Impact of an Online Learning Environment on Student Performance and Perceptions in a Fluid Mechanics Course

Dr. Paul Morrow Nissenson, California State Polytechnic University, Pomona

Paul Nissenson (Ph.D. Mechanical & Aerospace Engineering, University of California, Irvine, 2009) is an Assistant Professor in the Department of Mechanical Engineering at California State Polytechnic University, Pomona. He teaches courses in fluid mechanics, thermodynamics, and numerical methods. Paul's current research interests involve studying the impact of technology in engineering education.

Dr. Faye Linda Wachs, California Polytechnic State University, Pomona

Faye Linda Wachs is a professor of Sociology in the Department of Psychology & Sociology at California State Polytechnic University, Pomona. Dr. Wachs received her Phd in Sociology from the University of Southern California, along with a graduate certificate in gender studies. Dr. Wachs' published work focuses on gender equity, health, fitness, media, sport, sexuality and consumerism. Her book, Body Panic: Gender, Health and the Selling of Fitness, co-authored with Shari Dworkin was the recipient of the North American Society for Sport Sociology (NASSS) Distinguished Book Award in 2010. She is the California State Polytechnic University, Pomona 2012 Provost Award Winner for Distinguished Service as well as the 2009-10 Cal Poly Pomona College of Letters, Arts and Social Sciences Outstanding Advisor. Dr. Wachs is the former president of an international academic organization, the North American Society for Sport Sociology. Dr. Wachs' current research focuses on the impact of facial paralysis, innovative research methods, social media and identity and STEM Education. In her spare time, Dr. Wachs enjoys hiking, running, biking, sailing, knitting/crocheting/sewing and spending time with her family and dogs.

Prof. Juliana Lynn Fuqua, California State Polytechnic Pomona University

Juliana Fuqua, Ph.D., is an Associate Professor in the Department of Psychology and Sociology at California State University Polytechnic, Pomona who completed her doctoral degree at the University of California, Irvine. Dr. Fuqua's dissertation at the University of California, Irvine, was an evaluation of transdisciplinary scientific collaboration, which was part of a large National Institutes of Health Initiative. Dr. Fuqua is a quantitative and qualitative consultant, trained in survey methods, statistics, focus groups, interviews, and program evaluation. Consulting work has included local and national transdisciplinary endeavors. Current interests include evaluation of innovations in STEM products and education, transdisciplinary scientific collaboration, and understanding how the social and physical environment interacts with human development and behavior.

Dr. Yitong Zhao, California State Polytechnic University Pomona

Dr. Yitong Zhao is an Assistant Professor at the Mechanical Engineering Department of Cal Poly Pomona (California State Polytechnic University Pomona). After gained her B.S in MEMS from Tsinghua University in China, she joined in Dr. Chih-Ming Ho's lab at UCLA in 2009. Later she completed her Ph.D in Biomedical Engineering there in 2014. Her was engaged in the project of biofuel and later developed a unique cell-free system from microalgae that could dramatically increase the production rate of lipids, and used a unique optimization tool to urther increase the performance of the cell-free system with a huge reduction of cost. The results earned her two patents. After joining Cal Poly Pomona, she devoted herself in teaching and have been experimenting with many different techniques in improving the class experience in order to meet the need of modern study.

Sofia Pedroza, University of California, Irvine

Sofia Pedroza received her B.A in Sociology with an emphasis in Social Work from Cal Poly Pomona and is currently pursuing a joint PhD-JD degree from the University of California, Irvine. Her research interests include sociology of law, political sociology, gender, and higher education.

Dr. Angela C. Shih, California State Polytechnic University, Pomona

Impact of an online learning environment on student performance and perceptions in a fluid mechanics course

Abstract

Fluid mechanics is a major bottleneck in many mechanical engineering programs. "ME 311: Fluid Mechanics I," a course taken by third-year mechanical engineering and civil engineering students at California State Polytechnic University, Pomona (Cal Poly Pomona), is characterized by high enrollment and high repeat rates. During 2007-2014, approximately one-third of ME 311 students received repeatable grades (D, F, or Withdrawal), with another third receiving C's. In an effort to improve student performance in ME 311, the authors implemented a series of new pedagogical strategies during 2015-2016. The new strategies were introduced in stages and featured the use of McGraw-Hill Connect, an online assignment and assessment platform, as well as dedicating more class time for engaging activities. Faculty from the Department of Mechanical Engineering Department and Department of Psychology & Sociology at Cal Poly Pomona collaborated to measure student academic performance through the use of concept inventories, exam scores, and overall course grades, while student perceptions of the course were examined using surveys and focus groups. The concept inventories and surveys were administered at the beginning and end of the course to determine the extent to which students' knowledge of the subject matter and opinions changed during a quarter. Connect was introduced in Fall 2015 and Winter 2016; each quarter, one experimental section (with Connect) and one control section (without Connect) were taught, with other aspects of the course remaining the same. For Fall 2015, scores on the concept inventory indicated that the experimental section appeared to learn more throughout the course, and the repeat rate was much lower (23.5% for the experimental section versus 38.9% for the control section). For Winter 2016, the experiment was repeated with a different instructor. The difference between the experimental and control sections' performance on the concept inventory was not statistically significant, but the repeat rate was lower for the experimental section (26.7%) compared to the control section (38.7%). For Spring 2016, both sections were required to use Connect and the instructor experimented with a more engaging pedagogy. In the experimental section, class time was dedicated to discussing concepts and worked examples – as recommended by student focus groups in a prior quarter – with no derivations of equations. Instead, derivations were discussed in videos created by the authors that could be watched outside of class. In the control section, class time was used in a similar manner as previous quarters and included derivations. The experimental section performed better on exams and the repeat rate was much lower (20.0% for experimental versus 44.1% for control). For all three quarters, the attitudinal surveys indicate that students in the experimental sections felt more positively toward the course compared to the control sections, although the difference between the two sections varied by quarter. The results from this study suggest that the use of Connect and dedication of more class time to worked examples have the potential to positively impact student performance in fluid mechanics courses.

1. Introduction

During the past decade, increased access to high-speed internet has created numerous opportunities for instructors to experiment with novel pedagogies. There is growing evidence that the traditional lecture instructional model, in which class time is dominated by the instructor presenting information with minimal student interaction, is less effective than active learning pedagogical models. Felder & Brent (2009) define active learning as "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes."[1] Some examples of active learning exercises include group problem-solving, completing tutorials in class, and using personal response systems such as iClickers. Freeman et al. (2014) conducted a meta-analysis of 225 studies that examined the impact of active learning in STEM courses and found that courses employing active learning exercises resulted in higher scores on concept inventories and exams, and lower failure rates, compared to courses that relied primarily on lecture – average examination scores improved by about 6% in active learning sections, and students in traditional lecture classes were 1.5 times more likely to fail than students in classes with active learning.[2]

A pedagogical approach that usually incorporates many active learning exercises is the flipped (or inverted) classroom "in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter."[3] Bunce et al. (2010) found that students are able to focus longer when engaged in the active learning environment of a flipped classroom compared to a traditional lecture classroom.[4] However, additional research still needs to be conducted on the effectiveness of flipped classrooms in engineering courses. Both Bishop & Verleger (2013) and Redekopp & Ragusa (2013) report that most studies on flipped classrooms only "explore student perceptions and use single-group study designs," and often have mixed results regarding the efficacy of a flipped classroom approach.[5,6] However, most studies found that students' perceptions of flipped classroom materials and activities are favorable.[5-12]

The literature on the impact of a flipped classroom approach in a fluid mechanics course is sparse. In two recent studies, McClelland (2013) and Webster et al. (2016) utilized video lectures and class time was dedicated for problem solving, but achieved different results.[11,12] In McClelland's study, students in the flipped section performed slightly worse than a traditional lecture section on a common final exam, while Webster reported that students in a flipped section performed slightly better than a traditional section on both a common exam and a concept inventory. In both studies, students reacted favorably to the flipped format.

Despite the potential benefits of a flipped classroom model, most engineering instructors continue to use a traditional lecture pedagogical model. One reason for the persistence of this model is the large amount of time and resources required to develop and refine a flipped course. Often video tutorials need to be created for each topic, in-class activities must be developed, and decades-old teaching habits have to be revised. Additionally, it can take many iterations to create an environment in which the instructor and students feel comfortable.

This study describes the redesign of a fluid mechanics course from a traditional lecture format to a format that incorporates an adaptive online homework system, video tutorials, and activities that students generally find more interesting. These elements were introduced in stages over three quarters and are part of a larger effort to eventually completely flip the course. At each stage of development, the impact of particular elements of the redesigned course were evaluated using exams, surveys, and a concept inventory. It is hoped that this study could serve as a blueprint for other instructors who want to move toward a more active-learning environment in a fluid mechanics course.

2.1 Description of course prior to redesign

ME 311 (Fluid Mechanics I) is a 10-week course for mechanical and civil engineering students at Cal Poly Pomona that introduces students to core topics in fluid statics and fluid dynamics. Students attend class for 150 minutes per week, divided into either two 75-minute sessions or three 50-minute sessions, and there are no discussion sections. Homework consists of readings and problems from the textbook, and the assessments are usually a combination of in-class quizzes, midterm exams, and a final exam.

Historically, ME 311 has been a significant bottleneck due to high enrollment and high repeat rates. Table 1 shows that among the 3337 students enrolled in ME 311 during Fall 2007 to Summer 2014, 34% received a D, F, or withdrew (W).

Table 1: Grade distribution for ME 311 students from Fall 2007 to Summer 2014

Grade	Number of students
A	302 (9%)
B	658 (20%)
C	1233 (37%)
D/F/W	1144 (34%)

A possible contributing factor to the bottleneck is the pedagogical approach. Prior to the redesign, instructors used a traditional lecture format and class time was divided between derivations, conceptual explanations, example problems, and assessments. Anecdotally, students report that example problems are the most interesting part of the course, with derivations being the least interesting. However, due to the numerous topics that must be covered in only 10 weeks, there is limited time for example problems. Other issues with the course identified by the authors are the following:

- Feedback on homework, quizzes, and exams usually takes at least a couple days, by which time students have begun to work on new topics.
- There is minimal time for meaningful student-teacher interaction in class.
- Most students do not read the textbook thoroughly (or at all) and often copy answers from the solution manual, which is readily available online. The lack of engagement with the textbook is consistent with other studies such as Sadaghiani et al. (2012).[13]

As described below, the course redesign attempted to address these issues.

2.2 Course redesign overview

The ME 311 course redesign was implemented in stages in order to assess the impact of each element of the redesign on student performance and attitudes. In each quarter, an "experimental" section and a "control" section were taught back-to-back by the same instructor to reduce bias in grading and teaching styles. Although students were not randomly assigned to groups, they were not informed of the instructional format when registering for the course. The interventions are summarized in Table 2 and described in detail in the following sections.

Table 2: Overview of the course redesign

Quarter	Control	Experimental
Fall 2015 **Instructor #1**	n = 36* • Format: Traditional lecture (derivations, concepts, some examples) • Connect: None	n = 34 • Format: Traditional lecture (derivations, concepts, some examples) • Connect: SmartBook only
Winter 2016 **Instructor #2**	n = 31 • Format: Traditional lecture (derivations, concepts, some examples) • Connect: None	n = 30 • Format: Traditional lecture (derivations, concepts, some examples) • Connect: SmartBook only
Spring 2016 **Instructor #1**	n = 34 • Format: Traditional lecture (derivations, concepts, some examples) • Connect: SmartBook & Question Bank • Students were not informed of the existence of video tutorials	n = 35 • Format: Non-traditional lecture (concepts and examples, no derivations) • Connect: SmartBook & Question Bank • Video tutorials of concepts and derivations available as optional review materials

* n = total number of students who participated in a given section. The number of students who participated in a particular assessment may be lower due to absences.

In each quarter, a concept inventory and survey were deployed in the classroom during the first and last week of the course. The concept inventory was developed by the authors and consists of 13-questions that cover important topics in fluid mechanics. Although a much longer fluid mechanics concept inventory (FMCI) has been developed and validated by Martin et al. (2003), deploying the FMCI in class would have required too much time and too few students would have been able to meet outside of class.[14] The short survey also was developed by the authors and consists of questions regarding students' attitudes about the course and mechanical engineering in general. For example, students were instructed to think about the course and indicate the extent to which they felt satisfied, confident, and successful, on 7-point semantic differential scales. Students did not receive course credit for completing the concept inventory and survey.

During Winter 2016 and Spring 2016, focus groups were conducted by undergraduate research assistants outside of the regular meeting time to obtain open-ended feedback. The focus groups took place toward the end of the quarter and students received lunch for their participation, but did not receive course credit.

2.3 Stage I: Implementation of McGraw-Hill's Connect platform (Fall 2015, Winter 2016)

During Fall 2015 and Winter 2016, the SmartBook component of McGraw-Hill's Connect software was implemented in the experimental section while the control section did not have access to the Connect.[15] Connect is a teaching and learning platform that has an interactive textbook component (Smartbook) and algorithmically generated homework problem component (Question Bank). SmartBook periodically prompts students to answer conceptual questions to determine if they have met specific learning objectives in the text. When a student gives an incorrect answer, feedback is provided automatically and students are guided to the section of textbook related to the question. Students were allowed unlimited attempts to answer questions and meet the learning objectives. It was hoped that using SmartBook would enhance student engagement with the textbook and provide immediate feedback, which were two of the key issues with the traditional lecture format identified by the authors.

Both the control and experimental sections in Fall 2015 and Winter 2016 used a traditional lecture format, but the instructors differed for each quarter. Additionally, the number and type of graded assessments differed between the two quarters (Table 3). Given that the race, gender, and perceived country of origin of the instructors are likely to be distinguished as different by the students, and that all three of these factors have been shown to impact student assessment, the authors chose to treat the two quarters separately.[16-19]

Table 3: Weighting of graded assessments for stage I (Fall 2015, Winter 2016)

	Control (no Connect)	Experimental (Connect)
Fall 2015 – Instructor #1		
Homework problems (hardcopy)	5%	5%
SmartBook problems (online)	N/A	5%
Quizzes (4 total)	25%	20%
Midterm exam	30%	30%
Final exam	40%	40%
Winter 2016 – Instructor #2		
Homework problems (hardcopy)	5%	5%
SmartBook problems (online)	N/A	5%
Quizzes (3 total)	51%	45%
Final exam	44%	45%

2.4 Stage II: Incorporation of more example problem (Spring 2016)

During Spring 2016, the use of Connect was expanded to include both Question Bank assignments and SmartBook assignments in both the experimental and control sections. Using Question Bank assignments partially solves the problem of students using the solution manual for homework; students cannot simply copy the solutions since the inputs are algorithmically generated and unique to each student. The Question Bank assignments replaced the hard copy of homework problems that were required in previous quarters.

Table 4: Weighting of graded assessments for stage II (Spring 2016)

	Control (traditional lecture)	Experimental (more example problems)
Spring 2016 – Instructor #1		
Question Bank problems (online)	5%	5%
SmartBook problems (online)	5%	5%
Quizzes (4 total)	20%	20%
Midterm exam	30%	30%
Final exam	40%	40%

The control section was taught in the traditional lecture style and class time consisted of derivations, concepts, example problems, and assessments. However, derivations were removed in the experimental section classroom to create time for additional example problems and in-class discussion. Derivations of key equations were provided in a set of video tutorials created by the authors using the Camtasia Studio software. Each video covers one topic and were as short as possible, which students generally prefer.[9,20,21] The videos were captioned for accessibility and made available to the public at the department's YouTube Channel and video content website, ME Online.[22,23] Links to the videos were provided only to experimental section, but it is unknown if the links were shared with students in the control section.

3.1 Results for stage I, Fall 2015

Student performance on the concept inventory and graded assessments for Fall 2015 are presented in Figures 1 and 2. At the start of the course, the experimental group performed slightly better on the concept inventory, but the difference was not statistically significant. By the end of the course, both sections improved their scores and the difference between the two sections became statistically significant. Throughout the quarter, the experimental section had scored higher on five of six graded assessments, although the difference was statistically significant for Quiz 2 only. This resulted in a repeat rate (D and F) of 38.9% for the control group, but only 23.5% for the experimental group, as shown in Figure 3.

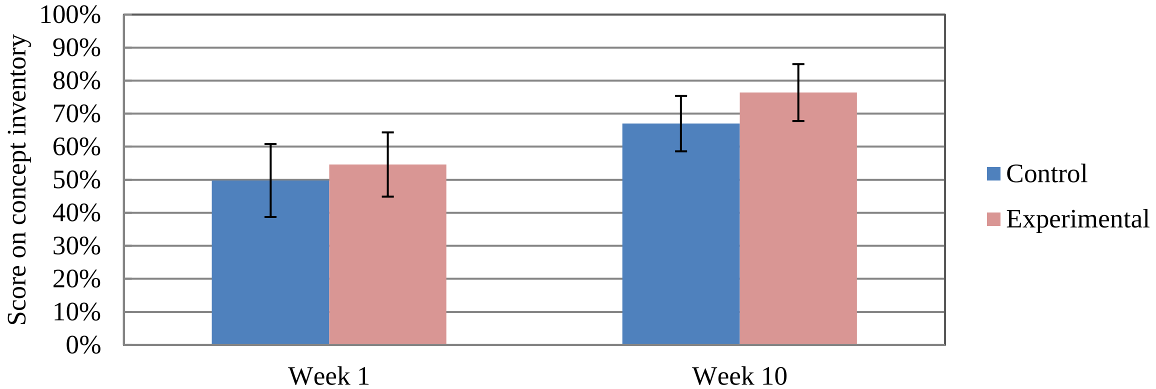

Figure 1: Student performance on a concept inventory for Fall 2015. The bars and whiskers represent the mean scores and 1σ values, respectively. A t-test reveals the difference between the two sections is statistically significant at the 95% confidence level for Week 10 ($p = 0.025$), but not Week 1 ($p = 0.18$). All t-tests were one-tailed for this report, unless otherwise indicated.

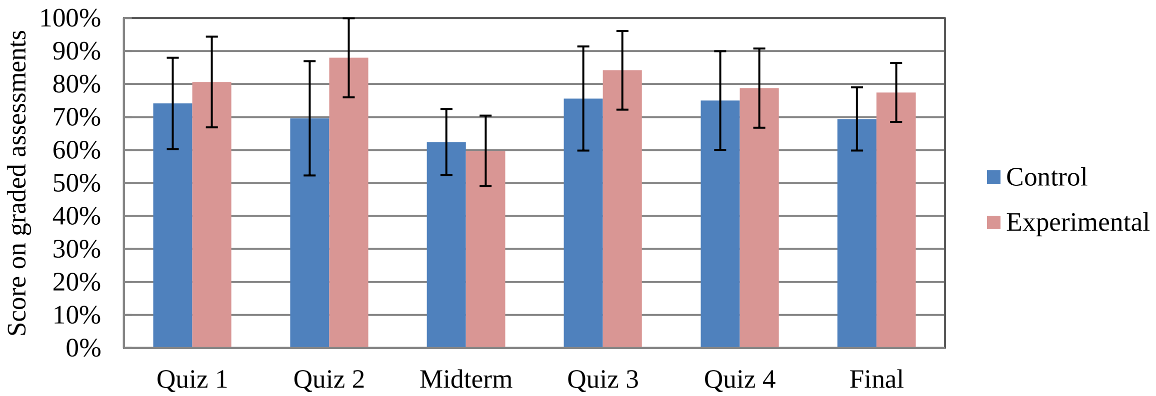

Figure 2: Student performance on quizzes, midterm, and final for Fall 2015. The bars and whiskers represent the mean scores and 1σ values, respectively. The difference between the two sections is statistically significant at the 95% confidence level for Quiz 2 ($p = 0.005$) and final exam ($p = 0.035$).

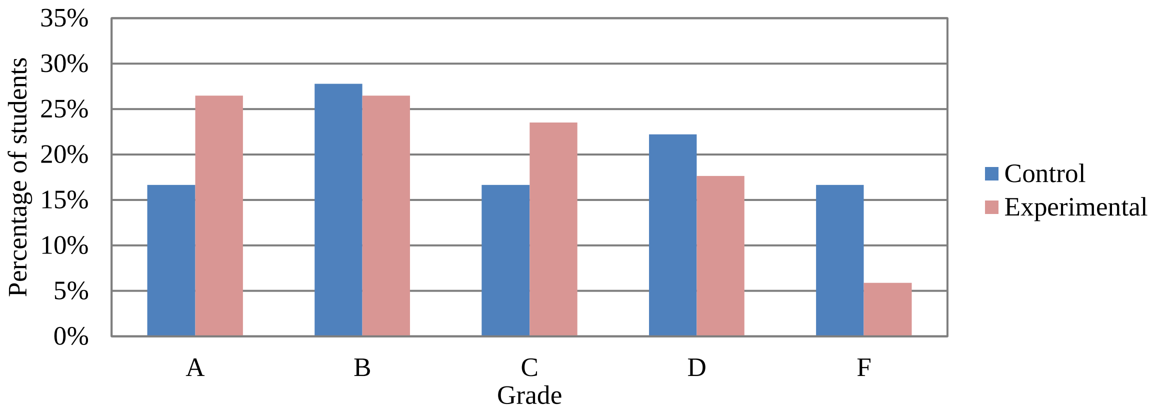

Figure 3: Overall course grades for Fall 2015. The experimental section had a lower rate of D and F scores (23.5%) compared to control section (38.9%).

A regression analysis was conducted to determine whether major, GPA, gender, and section are good predictors of student performance on the midterm exam, final exam, and overall course grade. The analysis shows that being a mechanical engineer and GPA are both predictors of student performance for all three metrics ($p < 0.05$). Class section and gender are predictors of midterm score, but not final exam score nor overall course score when accounting for the other possible predictors. Overall, the fact that class section is a weaker predictor than major and GPA suggest that the use of the SmartBook alone did not have a large impact on student performance.

A t-test analysis of the Week 1 survey revealed that the experimental and control groups did not differ significantly in their attitudes, feelings, and perspectives. The only exception was the control group experienced the course as more friendly ($p = 0.03$). By the end of the course, the experimental group reported feeling more confident in the course ($p = 0.03$), rated the class as less competitive ($p = 0.025$), were more satisfied ($p = 0.045$), and found the course more stimulating ($p = 0.05$) compared to the control group.

3.2 Results for stage I, Winter 2016

Student performance on the concept inventory and graded assessments for Winter 2016 are presented in Figures 4 and 5. Although the control group made slightly higher gains in the concept inventory compared to the experimental group, the difference between the two groups is not statistically significant at the beginning or at the end of the course. Additionally, the difference in performance on all assessments was not statistically significant. However, the experimental section had lower repeat rates (26.7%) compared to the control section (38.7%), as shown in Figure 6.

A regression analysis reveals that GPA is a predictor ($p < 0.05$) of performance on all three quizzes, the final exam, and overall course grade, while being a mechanical engineering major is a predictor only for the final exam. Being in the control section is a weak predictor of performance on Quiz 1. As in Fall 2015, these results suggest the use of SmartBook alone did not have a large impact on student performance. It should be noted that the data did indicate that civil engineers may have been helped by the intervention; among civil engineers, the experimental section scored higher on the final exam (mean = 65%) than the control section (mean = 51%), and the experimental section had a higher overall course score (71%) compared to the control section (58%). However, the sample is too small to definitively establish this given there was less than 16 civil engineering students in each section.

The Week 1 survey revealed that the experimental section felt the course was more stimulating ($p = 0.001$), friendly ($p = 0.001$), and enjoyable ($p < 0.001$), and they felt more confident ($p = 0.04$) compared to the control group. However, the pre-course survey was administered toward the end of Week 1, after students had met with the instructor twice. Thus it is unclear if students in the experimental group provided more positive ratings because of exposure to the class or because they came into the course with a more positive attitude. By the end of the course, the experimental group provided even more positive ratings. Compared to the control group, the experimental group experienced the class as more friendly ($p = 0.002$), satisfying ($p = 0.05$), and enjoyable ($p = 0.005$), and they felt more successful ($p = 0.005$), confident ($p = 0.005$), supported ($p = 0.015$), and hopeful ($p = 0.001$). Additionally, the experimental group valued the class more ($p = 0.01$) and felt that the class was better than most mechanical engineering courses ($p = 0.01$).

The focus groups conducted during Winter 2016 confirmed that students prefer to see more examples and find derivations less interesting. This information helped the authors devise the teaching strategy for Spring 2016 which moved the derivations from the classroom to video tutorials in order to increase class time for example problems.

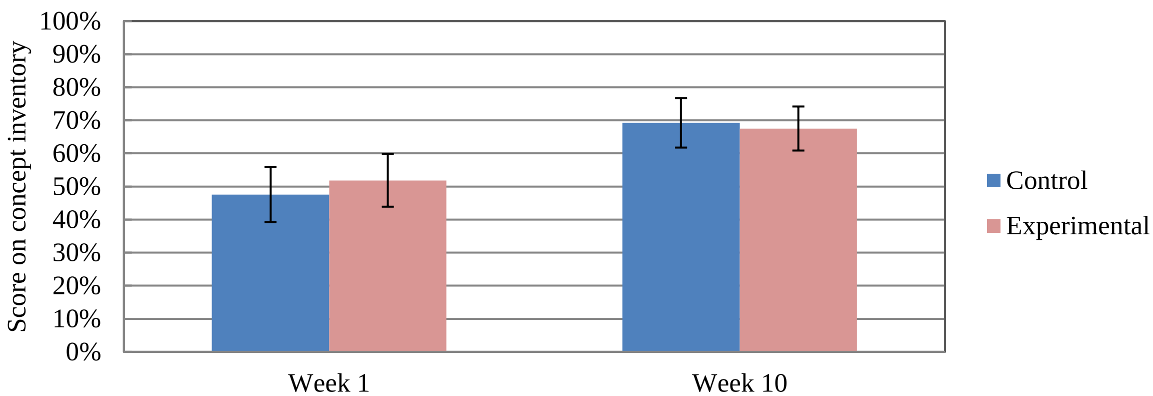

Figure 4: Student performance on a concept inventory for Winter 2016. The bars and whiskers represent the mean scores and 1σ values. A t-test reveals the difference between the two sections is not statistically significant at the 95% confidence level for both Week 1 ($p = 0.17$) and Week 10 ($p = 0.33$).

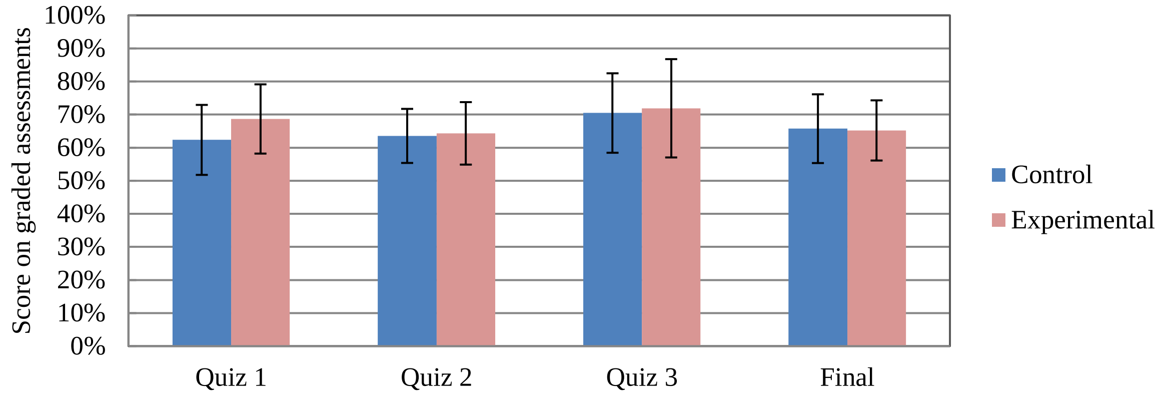

Figure 5: Student performance on quizzes, midterm, and final for Winter 2016. The bars and whiskers represent the mean scores and 1σ values, respectively. For all assessments, a t-test reveals the difference between the two sections is not statistically significant at the 95% confidence level.

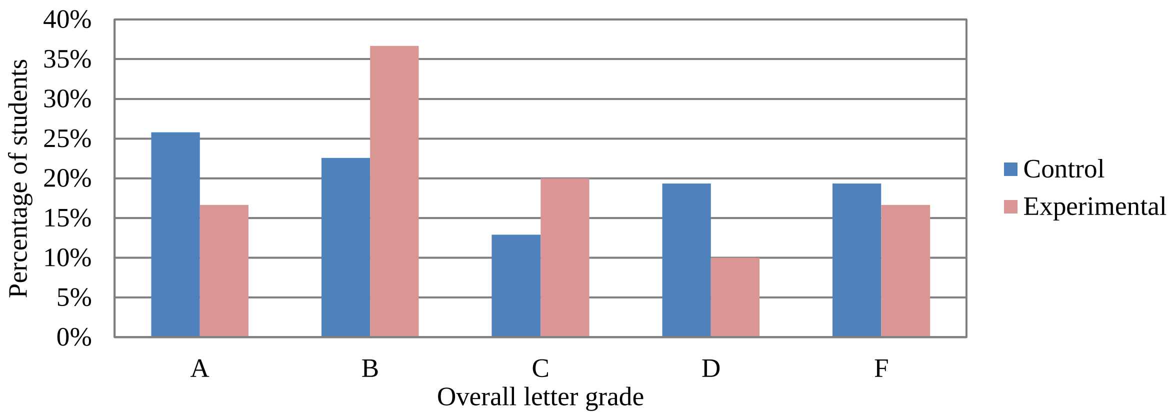

Figure 6: Overall course grades for Winter 2016. The experimental section had a lower rate of D and F scores (26.7%) compared to control section (38.7%).

3.3 Results for stage II, Spring 2016

Student performance on the concept inventory and graded assessments for Spring 2016 are presented in Figures 7 and 8. Although the experimental group made greater gains in the concept inventory compared to the control group, the difference between the two groups is not statistically significant. The experimental section scored higher on all assessments, although the difference was statistically significant for the midterm exam only. This resulted in a large difference in the repeat rate between the control group (44.1%) and experimental group (20.0%), as shown in Figure 9.

Spring 2016 was the only quarter in which both sections were required to complete Connect assignments. As shown in Figure 10, the experimental section performed better on every homework assignment.

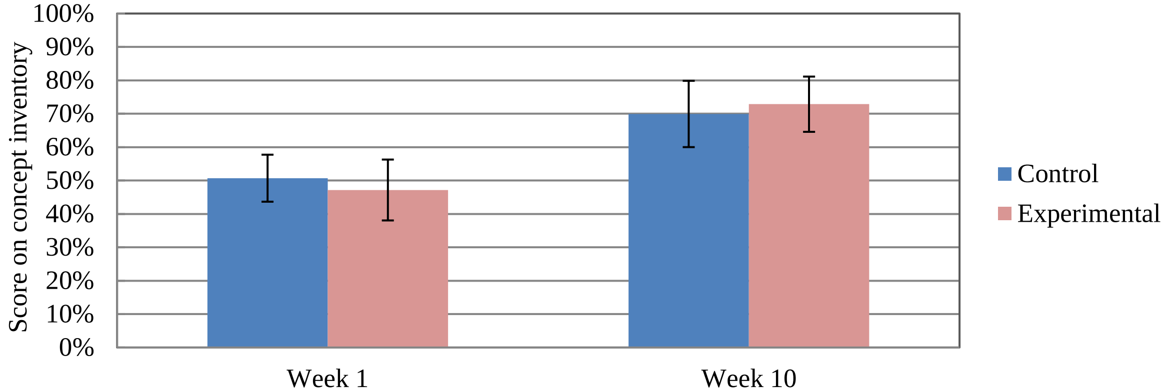

Figure 7: Student performance on a concept inventory for Spring 2016. The bars and whiskers represent the mean scores and 1σ values. A t-test reveals that the difference between the two sections is not statistically significant at the 95% confidence level for both Week 1 ($p = 0.19$) and Week 10 ($p = 0.26$).

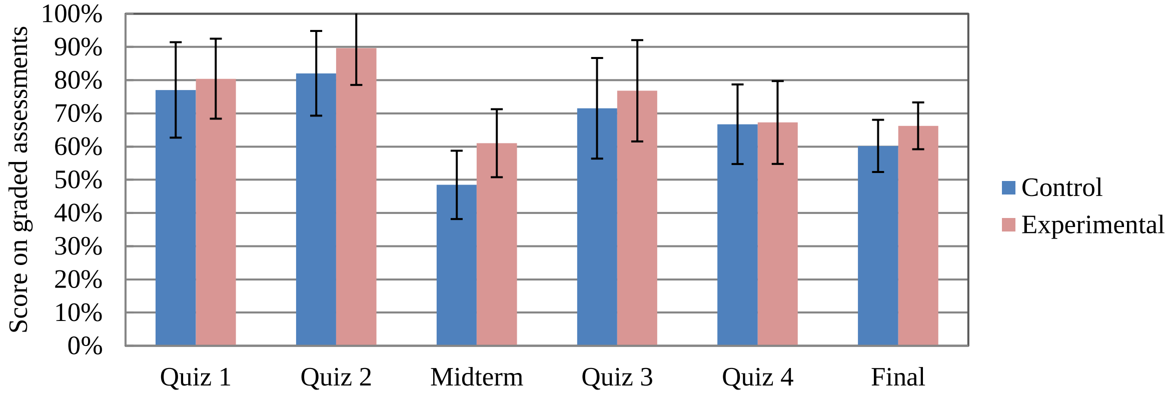

Figure 8: Student performance on quizzes, midterm, and final for Spring 2016. The bars and whiskers represent the mean scores and 1σ values, respectively. A t-test reveals that the difference between the two sections is statistically significant at the 95% confidence level for the midterm ($p = 0.005$) and the final exam ($p = 0.05$)

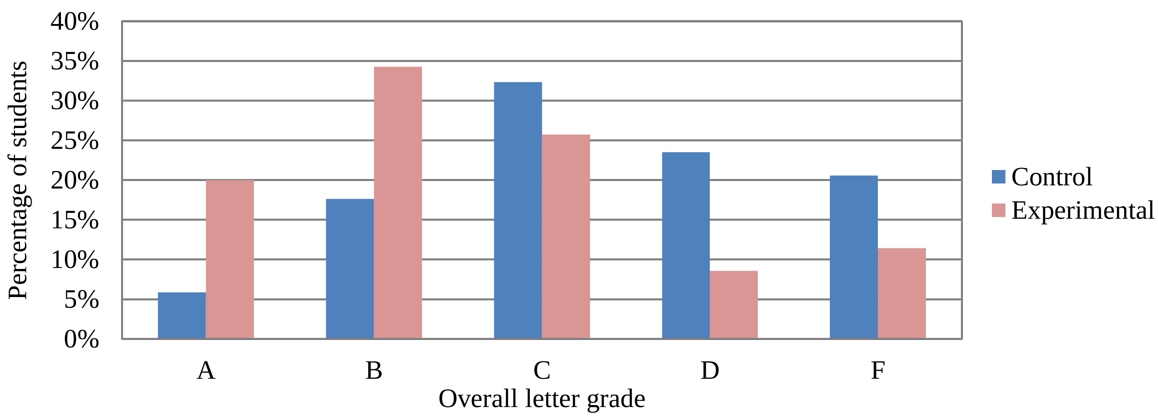

Figure 9: Overall course grades for Spring 2016. The experimental section had a much lower rate of D and F scores (20.0%) compared to the control section (44.1%).

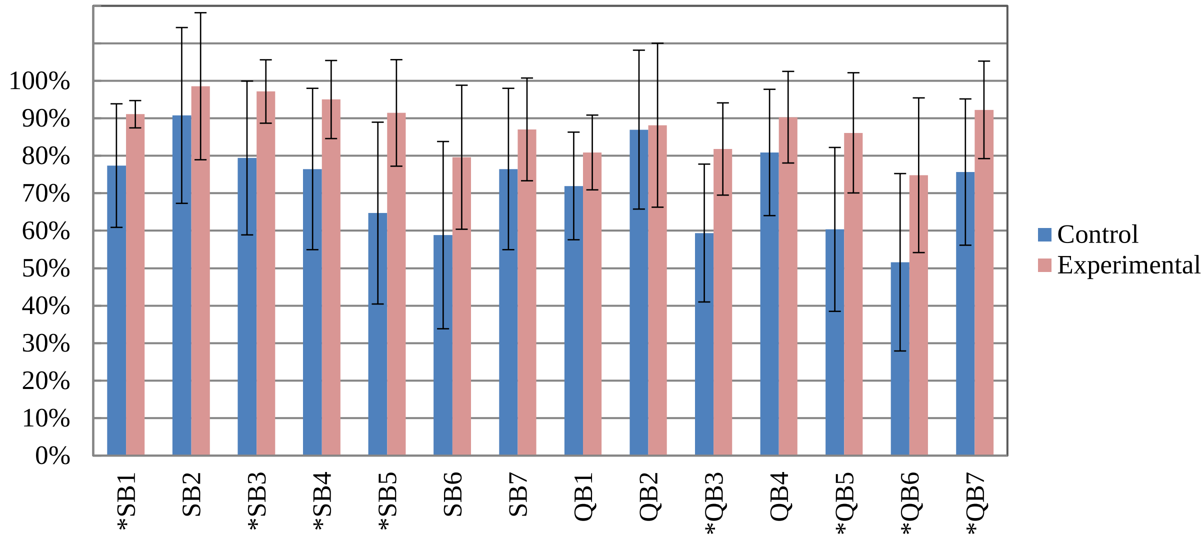

Figure 10: Scores on SmartBook (SB) assignments and Question Bank (QB) assignments for Spring 2016. An asterisk (*) indicates the difference between the two sections is statistically significant ($p < 0.05$) using a t-test.

As in the previous two quarters, the regression analysis shows that GPA is the strongest predictor of student performance on assessments and overall course score – it is positively correlated with the midterm, final, and overall score. Being a mechanical engineering major is a predictor of final exam and overall course score. Interestingly, class section is a predictor of performance on both the midterm and overall course score, which suggests the intervention likely had a significant impact on course performance.

In the Week 1 survey, the experimental group felt more successful ($p = 0.035$) compared to the control group. By Week 10, the experimental group felt the class was more useful ($p = 0.025$) and continued to feel they were more successful ($p = 0.025$) compared to the control group.

The focus groups conducted during Spring 2016 indicate that students liked many of the features of the Connect platform and appreciated guided learning. For example, one student recounted, "When I'm doing [LearnSmart], it shows me which [content] is the important part." This sentiment was echoed with the comment, "Learnsmart kind of helps because it makes you actually go to the concepts and answer questions." However, the cost of using Connect was an issue for some students; during the previous two quarters, access to Connect was paid for by a grant from the Cal State University Course Redesign with Technology Program. Spring quarter was the first time students were required to pay the approximately $100 for access to Connect. Although this cost includes access to the interactive eBook (SmartBook) and online homework system (Question Bank), and is much cheaper than a hardcopy purchased from the bookstore, many students would have preferred to purchase a hard copy of an older edition or obtain a pirated PDF copy online. Some students also noted that one could not recoup any of the cost by selling a textbook later, the platform worked better with a laptop compared to a tablet, and unreliable internet access at home impeded their ability to use Connect. One student stated, "It's nice if it works, but I was having problems … just trying to do the reading. The book just lagged. That was kind of frustrating because if we wanted [a hardcopy], we had to pay extra, but we had already paid [for Connect]." Another noted, "I have a Surface tablet computer. [Connect] doesn't really work with [touch screens] so it’s not really accessible. I usually prefer touch screens and so I don’t really use Connect that often."

3.4 Role of major in overall course grades

Mechanical engineering students generally obtained higher grades than non-mechanical engineering students in both the control and experimental sections for all three quarters. As discussed in Sections 3.1 and 3.3, a regression analysis found that major was a good predictor of overall course score in Fall 2015 and Spring 2016, and section was also a predictor of overall course score in Spring 2016. The difference between sections was much greater in Spring 2016 compared to Fall 2015 as shown in Figures 11 and 12. The reason for this discrepancy between majors is unknown, but it is consistant with anectodal evidence from fluid mechanics instructors in the past.

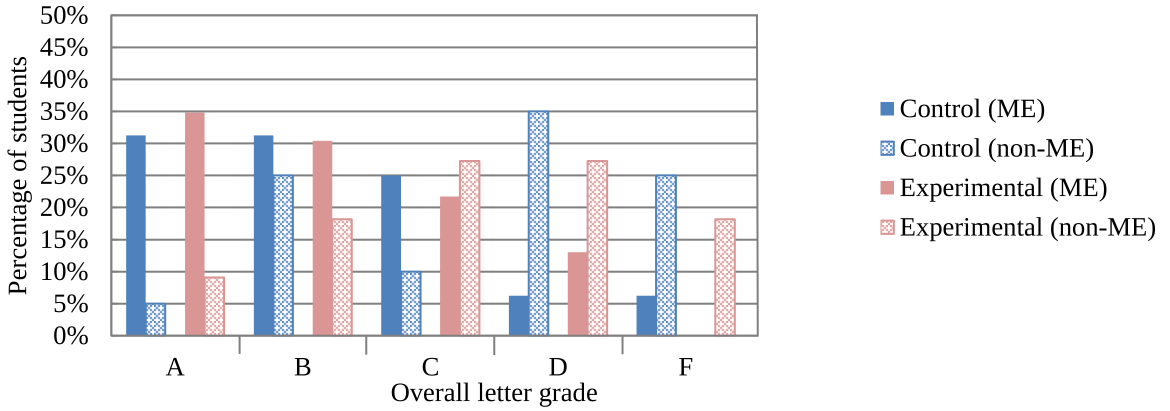

Figure 11: Overall course scores for Fall 2015 separated by section and major. "ME" indicates mechanical engineering students while "non-ME" indicates other engineering students (all civil engineering that quarter). The bars represent the percentage of students in a subgroup receiving a particular letter grade. The number of students in each sub-group are the following: Control (ME) = 16; Control (non-ME) = 20; Experimental (ME) = 23; Experimental (non-ME) = 11.

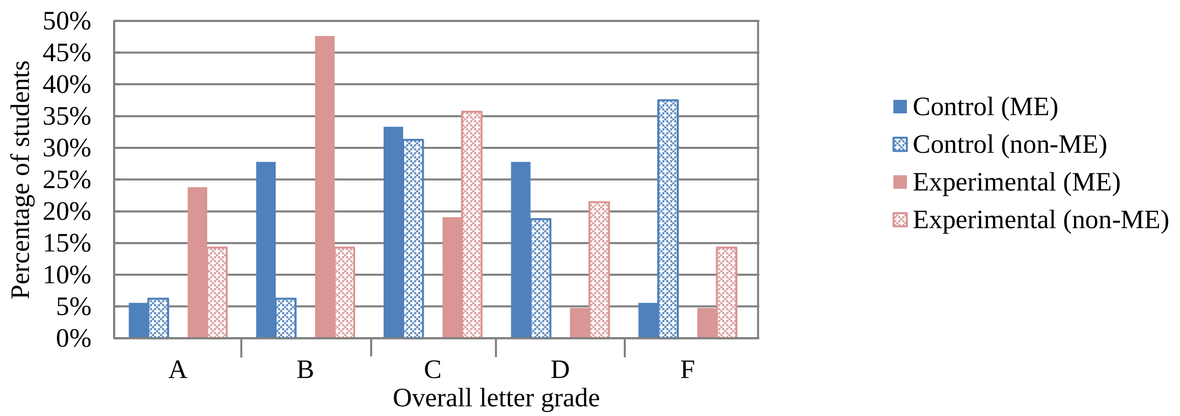

Figure 12: Overall course scores for Spring 2016 separated by section and major. "ME" indicates mechanical engineering students while "non-ME" indicates other engineering students (all civil engineering that quarter). The bars represent the percentage of students in a subgroup receiving a particular letter grade. The number of students in each sub-group are the following: Control (ME) = 18; Control (non-ME) = 16; Experimental (ME) = 21; Experimental (non-ME) = 14.

4. Discussion and future work

In this study, the repeat rate was lowest when Connect was combined with a pedagogy that focuses on in-class examples and discussion of concepts. At the very least, it appears that utilizing an online interactive assessment platform and moving derivations to videos does not pose a great risk to students' academic performance and perceptions of the course. There are a few notable limitations of this study.

- Sample sizes were relatively small, making it difficult to find significant results. This was particularly problematic when trying to look at differences between majors and gender.
- The control and experimental sections took the final exam on different days during finals week in all three quarters. For example, during Fall 2015 the control group took the final exam on a Tuesday while the experimental group took the final exam on a Thursday. The experimental group had more time to study for finals, but it is unclear whether the extra study time was a benefit – taking a final exam later in the week provides more study time, but this time might be utilized for other final exams that occur earlier in the week.
- Since the control and experimental sections met back-to-back in the same classroom, it is possible that information about quizzes and exams was shared. However, the instructors were not aware of this occurring. Additionally, each section received a different final exam for all quarters.

This study is part of an on-going project to completely flip a fluid mechanics course. Based on the positive results obtained during this study, the authors are currently attempting a flipped version of ME 311 during Winter 2017 and Spring 2017. Data will be collected over two quarters to get a larger sample size and surveys will gather new data such as parent education level and ethnicity.

5. Acknowledgments

The authors would like to thank the Cal State University Course Redesign with Technology program for providing funding for this redesign effort. The authors also would like to thank undergraduate student assistants Chantel Ylaya and Sekani Robinson for assisting with the data collection and analysis.

6. References

[1] Felder, R. M. and Brent, R. (2009). Active learning: An introduction. ASQ Higher Education Brief, 2 (4).

[2] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., and Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111, 8410-8415.

[3] Definition from Flipped Learning Network website. Accessed January 2017. Available at: http://flippedlearning.org/Page/1

[4] Bunce, D., E. Flens, and K. Neiles (2010). How long can students pay attention in class? A study of student attention decline using clickers. *Journal of Chemical Education*, 87, 1438-1443.

[5] Bishop, J. and M. Verleger (2013). The flipped classroom: A survey of the research. In *Proceedings of the 2013 Annual Conference of the American Society of Engineering Education*.

[6] Redekopp, M. and G. Ragusa (2013). Evaluating flipped classroom strategies and tools for computer engineering. In *Proceedings of the 2013 Annual Conference of the American Society of Engineering Education*.

[7] Kaw, A. and S. Garapati (2010). Development of digital audiovisual lectures for an engineering course: A YouTube experience. In *Proceedings of the 2010 American Society of Engineering Education Southeast Section Conference*.

[8] Thomas, J. and T. Philpot (2012). An inverted teaching model for a mechanics of materials course. In *Proceedings of the 2012 Annual Conference of the American Society of Engineering Education*.

[9] Zappe, S., R. Leicht, J. Messner, T. Litzinger, H. Lee (2009). "Flipping" the classroom to explore active learning in a large undergraduate course. In *Proceedings of the 2009 Annual Conference of the American Society of Engineering Education*.

[10] Nissenson, P. (2015). Impact of a hybrid format on student performance and perceptions in an introductory computer programming course. In *Proceedings of the 2015 American Society of Engineering Education Pacific Southwest Conference*.

[11] McClelland, C. J. (2013). Flipping a Large-enrollment Fluid Mechanics Course – Is it Effective? In *Proceedings of the 2013 Annual Conference of the American Society of Engineering Education*.

[12] Webster, D. R., Majerich, D. M., and Madden, A. G. (2016). Flippin' fluid mechanics - Comparison using two groups. *Advances in Engineering Education*, 5 (3).

[13] Sadaghiani, H. (2012). Online prelectures: An alternative to textbook reading assignments. *The Physics Teacher*, 50, 301-303

[14] Martin, J., Mitchell, J., & Newell, T. (2003). Development of a concept inventory for fluid mechanics. Presented at the 33rd ASEE/IEEE Frontiers in Education Conference, Boulder, CO.

[15] McGraw-Hill Connect informational website. Available at: http://www.mheducation.com/highered/platforms/connect.html

[16] Kogan, L. R., Schoenfeld-Tacher, R., and P. W. Hellyer (2010). Student evaluations of teaching: perceptions of faculty based on gender, position, and rank. *Teaching in Higher Education*, 15, 623-636.

[17] Smith, B. P. (2007). Student ratings of teaching effectiveness: An analysis of end-of-course faculty evaluations. *College Student Journal*, 41, 788-800.

[18] Subtirelu, N. C. (2015). She does have an accent but…Race and language ideology in students' evaluations of mathematics instructors on RateMyProfessors.com. *Language in Society*, 44, 35-62.

[19] Templeton, K. (2016). Impact of gender on teaching evaluations of faculty: Another example of unconscious bias? *Journal of Women's Health*, 25, 420-421.

[20] Johanes, P., Lagerstrom, L. (2016). Online Videos: What every instructor should know. In *Proceedings of the 2016 Annual Conference of the American Society of Engineering Education*.

[21] Bolliger, D., S. Supanakorn, and C. Boggs (2010). Impact of podcasting on student motivation in the online learning environment. *Computers & Education*, 55, 714-722.

[22] Playlist of video tutorials used in the course are available on the Cal Poly Pomona Mechanical Engineering YouTube Channel (CPPMechEngTutorials). Available at:
https://www.youtube.com/playlist?list=PLZOZfX_TaWAH0baRhA8OosWVbEsJK5sPe

[23] Cal Poly Pomona Mechanical Engineering video content website, ME Online. Available at:
http://www.cpp.edu/meonline