Successful implementation of an online learning environment: Reducing the failure rate in a fluid mechanics course

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Abstract

At many universities, specific bottleneck courses stymie student progress toward graduation. For many engineering majors, Fluid Mechanics (ME 311) is such a course. As a required course for mechanical and civil engineering majors, a repeat rate of 34% created a road block for students and programmatic challenges. To reduce the repeat rate in the course, an interdisciplinary team designed, implemented, and assessed curricular changes in two stages during one academic year (2015-2016). In the present paper, we elaborate on our previous work (Nissenson et al., 2017) by first summarizing our quantitative results and then presenting additional qualitative results that helped us design and evaluate the second stage. In stage I, McGraw-Hill's Connect Online platform, (which included a textbook, assignments, and quizzes), was introduced to an experimental class section, while the control class section was taught in the traditional format in Fall 2015 and repeated by another instructor in Winter 2016. The experimental and control sections were designed to be alike otherwise. In stage II (Spring 2016), the Connect platform was adopted for both the experimental and control sections. In addition, the instructor experimented with creating a more engaging class structure (e.g., more problem-solving time in class and derivations` moved to videos viewed outside of class) in only the experimental section. The department further provided supplemental videos (online video tutorials), available to all majors, as part of a larger effort to use technology to enhance student success. The evaluation plan was developed by an interdisciplinary collaboration of mechanical engineers, psychologists, and sociologists at the university. Student academic performance was measured using concept inventories, exam scores, and overall course grades. Student perceptions of the course emerged through focus groups and were assessed with surveys. The concept inventories and surveys were distributed in the first and last week of the course, and the focus groups were held near the end of the quarter, which generated data about changes in student opinions and understanding of course concepts. Results indicated that the repeat rate, defined as a course grade of D, F, or Withdrawal (D/F/W rate), was lower in the experimental sections than in the control sections all year (23% vs. 39% in fall, 27% vs. 39% in winter, and 20% vs. 44% in spring). There was additional evidence of some success; the experimental section performed better than the control section on some measures such as the final exam during some quarters but the differences were not always significant. During all three quarters, more positive comments and ratings on psycho-social rating scales were provided by students in the experimental sections than the control sections. In focus groups, students provided many positive comments about how the online videos provided an opportunity to pace the course more slowly when needed. The findings from this study indicate that the use of technology combined with a more engaging classroom environment have the potential to improve student performance and student attitudes in an engineering course.

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 repeat rates. Table 1 shows that among the 3,337 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 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
Stage I		
Fall 2015 **Instructor #1**	n = 36* • Format: Traditional lecture (derivations, concepts, some examples) • Online access to recording of class lecture • Connect: None	n = 34 • Format: Traditional lecture (derivations, concepts, some examples) • Online access to recording of class lecture • **Connect: SmartBook**
Winter 2016 **Instructor #2** (Experiment Repeated)	n = 31 Same as previous quarter • Format: Traditional lecture (derivations, concepts, some examples) • Class sessions were not recorded • Connect: None	n = 30 Same as previous quarter • Format: Traditional lecture (derivations, concepts, some examples) • Class sessions were not recorded • **Connect: SmartBook (including problems)**
Stage II		
Spring 2016 **Instructor #1**	n = 34 • Format: Traditional lecture (derivations, concepts, some examples) • Connect: SmartBook & Question Bank problems • Students were not informed of the existence of online video tutorials • Online access to recording of class lecture	n = 35 • Format: **Non-traditional lecture** (concepts and examples, no derivations) • Connect: SmartBook & Question Bank • **Online video tutorials** of concepts and derivations available as optional review materials • Online access to recording of class lecture

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

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, Mitchell, & Newell (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 class 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 1: Implementation of McGraw-Hill's Connect platform (SmartBook) in the experimental section (Fall 2015, Winter 2016)

McGraw-Hill's Connect is a teaching and learning platform that has an interactive online textbook component (SmartBook). During Fall 2015 and Winter 2016, the SmartBook was incorporated in the experimental section while the control section did not have access to the Connect.[15] SmartBook periodically prompts students to answer conceptual questions to determine if they have met specific learning objectives as they read 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 are 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. Connect also provides an algorithmically generated homework problem component (Question Bank), which was not assigned during this stage of the present project (Stage 1).

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 (Spring 2016): Incorporating in-class examples and online video tutorials of derivations in the experimental section (along with SmartBook problems and Question Bank problems in both sections)

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 2 (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. In the experimental section classroom, derivations were removed 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 Camtasia Studio software. Each video covered one topic and was 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 the experimental section, but it is possible that the links were shared with students in the control section.

Both the control and experimental sections had access to a second type of video in Fall 2015 and Spring 2016. Class sessions (approx. one hour in duration) were recorded by the instructor while class was occurring, using the screen-capture software Camtasia Studio. Each recording covered one class session, allowing students to see the instructor's computer screen and hear the instructor's voice (which was captured by a microphone). Students could not see the instructors' face or the class. Each recording was uploaded to YouTube to allow students to easily review the content at their convenience. Both sections had access to these videos. These recordings were incorporated in the course to help students who were absent from class. The Winter 2016 instructor chose not to record class.

2.5 Analysis plan. Course grades were assessed, and t-test analyses and regression analyses were conducted. Also, after focus groups were transcribed, content analysis was conducted to generate themes that describe student perceptions of needs and what students found helpful from the innovation. Analyses are summarized here and described in more detail in a previous report (Nissenson et al., 2017).[24] Additional analyses and discussion are provided.

3. Summary of quantitative results

3.1 Results for Stage I (Fall 2015 and Winter 2016)

In Fall 2015, the repeat rate was higher for the control section than the experimental section as shown in Figure 1.

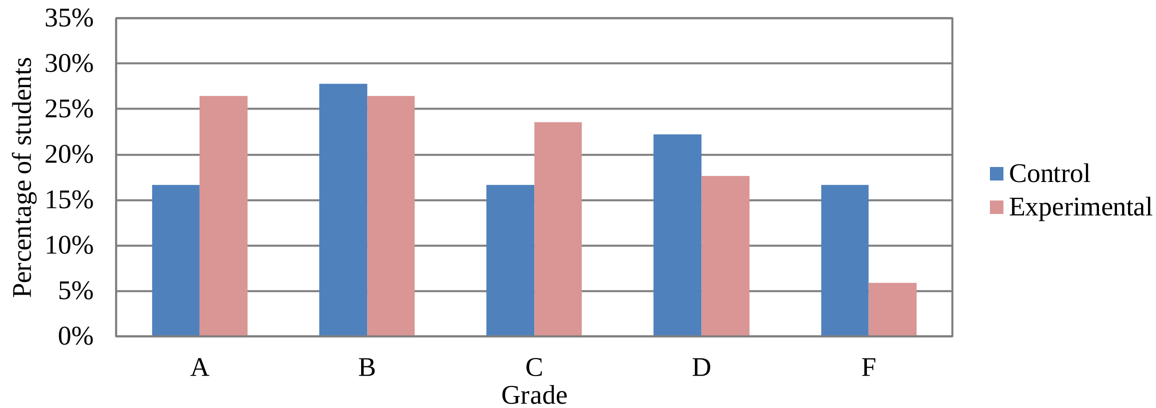

Figure 1: Overall course grades for Fall 2015. The experimental section had a lower rate of D and F scores (23.5%) compared to control section (38.9%).

The final exam score and concept inventory score were statistically significantly higher for the experimental section on average at the end of the quarter (Week 10), according to Student's t-tests. The experimental section reported feeling less competitive, more confident, and more satisfied (in the course), and they found the course more stimulating compared to the control section (t-test, $p <= 0.05$). T-tests indicated that the experimental section did not significantly higher scores than the control section during Week 1, which suggests that these results are not due to the experimental section having greater knowledge or more positive attitudes at the start of the quarter.

In Winter 2016, a second instructor repeated the experiment and had similar success improving the repeat rate. Students reported even more positive attitudes in the experimental section than the control section. As shown in Figure 2, the experimental section had lower repeat rates than the control section.

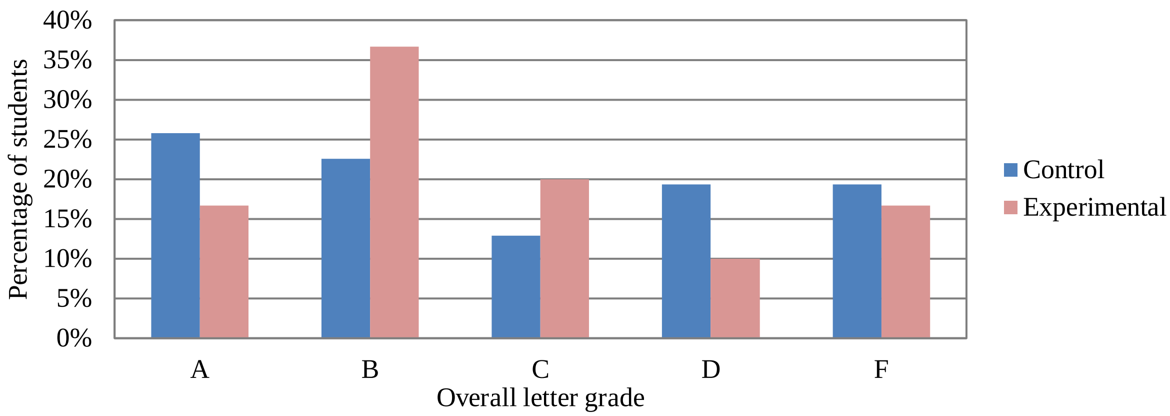

Figure 2: Overall course grades for Winter 2016. The experimental section had a lower rate of D and F scores (26.7%) compared to control section (38.7%).

Unlike the previous quarter (Fall 2015), the experimental section did not have statistically different average scores on most other performance markers (e.g., exams, quizzes, and concept inventory). However, similar to the prior quarter the experimental section was more likely to rate that the class positively. The Winter 2016 experimental section held more positive attitudes in Week 10 than the control section on several variables. They rated their class as more friendly, satisfying, and enjoyable, and they felt more successful, confident, supported, and hopeful than the control section. Additionally, they valued the class more and felt that the class was better than most mechanical engineering courses (t-test, $p <= 0.05$).

3.3 Results for Stage II (Spring 2016)

Figure 3 shows there was a large difference in the repeat rate between the control section and experimental section in Spring 2016.

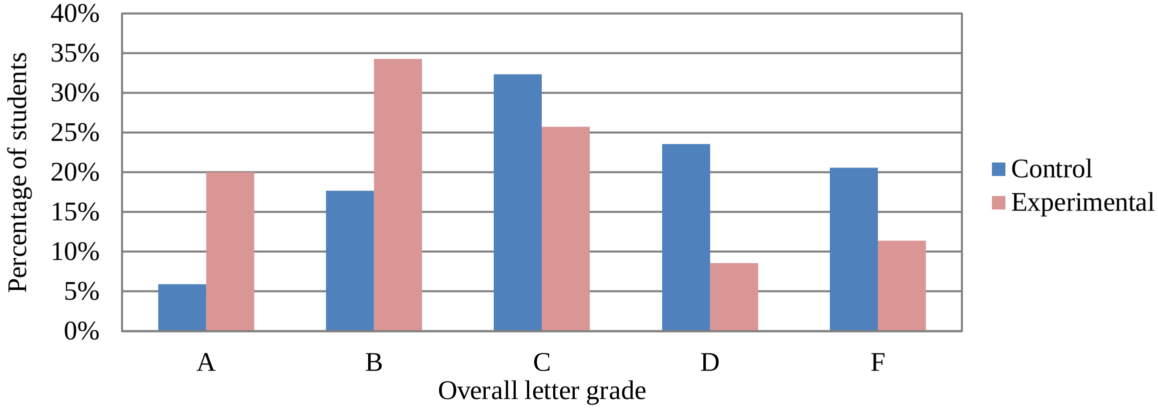

Figure 3: Overall course grades for Spring 2016. The experimental section had a much lower rate of D and F scores (20.0%) compared to the control section (44.1%).

The experimental section scored higher on all assessments (concept inventory, final exam, etc.), although the difference was statistically significant for the midterm exam only. Spring 2016 was the only quarter in which both sections were required to complete Connect assignments. The experimental section performed better on all homework assignments, but the difference was only statistically significant for 4 of the assignments (t-test, $p < 0.05$). In terms of psycho-social ratings, the experimental section showed a few differences with the control group. They felt the class was more useful, and they felt more successful in the class (t-test, $p < 0.05$) than the control section in Week 10. The themes which emerged in the focus groups helped explain and contextualize our findings.

4. Focus groups results and discussion

As expressed by the students in focus groups held during Stage 1 in Winter 2016, anxiety about success and lack of success tended to hinge on two critical issues---the pacing/delivery of material and insufficient time to engage with the instructor about how to solve problems. Fortunately, online innovations appear to be able to address these two critical challenges, as expressed by students in the focus groups in Stage II (Spring 2016). In this section, we discuss these issues and other themes that emerged from the focus groups.

4.1 Challenges with pacing and delivery of material

ME 311 is required for mechanical and some other engineering majors (i.e., civil engineering) at Cal Poly Pomona during 2015-2016. Students often enter with different abilities, goals, and skills. As a result, some students find the class pace challenging. One student complained that they were barely able to "keep up" in the lecture. When lecture is too fast-paced, struggling students indicated that they felt forced to "scribble pages and pages of notes in lecture". In contrast, one student who had already completed a different course with similar concepts said the course pace was too slow. Another student who was re-taking the ME 311 course felt the class pace was very slow, particularly compared to other courses:

> "The pace of the class [lectures are] extremely slow. I… I often joke with roommates that I can probably leave the class for 30 minutes, come back, and we're on the same thing, and I'd be able to write something down. And… I rarely feel out of it [unable to figure out what is going on], whereas I have another hour-long class before this class where I'm just scrambling to get everything into my notes."

Traditional lectures often lack an appropriate pace (too fast or too slow), given that students do not have the same abilities (e.g., weak previous knowledge, slow grasp of new concepts). Instructors are faced with a rather impossible-seeming task to pace in-class delivery appropriately for all students. Students have no control over the pace a professor sets and have minimal control over their note-taking pace in-class as the instructor speaks, leading some students to feel the class is too slow and boring, or too fast and hard, making it difficult for students to pay attention and learn.

Online videos help solve this pacing problem because students are able to pause, re-watch, or skim material at their pace, thereby facilitating student learning, as noted by this student in the Spring 2016 experimental section:

> "Some online videos are… [the same as] our lecture. So, if we write something [take notes in class], and didn't get it [or understand the class material], we review the lectures."

That student implied that he appreciated having access to the two types of instructor-provided types of videos: online video tutorials of derivations (of short duration) and recordings of each class session (of long duration). Other students in the experimental section agreed that they liked having access to both types. One student reported that he felt videos of shorter duration are generally better than videos of longer duration, saying "I like short videos, which make it easier for me to understand the information." Students' other comments suggested that they liked how the online video tutorials (the short videos) were made into small "digestible" parts, which was helpful to them.

Future research is needed to determine what aspects of the videos were most helpful to students. It is possible that shorter videos are helpful because they help students chunk. Previous scholarly work has supported the notion that breaking material down into small chunks is helpful for memory. (Seminal work by Miller (1956) and recent research including Gobet, Lloyd-Kelly, & Lane, 2016 has suggested that short-term memory is limited, and people can recall more if they can combine information into small chunks).[25,26] Perhaps future research will reveal that students benefit from guided chunking[26] as they watch the short videos and benefit from deliberate chunking, as they pause, process, re-organize, and replay lectures in small parts.

Having the extra support of the online videos and the ability to pace them appropriately, combined with extra online support offered by Connect, was useful to students. Students implied that the online videos helped assist them and made the material easier to understand because they could pause and think about the material.

Making the material easier, especially for students who lack a strong background in the content, is supported by Vygotsky's theory (1978),[27] which highlights the importance of level of difficulty. If a task is too hard, learners will not understand much and might feel hopeless and lack confidence. If a task is too easy, the learner will not learn much because they already know what is being taught and they will be bored and not pay attention. When a task is not too hard and not too easy, the learner is in the "magic middle" and the learner is in the zone of proximal development, enabling them to learn the most, according to Vygotsky. This notion may seem rather simple, but it can be difficult for instructors to create materials and tasks that are most appropriate, and it can be difficult for students to find ways to make materials and tasks appropriate for themselves. Universities with students with a wide range of preparedness exacerbates the challenge.

Pacing is one thing that might help. In focus groups, some students felt that when the class was too fast-paced (which sometimes made them feel the class was too hard), they checked out, stopped taking notes, and stopped listening in class. Students seemed to feel dejected, helpless, exhausted, experienced a sense of failure, and the task of paying attention in class and taking notes seemed was too difficult and possibly not worth the effort for them. By contrast, students seemed more calm and had more positive comments when the task seemed appropriate for them, and they gave more positive comments when their task was perceived as not too difficult. Such positive comments were provided more frequently by focus group participants in the experimental section in Spring 2016, who were given access the online video tutorials.

4.2 In-class time for examples with the instructor

Focus groups indicated that the online videos of derivations gave students more time in-class to discuss how to apply concepts to example problems. This was a result of focus groups in Winter 2016, in which students explained they wanted less time spent in class on derivations and more time spent on examples that the professor carefully chooses, as well as more time for questions, in order to improve their success in class. Students liked that the publishers' online program gave them extra problems, but they wanted the examples to be picked by the professor so that the examples would be similar to problems on exams. Specifically, their comments implied that they wanted derivations to be posted online and more examples to be completed in class that are chosen by the instructor.

> "He [the instructor] spends 30-40 minutes [of each class] going over derivations and...it's like…I really don't care about the derivations that much. I want to see an example of how the actual formula is used in an example problem. [Also, more carefully chosen examples are needed]. He doesn't hand pick his examples. Every professor I get is different, and it [the publisher's online program] is supposed to give you the best array of problems that, you know, you might see [on an exam or in the profession]."

4.3. Intrapersonal factors (motivation, expectation for success)

Research demonstrates a link between motivation, expectations for success and the supportiveness of the learning environment.[28] For students who believe that they can be successful, research has demonstrated a link between a supportive environment and student response, such that students in less supportive environments tend toward defiance, whereas, students in more supportive environments tend toward motivation.[29] These observations were mirrored in our focus group results. Students who expected to succeed expressed greater interest in the course and saw greater value in (and expressed more motivation to use) course resources. One student described the course as being "worth it" despite "difficult moments."

In addition, anxiety about success in a class is negatively tied to course performance primarily because it decreases effort and engagement.[30] In our project, students in the control section expressed frustration and concern at the disconnect between coursework and exam content, during Spring 2016 focus groups. This concern centered around the ability to succeed on assessments. Students consistently reported that access to more resources, especially those that allowed them to work at their own pace, were valued and increased perceptions of their ability to succeed.

Moreover, students who believe they are more likely to succeed are more likely to be engaged in the course, as perceptions of competency and success are tied to views about self and expectations for success.[31,32] Our data demonstrates that students who experienced our innovations (in the experimental section) were more confident of their ability to succeed in the course, and they felt more satisfied or successful in the course in most quarters, when compared to students in the control section at the end but not the start of the quarter. In addition, students in the Spring 2016 experimental section rated the class as more useful, when compared to the control section ($p = 0.05$), and perceptions of utility are explicitly linked to motivation (Jones et al, 2013).[31]

That perception further impacted attitudes toward the use of Connect. Students expressed feeling "disheartened" and noted a "disconnect between homework and quizzes," and wanted "less time spent on equations and derivations." Students connecting course content to success in the course and the field tend to show more engagement in and motivation for success in courses and programs.[33]

4.4 Improving motivation and success.

Student comments in focus groups informed the next steps as we continued this project in the following academic year (2017-2018). We completed additional iterations (experimenting with the online innovations and flipped class format), which we found to be the most impactful way of teaching ME 311 course and directly addressed student concerns.[34] We addressed students' suggestions to improve motivation through competition and games[35] and through peer groups working together in class. Specifically, the 2017-2018 version of the class features a competitive "Team Battle" that challenges students to solve problems collaboratively for small rewards. Group activities have been found to enhance motivation among female students in engineering, a drastically under-represented group and a group that feels less confident.[36-37]

4.5 Social justice

Students' comments reminded us that online access can also be a social justice issue. "I cannot always make it to class, which is really frustrating, you know. It's very bad for my grades when I can't make it to class," said one focus group participant in Spring 2016, who appreciated being able to watch the videos online after class. Multiple people agreed that they appreciated that they could access material online if they missed class. For working students, students facing personal challenges, or students with children or other dependents, being able to control the time and location of watching the online video lectures (e.g., at a time that worked for them at home), facilitates success. Some students noted that they work many hours at jobs and other commitments, and their necessary employment sometimes conflicted with attending class. Even when they knew that class absences hurt them, they still felt they had no other options but to miss class sometimes.

5. Further discussion: Summary, limitations, and future direction

In this study, the repeat rate was lowest in Spring 2016, when Connect was combined with a pedagogy that focuses on in-class examples and discussion of concepts rather than in-class lectures on derivations (which can seem irrelevant and boring to students). Students provided comments that suggest they appreciated the online videos and having more time in class with others to do problem-solving. At the 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 course perceptions. Online videos did not replace lectures or students' desire for instructor contact.

It is unclear why the Spring 2016 control section had a rather high repeat rate, given that they had access to publisher-provided online resources and access to recordings of in-class lectures. Future research is needed to overcome the limitations of this study. 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.
- In Spring 2016, there were more civil engineering students in the control section than the experimental section, and civil engineering students tend to do worse in the course. Regression analyses indicated that academic major was a predictor of student performance in our previous report (Nissenson et al, 2017).[24] We plan to adjust for 'major' in future work.

The development of the online videos has been helpful to reduce student repeat rates, but guidance by instructors in class is still useful and valued. Based on the positive results obtained in this project, the authors have continued to innovate and disseminate innovations to new instructors. Data is being collected and analyzed to determine what factors facilitate or hinder another instructor from successfully adopting the innovations in this project and to determine the impact of this project on student retention, long term performance, and attitudes toward their experience in the program.

6. 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 assistant Chantel Ylaya for assisting with the data collection and analysis. For more information, please email Jfuqua@cpp.edu.

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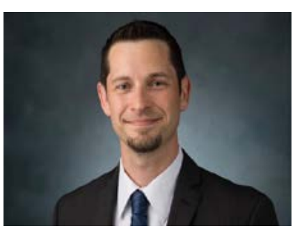

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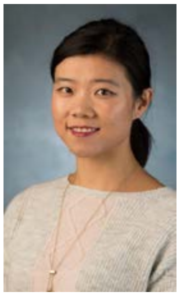

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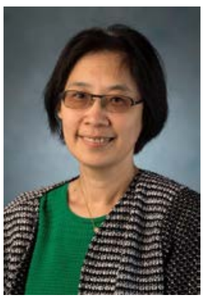

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