture course was simultaneously offered to a separate cohort of students who had attended all lectures in-person. Students from the online and the in-person lecture course both participated in lab sessions, instructed by teaching assistants. We evaluated the online class by student self-assessed surveys to gauge what course features students valued in an experiential-learning engineering design course, and whether a similar learning experience could be provided in comparison to the in-person class. Student performance was also measured by comparing the overall grades between the in-person and online sections.

Introduction

The traditional engineering curricula require students to take majority of their first-year and second-year courses in physical sciences and math before enrolling in engineering courses to complete their upper division. This lack of engineering-based experiences during the first years of students' college experience may have a negative impact on retention, in that many students lose interest and leave engineering during the first year, without understanding the importance of rigorous training in math and physical sciences. Many universities have implemented innovative first-year programs to improve the retention[1].

We started our first-year program six years ago by incorporating evidence-based practices that prior work has shown to be effective [2]. The program has expanded from 100 in 2012 to over 360 students in 2017. However, in the Fall of 2016, the number of students intending to enroll in the first-year engineering course exceeded the maximum seat capacity of the assigned lecture hall. Furthermore, due to financial constraints, additional in-person lecture sections could not be implemented without hiring extra instructors. To accommodate the student growth, an online section was offered to resolve the challenge and allow all students to enroll. Moreover, the option of introducing an online section attempted to solve the issue of schedule conflicts for students who had another required course arranged at the same time as the first-year course.

To understand the effectiveness of online courses, a literature search was conducted to incorporate best practices of effective pedagogical approaches in the instruction. The integration of various forms of online learning in all majors has become increasingly important in higher education when university administrations are facing budget cuts, with some aspects of distance learning may potentially assist in the enhancement of education quality [3]. Research studies

examined the differences and effectiveness in learning outcomes between traditional lecture courses and online learning instructions indicated mixed results with respect to student course performance [4-7]. For example, Means [8] stated that students in online learning conditions had performed modestly better than those receiving in-person instructions. On the contrary, Xu and Jaggers [7] examination of 500,000 courses at a technical community college indicated that student performance was higher for students in in-person courses modalities. Among first-year engineering program practices, Calabro [9] used flipped classroom by replacing the traditional lecture sequences with a series of pre-recorded video segments. With the same lecture information provided, Calabro concluded that the integration of online format had been more effective as a pedagogical approach than the traditional lecture model.

Prior to incorporating online learning, the first-year engineering course consisted of two lectures and a two-hour lab per week in Fall, and one lecture and a two-hour lab per week in Winter quarter. The project was to design, build and test a radio-controlled quadcopter in Fall, and an autonomous object mapping quadcopter in Winter. When implementing the online course, all technical lectures were converted to short pre-recorded segments. Guo [10] suggested that students were more engaged with shorter lecture recordings from six to 12 minutes. However, due to complexity of lecture content and the intention of joining the same technical topics into one segment, we recorded lecture slides with instructor's voice in a time range between seven and 15 minutes. A total of 23 modules (average video time: 11.0 minutes) and 18 modules (average video time: 10.5 minutes) were posted for student in Fall and Winter quarter, respectively. These videos provided the same theoretical information as covered in the in-person lecture course. During Fall quarter, students watched an average 3-4 modules on a weekly basis. These lecture videos covered the technical content during the first seven weeks. During Winter quarter, students watched 2-3 video modules on a weekly basis during a seven-week period. In addition, guest speakers including faculty from each department within the School of Engineering and industry leaders were recorded from the in-person class, and posted on the course website within the same week for students enrolled online.

Canvas was used as the web platform to host the website for the online course, where weekly modules were posted including all necessary information such as lecture videos, announcements, homework assignments, etc. To encourage student participation online, a weekly quiz was administered to students with questions directly related to the lecture content, and to assess whether students understood the lecture materials. Unlike the flipped classroom model, students of the online session watched the lecture videos from the course website without interacting with the instructor (besides office hours), and attend the lab in person. During lab sessions, teaching assistants taught students from both lecture sections in person. We evaluated the online course through student surveys by understanding how important each course aspect was to student learning.

To assess whether students from the online course had a similar experience as those from the in-person lecture section, we examined the following research questions:

1) Did students' experiences of selected course features differ across Fall and Winter terms within the online section and the in-person section, respectively?
2) Did students' experiences of selected course features differ for students enrolled in online course section compared to students enrolled in the in-person course sections?

3) Did students' overall grades differ for students enrolled in online course section compared to students enrolled in the in-person course sections?

Methodology

A student survey was administered to both the in-person and online sections at the end of each quarter. The response rates were 72% (n=223) for the in-person class and 70% (n=39) for the online class in Fall quarter, and 87% (n=146) for the in-person class and 83% (n=44) for the online class in Winter quarter.

The following questions were asked to assess how important each course aspect was to student learning on a scale of 1 to 5, where 1 is "very unimportant to my learning", 2 is "unimportant to my learning", 3 is "somewhat important to my learning", 4 is "important to my learning", and 5 is "very important to my learning".

When thinking about the course, how important were following features to your learning?

- Lecture videos (online section)/Attending lectures in person (in-person section)
- Lecture PDF slides
- Quadcopter project related items
- Quadcopter video tutorials
- Weekly quizzes (For online course only)
- Industry guest speakers
- Introduction to Engineering Design textbook
- Homework assignments
- Office hours
- Lab sessions
- Facebook forum (a forum created in class to allow students to post questions and receive assistance from instructors and fellow students)

We evaluated student attendance in both the in-person and online sections by asking the following question.

- What percentage of the lecture videos did you watch for this course? (for online section)
- What percentage of the technical lectures did you attend for this course? (for in-person section)

Students chose among the following answers for the above-mentioned question:

- Less than 40% of the lecture (for in-person) or lecture videos (for online), scored as 1.
- Between 40-59% of the lecture (for in-person) or lecture videos (for online), scored as 2.
- Between 60-79% of the lecture (for in-person) or lecture videos (for online), scored as 3.
- Between 80-99% of the lecture (for in-person) or lecture videos (for online), scored as 4.
- 100% of the lecture (for in-person) or lecture videos (for online), scored as 5.

For statistical analysis, differences on course features between the in-person and online sections were tested by the Student's *t*-test to evaluate differences in student experiences. The first research question tested differences across terms, and the second question tested differences

between the online and the in-person sections. The third research question descriptively compared the overall grades between the in-person and online sections for Fall and Winter quarter to assess how students performed in each course format.

Results and Analysis

Figure 1 compares differences in student ratings of the importance of each course feature: (a) lecture videos/lecture attended in person, (b) lecture slides, (c) project related items, (d) quadcopter video tutorials, (e) weekly quizzes(online section only), (f) industry speakers, (g) homework assignments, (h) office hours, (i) lab sessions, and (j) Facebook forum discussion. In Figure 1, each bar represents the average score/mean of student ratings on a 1 to 5 scale. Error bars represents the standard deviation. 39 students participated in the Fall and 44 students participated in the Winter survey from the online section. 223 students participated in Fall and 146 students participated in Winter from the in-person section.

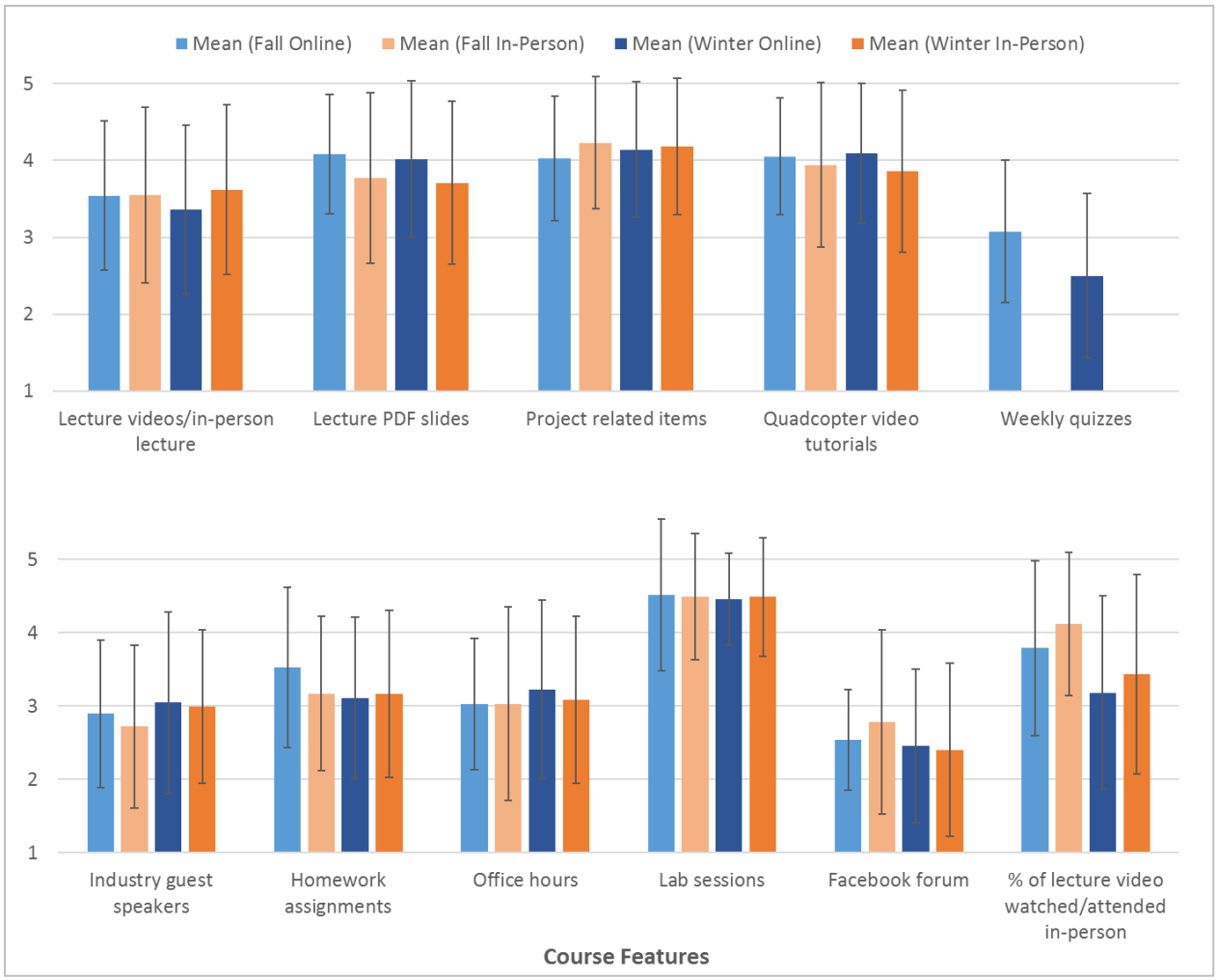

Figure 1. Importance of course features on a scale from 1 to 5 for the online section (blue) and the in-person section (orange), assessed at the end of Fall (lighter) and Winter quarter (darker).

Research question 1: course feature differences across terms

For this introduction to engineering course, no substantial differences in student ratings of most course features were observed across terms for the online and the in-person sections (Table 1). Notably, student ratings did not increase significantly from Fall to Winter quarter on all observed course aspects, except regarding industry guest speakers, which the ratings increased significantly for the in-person section from Fall (mean=2.72, SD=1.11) to Winter (mean=2.99, SD=1.05) quarter, $p<0.05$. Furthermore, for several course features, student ratings decreased significantly from Fall to Winter term. For example, in the online section, the importance of the weekly quizzes decreased from Fall (mean=3.08, SD=0.93) to Winter (mean = 2.50, SD=1.07), $p < 0.05$, which needed further investigation on the cause of the change. Moreover, the percentage of lecture videos watched in the online section decreased from Fall (mean=3.79, SD=1.19) to Winter (mean=3.18, SD=1.32), $p < 0.05$. This change showed that more students had watched 80-99% of lecture videos during Fall than Winter quarter.

	In-Person Section			Online Section		
Course Aspect	**Fall Quarter Mean ± S.D. n=223**	**Winter Quarter Mean ± S.D. Mean, n=39**	**p-value**	**Fall Quarter Mean ± S.D. n=146**	**Winter Quarter Mean ± S.D. Mean, n=44**	**p-value**
Lecture Files (PDF slides)	3.77 ± 1.11	3.71 ± 1.06	0.59	4.08 ± 0.77	4.02 ± 1.02	0.79
Quadcopter project related items	4.23 ± 0.86	4.18 ± 0.89	0.61	4.03 ± 0.81	4.14 ± 0.88	0.55
Quadcopter video tutorials	3.94 ± 1.07	3.86 ± 1.05	0.49	4.05 ± 0.76	4.09 ± 0.91	0.83
Weekly Quiz				3.08 ± 0.93	2.50 ± 1.07	0.01
Industry guest speakers	2.72 ± 1.11	2.99 ± 1.05	0.02	2.89 ± 1.01	3.05 ± 1.24	0.55
Homework assignments	3.17 ± 1.05	3.17 ± 1.14	0.97	3.53 ± 1.10	3.11 ± 1.10	0.07
Office hours	3.03 ± 1.32	3.09 ± 1.14	0.64	3.03 ± 0.89	3.23 ± 1.22	0.42
Lab sessions	4.49 ± 0.86	4.49 ± 0.81	0.97	4.51 ± 1.04	4.45 ± 0.63	0.69
Facebook Forum	2.78 ± 1.26	2.40 ± 1.18	0.004	2.54 ± 0.68	2.45 ± 1.04	0.73
% of lecture watched/attended	4.12 ± 0.98	3.43 ± 1.36	<0.001	3.79 ± 1.19	3.18 ± 1.32	0.03

Table 1. Comparison of the importance of the course features to students across terms for the two course modalities.

A similar trend was found with the in-person class that the average score of lectures attended significantly decreased from Fall (mean=4.12, SD=0.98) to Winter (mean=3.43, SD=1.36), $p < 0.001$. This observation could be attributed to the differences in the lecture contents across terms. The lectures during first quarter focused a variety of engineering topics including center of gravity, moments, flight dynamics, basic materials, project management, presentation skills, etc. The lectures during the second quarter focused on sensors, circuity and programming, which might be more difficult, but less appealing to students who did not major in mechanical, electrical and computer engineering. Both changes in student experiences on weekly quizzes and percentage of watched videos/lectures attended might reveal that for an experiential-learning

engineering course, students appreciated the hands-on experiences more than theoretical-learning. In addition, the importance of using Facebook online forum reduced significantly from Fall (mean=2.78, SD=1.26) to Winter (mean=2.40, SD=1.18), $p<0.005$. The Facebook forum was mainly used to assist students in homework and any miscellaneous discussions such as open lab hours, scheduling, etc. during the quarter. The decrease in importance could be attributed to the possible community formation among students to assist and support each other in person rather than online, which will need further investigation.

Research question 2: course feature differences across course modalities

Similar to the comparison across terms, no substantial differences in student ratings were observed for the majority of course features between the online and the in-person sections, for Fall and Winter quarter (Table 2). The only significant difference across course modalities occurred regarding homework assignments. Students from online section (mean=3.53, SD=1.10) rated the importance of homework assignments significantly higher than students from the in-person section (mean=3.17, SD=1.05), $p<0.05$.

Thus, student experiences were overall rated consistently in both the in-person and online section. Among all course features, students rated lecture videos and slides, project related items, video tutorials and lab sessions as the most valuable to their learning in this introduction of engineering course.

	Fall Quarter, 2016			Winter Quarter, 2017		
Course Aspect	**In-Person Mean ± SD n=223**	**Online Mean ± SD n=39**	**p-value**	**In-Person Mean ± SD n=146**	**Online Mean ± SD Mean, n=44**	**p-value**
Lecture Files (PDF slides)	3.77 ± 1.11	4.08 ± 0.77	0.10	3.71 ± 1.06	4.02 ± 1.02	0.09
Quadcopter project related items	4.23 ± 0.86	4.03 ± 0.81	0.16	4.18 ± 0.89	4.14 ± 0.88	0.74
Quadcopter video tutorials	3.94 ± 1.07	4.05 ± 0.76	0.54	3.86 ± 1.05	4.09 ± 0.91	0.19
Industry guest speakers	2.72 ± 1.11	2.89 ± 1.01	0.38	2.99 ± 1.05	3.05 ± 1.24	0.78
Homework assignments	3.17 ± 1.05	3.53 ± 1.10	0.047	3.17 ± 1.14	3.11 ± 1.10	0.76
Office hours	3.03 ± 1.32	3.03 ± 0.89	0.99	3.09 ± 1.14	3.23 ± 1.22	0.49
Lab sessions	4.49 ± 0.86	4.51 ± 1.04	0.86	4.49 ± 0.81	4.45 ± 0.63	0.79
Facebook Forum	2.78 ± 1.26	2.54 ± 0.68	0.26	2.40 ± 1.18	2.45 ± 1.04	0.79
% of lecture attended	4.12 ± 0.98	3.79 ± 1.19	0.06	3.43 ± 1.36	3.18 ± 1.32	0.28

Table 2. Comparison of the importance of the course website features and the course features to student learning between cohorts from the in-person and online sections.

Research question 3: differences in student grades

Table 3 shows the comparison of the overall grades achieved by students from the in-person and the online sections. "A Range" indicated the percentage of students who had received A+, A and A-. "B Range" indicated the percentage of students who had received B+, B and B-. "Below B" indicated the percentage of students who received in the C and D range. Since the course

remained as an elective for the first-year students, we mainly evaluated students based on their efforts, e.g., 60% of the overall grade was based on their team performances in design presentations, final report and quadcopter design. Therefore, majority of students obtained an A or a B in the course. Receiving a grade below B indicated that the students had performed extremely poor in the course such as missing most of the lecture and lab sessions.

	Fall, 2016		Winter, 2017	
Grades	In-Person, n=310	*Online*, n=56	In-Person, n=168	*Online*, n=53
A Range	81.6%	58.9%	81.0%	86.8%
B Range	15.5%	35.7%	17.8%	13.2%
Below B	2.9%	5.4%	1.2%	0.0%

Table 3. Comparison of the overall grades obtained by students in the in-person and online sections in Fall and Winter quarters.

During Fall quarter, the percentage of students from the in-person section receiving A's is higher than the percentage of students from the online section. During Winter quarter, the percentage of students receiving A's is similar across both sections. Students from the in-person lecture section demonstrated a consistent performance during Fall and Winter term as the percentage of those receiving A's and B's had remained nearly constant. However, the online section demonstrated an apparent increase during the second term with a higher percentage of students receiving A's and no one receiving below a B. This could be attributed to the student academic preparedness to be enrolled in an online course. Since Fall was their first term in college from high school, an online engineering course might be challenging to adapt. In contrast, students were more academically prepared during the second quarter, especially being more familiar with the online format.

Conclusion

This evidence based practice paper reports on the integration of online learning into a first-year engineering design course during Fall of 2016 and Winter of 2017. This study is unique in the engineering education context as it addressed the challenge of course enrollment overflow in combination with limited resources offered to compensate enrollment increase. Overall, this study provides an example for successful incorporation of online learning in an introductory engineering course with a focus on experiential learning. Its main findings are as follows:

First, both student in online and in-person course sections experienced core course features similarly across terms. Second, student experiences were similar across course modalities. This indicates that students enrolled in the online course component of this class were not a disadvantage. Third, for overall student grades, the in-person section performed better than the online section during Fall quarter. However, students from the online section improved their overall grades substantially during the Winter quarter.

Future work will further examine student course engagement with students' course ratings and course performance by analyzing learning analytics data (e.g., site access, timestamps, etc.) captured within the learning management system. Additionally, students from both online and in-person sections will be invited to participate in focus group interviews to explore faculty-student

connections and course enjoyment. Furthermore, a follow-up study will further assess the impact on student outcomes, student motivation, effort regulation and self-efficacy between the in-person and online sections as part of a retention study.

References

[1] M. Borrego, J. E. Froyd, T. S. Hall, "Diffusion of Engineering Education Innovations: A Survey of Awareness and Adoption Rates in U.S. Engineering Departments," *Journal of Engineering Education*, vol. 99, no. 3, p. 185-207, 2010.

[2] L. L. Wu, J. C. LaRue, R. Cassidy, J. M. McCarthy and G. Washington, "Implementation and Impact of a First Year Project-Based Learning Course," *American Society of Engineering Education Annual Conference*, June 26-29, 2016, New Orleans, LA

[3] W. G. Bowen., *Higher Education in the Digital Age*, Princeton, NJ: Princeton University Press, 2013.

[4] W. G. Bowen, M. M. Chingos, K. A. Lack and T. I. Nygren. "Interactive Learning Online at Public Universities: Evidence from a Six-Campus Randomized Trial," *Journal of Public Policy Analysis and Management*, vol. 33, no. 1, p. 94-111, 2014.

[5] D. Figlio, M. Rush, and L. Yin, "Is it Live or Is It Internet? Experimental Estimates of the Effects of Online Instruction on Student Learning," *Journal of Labor Economics*, vol. 31, no. 4, p. 763-784, 2013.

[6] E. P. Bettinger, L. Fox, S. Loeb, and E. S. Taylor, "Virtual classrooms: How online college courses affect student success", *American Economic Review*, vol. 107, no. 9, p. 2855–2875, 2017.

[7] D. Xu and S. S. Jaggars, "Performance gaps between online and face-to-face courses: Differences across types of students and academic subject areas," *The Journal of Higher Education*, vol. 85, no. 5, p. 633–659, 2014

[8] B. Means, Y. Toyama, R. Murphy and M. Baki, "The Effectiveness of Online and Blended Learning: A Meta-Analysis of the Empirical Literature," Teachers College Record, vol. 115, no. 3, p. 1-47, 2013.

[9] K. M. Calabro, "Flipping the Classroom on an Established Introduction to Engineering Design Course", *the 5th First Year Engineering Experience (FYEE) Conference*, August 8-9, 2013, Pittsburgh, PA

[10] P. J. Guo, J. Kim, and R. Rubin, "How Video Production Affects Student Engagement: An Empirical Study of MOOC Videos", L@S '14 Proceedings of the first ACM conference on Learning @ scale conference, p. 41-50, March 4 - 5, 2014, Atlanta, Georgia