



Developing and Implementing Effective Instructional Stratgems in STEM

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Stratagems in STEM

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Abstract

A student passage rate from 65% to above 90% requires student grade improvement of two-sigma. The different components of active learning techniques and the percentage of their additive standard deviations were considered over the past four semesters in an “Introduction to Circuit Analysis” course at San José State University (SJSU) to achieve such a result. A blended model of learning by merging content from an online MOOC with in-class, team-based instruction as part of a required undergraduate circuit theory course was implemented in the Fall 2012 semester and is ongoing at our university. The central objective of this pilot was to examine how adaptation and later adoption of the new MIT edX 6.002x (Electronics and Circuits) MOOC content in a flipped model of teaching might improve student learning in a credit-bearing college course. Multiple objectives for this pilot included: to improve the department’s typical passage rate of 59% for this course; to improve students’ retention rate; to shorten students’ time-to-degree; to improve the quality of the content of the course; and to reduce the prerequisite contribution for successful passage of subsequent courses. Student pass rates from the blended learning model Fall 2012 pilot jumped to 91%, as compared to a 59% passage rate from the previous year’s traditional face-to face lecture class. Fall semester 2012 flipped classroom instruction was augmented with enhanced content and problem-based learning in Spring 2013, resulting in a passage rate of 87%, while the content of the course nearly doubled. For Fall 2013, an in-class laboratory segment using National Instruments myDAQ was added to the Spring 2013 version of the course to include the hands-on approach. The passage rate of 91% was achieved. It appears that adaptation of high quality MOOC content using a blended approach in conjunction with a highly structured, in-class team-based, problem-based and hands-on approach can produce significant benefits in effectively improving student learning and success. This study provides stratagem with different components for faculty to select from, which allows them to achieve the 2 sigma improvement in their students’ grades.

Introduction

Striving for enriched content and better and more effective instructional delivery models are sincere desires of every faculty member. The advent of Massive Online Open Courses (MOOCs) has opened new possibilities. One of the innovative ways of utilizing MOOCs, especially for challenging subjects and more challenging courses, is as a “flipped classroom”. These new delivery models can enhance student engagement, improve student retention, and reduce significantly student failure rate. This is even more critical today with millennial students, because keeping their attention for a traditional 50 to 75 minutes in the lecture hall and having them listen passively to their lecturer is not realistic.

Currently in the U.S. only six percent of the 24-year-olds attain a first degree in a Science, Technology, Engineering, and Mathematics (STEM) field. The U.S. is ranked in the bottom

quartile, (20th out of 24) among comparative nations. Unless we find new breakthroughs to significantly improve the success of students, especially in gateway courses, we will not be able to increase the number of STEM graduates that are needed to maintain our economic vibrancy. Our experiment at SJSU bears a lot of hope as an effective approach that can enhance the success of engineering students in a major gateway course.

The emergence of Massive Open Online Courses (MOOCs) received significant media attention¹. Recently more than four million people around the world have enrolled² in these free online courses and numbers are increasing daily. At SJSU there has been a traditionally low passage rate for “Introduction to Circuit Analysis” (EE098). Students learn the laws of circuits, and it is a foundational course for any engineering major. The course is dubbed a “core course,” meaning that it is necessary to complete a student’s degree in any of the engineering majors. Repeating students prolong their time-to-degree by at least one semester, and multiple repeaters are vulnerable to lose interest in engineering and drop the major. Rather than chalking up the class as a trial by fire that weeds out students unfit for continuing in the field or compromise the academic integrity of the course, lower the bar, and artificially increase passage rates, we chose to look internally and examine why the failure rate was high and what we could do to ensure students’ passing, while keeping our commitment to academic excellence.

Achieving this posed some significant challenges.

First, the course prerequisites for EE098 are high school Advanced Placement physics and calculus or their university equivalent. This can be problematic because learning objectives can differ significantly from class to class, especially across different learning institutions. The consequence is that students have varying levels of knowledge in the necessary prerequisites for the class. In some cases, professors are forced to cover material that students were already expected to know, not leaving enough time to adequately cover the breadth of the course. As this course is foundational, inadequate coverage bleeds into all the follow-up courses causing a domino effect.

A different way to think about this question is “How do we marginalize the prerequisite contribution to success?”

The second challenge is institutional and speaks to the very manner in which academia approaches teaching. The challenge is ensuring that students complete the reading and attend the lectures. This issue is not unique to EE098 and many educators struggle with finding solutions to this concern. Unfortunately, it is often unrealistic to test everything that is taught in class, and rigorous testing as a means of oversight often fails. Student success depends not only on attending the lecture but being focused during it. Students have approximately a ten-minute attention span during a traditional lecture^{3,4}. The realities of paying for college and burgeoning educational debt⁵ necessitate many students’ needs for a job during the semester. Having to retake a class costs money and only exacerbates the problem. Students who work jobs while going to school often can’t pay attention because they are tired, they don’t understand the

lecture, and they do poorly on the tests. Our method helps negate extra office hours, and is a more efficient use of time. It is simply not working for students to perform poorly on tests and fail the class, have to pay for the class again, incur more debt, and still have to work while being a student.

In a time where nearly all information is available at our fingertips with a push of a button over the Internet, the viability and efficacy of our systems should be questioned. We must ask ourselves: Do traditional lectures work? How do we adapt our teaching methodology to the realities of the Internet age? Can we still use lectures to better serve students?

The importance of making sure the students complete the reading and lectures is exacerbated because of the foundational element of EE098. A weak understanding of the principles taught in the class puts students in a disadvantage and sets them up for failure in subsequent classes where EE098 is a prerequisite.

These problems highlight why it is critical for students not only to pass EE098, but do so with a strong understanding of all the key concepts. The question remains of what techniques educators can employ in order to achieve these goals.

Blended flipped classroom and team-based learning

Blended learning model integrates a combination of the traditional face-to-face classroom instruction with virtual, online activities. The flipped classroom is a form of blended learning that utilizes the online component to dedicate more time to teacher interaction in the classroom, rather than so much lecturing. We chose to use a flipped classroom approach with online lectures for students to watch. Online lectures by themselves have had some success in increasing student performance in class⁶. When thoughtfully integrated with the rich dynamic of fast-paced, spontaneous verbal communications in a face-to-face learning environment, the educational possibilities are multiplied⁷. Flipped classrooms have the convenience of online lectures and the benefit of face-to-face activities.

But we need more. In order to have dynamic students capable of using what they learn in real world situations, we have chosen to integrate team based learning concepts to the flipped classroom model. No two blended learning models are the same. We decided team-based learning principles were a necessary and unique ingredient to our blended learning design. Team-based learning attempts to form a cohesive learning team with the ultimate goal of having the students achieve a deep and practical understanding of the subject matter, which might be impossible through individual study. Team-based learning engages the students in course content at the applied level, as they will face material on the Web, motivated both by task design as well as incentive instructions. We identified four necessary ingredients to maximize student performance during face-to-face classroom time: stable and properly managed groups, better student accountability, frequent and timely feedback, and detailed assignment design. Face-to-face classroom time must be carefully tailored to utilize all these ingredients.

With this merged flipped classroom team-based learning model students can be introduced to real-world interaction and accomplishment.

Alternatively, we tried problem solving based learning in the Spring 2013 semester by giving students thirty team quizzes and thirty individual quizzes. Two traditional face-to-face sections with 39 students and 49 students respectively were scheduled. One section of the blended learning class EE 098-MIT6.002x of 80 students was offered. For better controlled results, a final exam was created and graded by a faculty member who was not teaching the course. The face-to-face class covered the traditional EE098 SJSU curriculum (shown in the smaller white circle) while the blended class covered the MIT curriculum (shown in white and gray circles) which included nonlinear devices, diodes, MOSFET transistors, both large and small signal analysis, digital gates and signal integrity as shown in Figure 1.

The passage rate was 93% between the students that participated in on cloud and in class activities and took the finals. Six students out of 80 students withdrew or did not participate in class or on cloud activities.

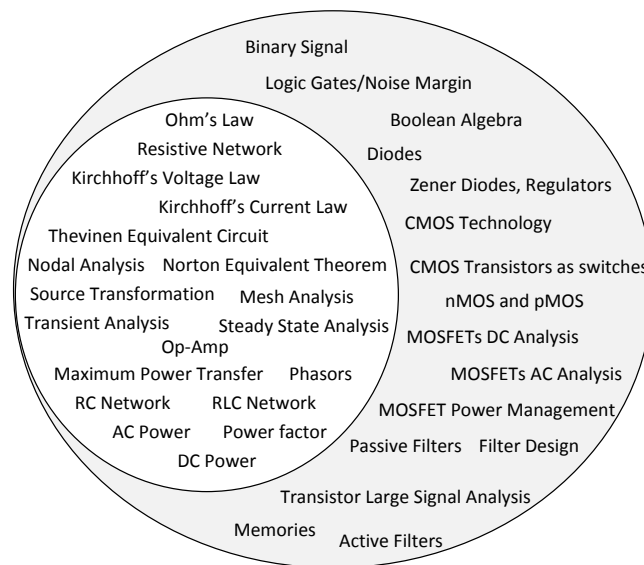


Figure 1. The blended model of learning, EE098-MIT6.002x and the EE098,face-to-face SJSU curriculum contents.

The student common final exam was based only on the face-to-face syllabus. The common final was given to all three sections of EE098 on the same day and same time. The results of the flipped class were slightly better than mean of two traditional classes. The effect of the class prerequisites and prior GPA of students had no effect on the outcome.

We used the edX studio dashboard to track students' clickstream data as they access Web instructional materials. This tool is used to assess students' behavior, study habits, and evaluate their performance in the course. The contribution of different course modules and their statistical regularity of watching the videos and its pattern in success rate will be analyzed in forthcoming

studies. We are interested to find critical factors (human, organizational, behavioral, and resource) that affect student success.[84-86] The faculty of the blended learning model also taught the immediate follow-up class “Circuits and Systems” EE 110 to get some insight on the student retention rate. This topic will be the subject of the future research; however, preliminary observations indicate that the students who participated in the blended learning course sections immediately formed teams in the face-to-face EE110 class. Therefore, they took the initiative to carry on the study habit they acquired in EE098-MIT6.002x flipped classroom.

In Fall 2013, two sections of EE098 of 87 and 85 students were flipped and one section was kept in the traditional face-to-face format. One of the flipped sections was kept in the same format of Spring 2013 blended-model of learning as a control and the second flipped class was augmented with the National Instruments myDAQ hands-on experiment in the classroom. The passing rate was 91%.

In Spring 2014, one of the two sections of the EE098 with 89 students is being offered in flipped format and one in traditional form.

Class Design

The class was divided into two distinct sections, an on-cloud e-learning component and face-to-face brick classroom instruction. Throughout both components of the class strategies were utilized to serve as safety net to ensure student learning.

e-learning on cloud

The e-learning on cloud portion of the course is based on MIT6.002x, which is an online course developed by professor Anant Agrawal at the Massachusetts Institute of Technology for their electrical engineering department. The e-learning component consists of four intertwined modules with rich content and appealing presentation style.

Video lecture

The students are required to watch an online lecture that pedagogically introduces the basics and fundamentals of circuit theory from physical phenomena to abstraction, and back to physical phenomena application. The lectures are designed as modular, interwoven video snippets consisting of a series of short lectures from 30 seconds to 10 minutes each explaining a key concept of the course. The videos are presented in “khan style” with a Power Point presentation in the background with the slide being annotated in real time⁸. The lecture is transcribed on the right hand side of the screen and highlighted by lecture flow.

Having the video lectures simply be online reiterations of classroom-based lectures defeats the purpose of flipping the classroom and negates the advantages having online material offers. MIT6.002x courseware gives students the ability to control the tempo of the lecture with a pause and continue function, as well as the ability to change the speed of the lecture to their convenience. The short videos and added functions of the courseware are a unique aspect of

online lectures. This online lecture experience combats the attention span problem described previously because students are no longer confined to learning at a predetermined pace while sitting in a lecture hall.

The added benefit of both seeing and hearing material reinforces concepts. This ensures that students maximize their learning potential while watching lectures.

Although the snippet format of the lectures and khan style of presentation are infeasible in a traditional lecture setting, the flipped classroom model allows faculty to employ these methods and combat the deficiencies in traditional face-to-face to lectures.

There are numerous other features of the e-learning component to the course, which reinforce the principles of flipped classrooms to ensure that students are adequately prepared for the in-class portion of the course. For instance, there is a problem-set section in the courseware. An application problem is carefully chosen to cover fundamental principles reviewed in the lectures. Students enter answers to the problems online and are rewarded with an explanation and methodology to the correct answer. Completion of the “Problem Set” solidifies understanding of the materials covered in the course.

Lecture retention and practical understanding of the concepts is further solidified with a unique “Discussion” section focusing on problem solving techniques. A problem is presented that corresponds to the lecture the student just watched. Two of the faculty then argue alternative ways to solve the problem; they ultimately reach the same solution, but in different ways. This exposes students to alternative methodologies to approach problems and allows students to choose the approach they feel most comfortable with.

Finally, there is a “Virtual Laboratory” where students can place virtual components together by dragging components from a parts bin onto a gridded screen. Students can create circuits with different functionalities and observe their behavior by creating a simulation. This process gives students a practical understanding of how circuits work and takes the theoretical and grounds it in real life application.

Live Portion Brick Classroom

Budgeting the invested student and faculty time in classroom and proportionating it appropriately to achieve desired objectives was an important step. A system of intervention that catches students that need help at the early stages of the course and provides the help needed (i.e., the safety net) and properly managed groups are needed to foster student accountability, frequent and timely feedback, and detailed assignment design. Face-to-face classroom time was carefully tailored to utilize all these ingredients.

In the live portion of the class, students are placed in predetermined groups for the duration of the course to form cohesive learning teams. This feat can only be accomplished with time, allowing students to become comfortable with each other and develop a self-managed and effective learning unit. The faculty takes great pains to foster this growth and help manage these teams throughout the semester.

The live portion of the class necessitates the utmost faculty preparation and organization. In the first ten minutes of the class, a question and answer discussion is held reflecting the material covered in e-learning to gauge the level of understanding of the students. Concurrently, the teacher assistants gather e-learning surveys that the students filled out after watching the online lectures. The results are quickly compiled identifying common difficulties for the faculty to address. A 15-minute formal lecture based on the results of the survey clarifies in depth the troublesome concepts.

After the lecture, a group quiz is administered. The group quiz is designed to spark class discussion and enhance students' collaborative critical thinking. During this period the students polish their verbal and written communication skills and develop the spirit of team work. The objective of this period is to activate students as instructional resources for one another. Students are exposed to different ideas and approaches and develop interpersonal team interaction skills. The faculty and teacher assistants act as facilitators during this period to ensure students are staying on track.

The solution is then provided for the students, they have immediate feedback on their work. Frequent and immediate feedback has been shown to enhance learning⁹. This feedback reinforces key concepts, and coupled with a team learning experience should increase retention rates. Another advantage of providing immediate feedback for the students is that it encourages team building by student interaction.

Finally, an individual quiz is administered to evaluate the technical skill and performance of the student on his or her own merits and identify areas of weakness and success. Shortcomings are overcome by tailor-made material that is presented at the correct time to meet student learning needs and tests to be done outside of the classroom. This approach combats the earlier identified problem of varying background knowledge (based on the variance between institutions on the course prerequisites) before taking the course. By having customized content developed to address students' weaknesses, the prerequisite's contribution to success can be mitigated. The Figure 2 shows the on-cloud-class components and in-brick-class components. Essentially, students watch videos and do online exercises and labs before coming into class. In the class, they engage in active learning.

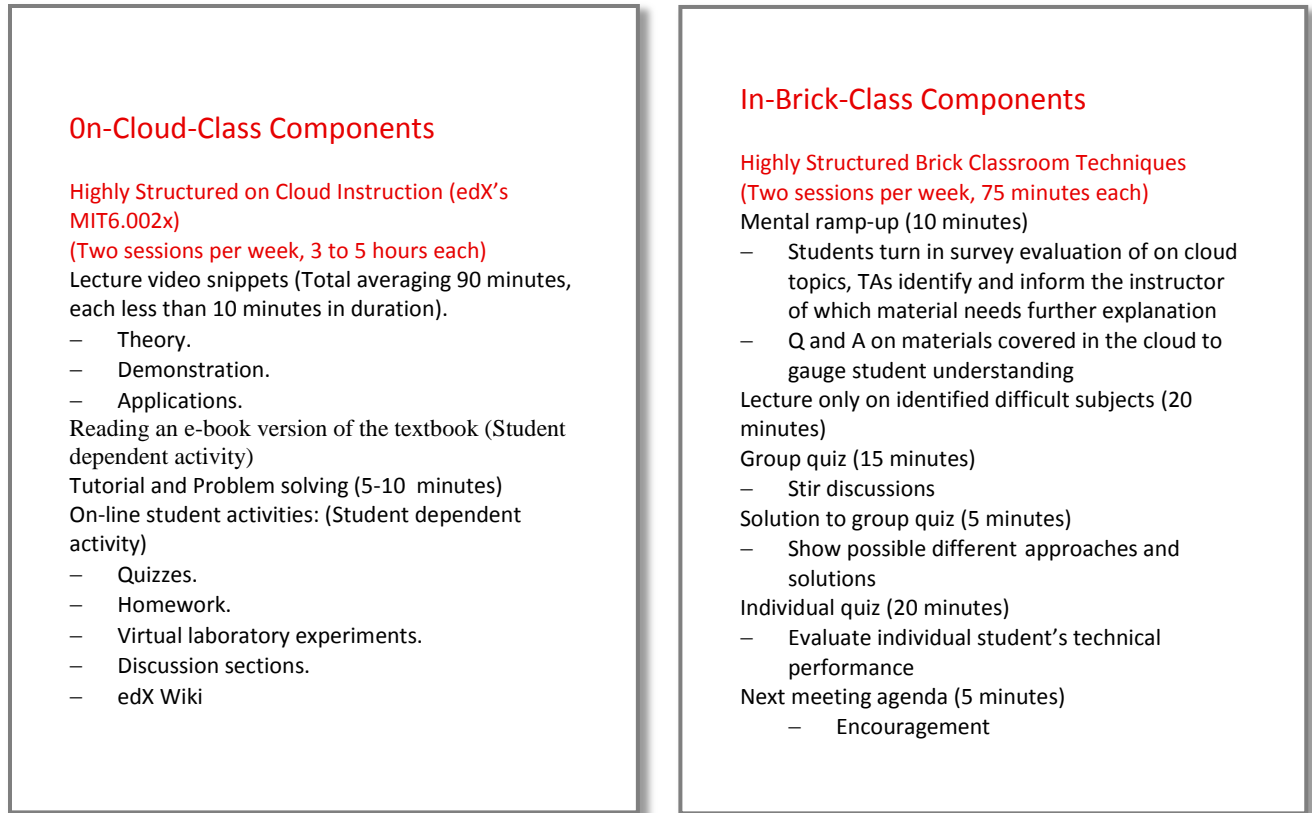


Figure 2. In-brick-class and on-cloud class components of the blended model of learning.

The combination of a flipped classroom merged with team-based learning demands a lot from both students and teachers.

First, for faculty the workload is significantly increased due to the personal attention needed for student scaffolding. The faculty is called upon to make a more personal investment in individualized instruction in this blended model of learning. Second, Faculty should be more vigilant when encouraging student to access online resources, which poses a problem due to the abundance of unedited information on the web. Third, Faculty placing his or her lectures online is no longer lecturing a limited captive audience, but is rather placing the course content for constant public review.

For students, extra work, focus on task, on time delivery, and constant testing can be cumbersome at first, until they see the results.

Results

The first midterm exam in Fall 2012 was coordinated very closely with the previous semester's face-to-face instructor for comparison purposes. The results were encouraging. The entire blended class performed 11 points higher when compared to the average of the face-to-face traditional class sections. The standard deviation was lower by 5 points. Most interesting was the

disappearance of the lower tail of Gaussian curve. Not only was the entire class grades higher but also the poor performers in the class had done better. These encouraging results occurred even during a phase of student resistance to the blended model.

Sharing the results of their first exam and comparing them with the previous semester first exam brought a new phase of enthusiasm to the students. The results of the second midterm coordinated exam are shown in Figure 2. Again the results are encouraging. There was a clear 10-point advantage by the blended model class as compared to the face-to-face class. The results of the first and second midterms of the blended-mode class as compared with the three other sections are shown in Figure 3.

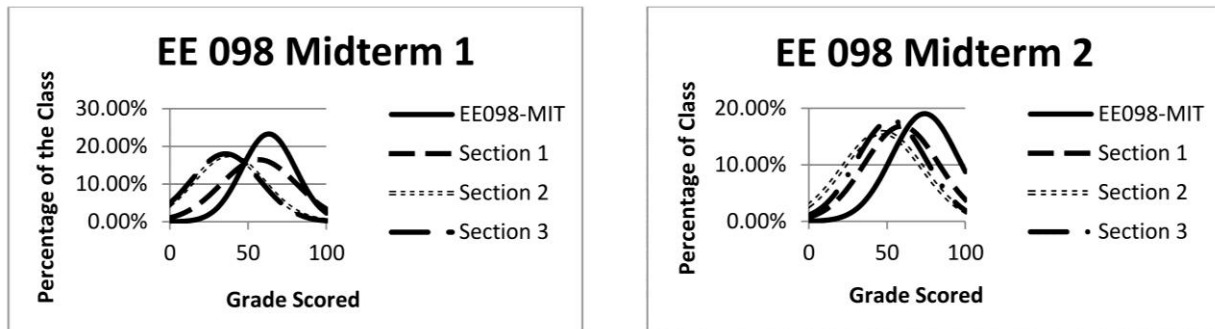
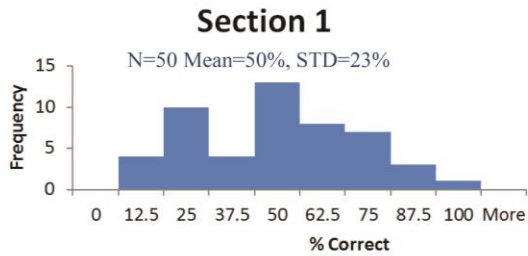
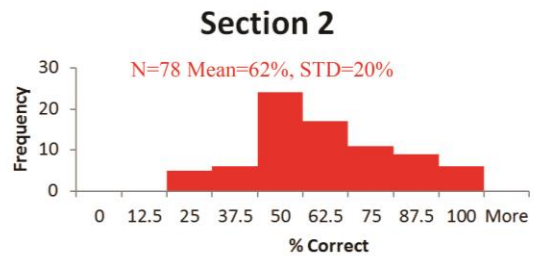


Fig. 3. The EE098-MIT6.002x first and second midterm exam results as compared with the three other sections.

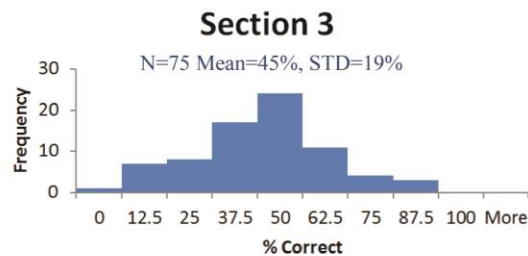
The common final was given to all three sections of EE098 on the same day and same time in Fall 2012. Fifty students took the final exam in the first face-to-face traditional class and the mean was 50 with a 23% standard deviation. Seventy-eight students took the final exam in the blended learning model class with the mean score of 62 and with standard deviation of 20%. Seventy-five students took the final exam in the third section of EE098, which was a face-to-face traditional class with a mean of 45% and a standard deviation of 19% the results are shown in Figure 4.



The EE098 section 1 of 50 students taking common final exam results with mean of 50% and standard deviation of 23%.



The EE098-MIT6.002x section 2 of 78 students taking a common final exam with mean of 62% and standard deviation of 20%.



The EE098 section 3 of 75 students taking common final exam results with mean of 45% and standard deviation of 19%.

Figure 4. The results of section 1 and 3 of the face-to-face and section 3 of the blended model of learning.

In conclusion 91% of the blended class passed the course with grade C or better compared with previous semester of 59%. Students were not aware of their assignment to enroll in a blended section. The beginning term “GPA” of EE098 students shows no significant difference. The student passing rate has improved over the last three semesters significantly. The results of the last seven years of all sections of EE098 are shown in Figure 5.

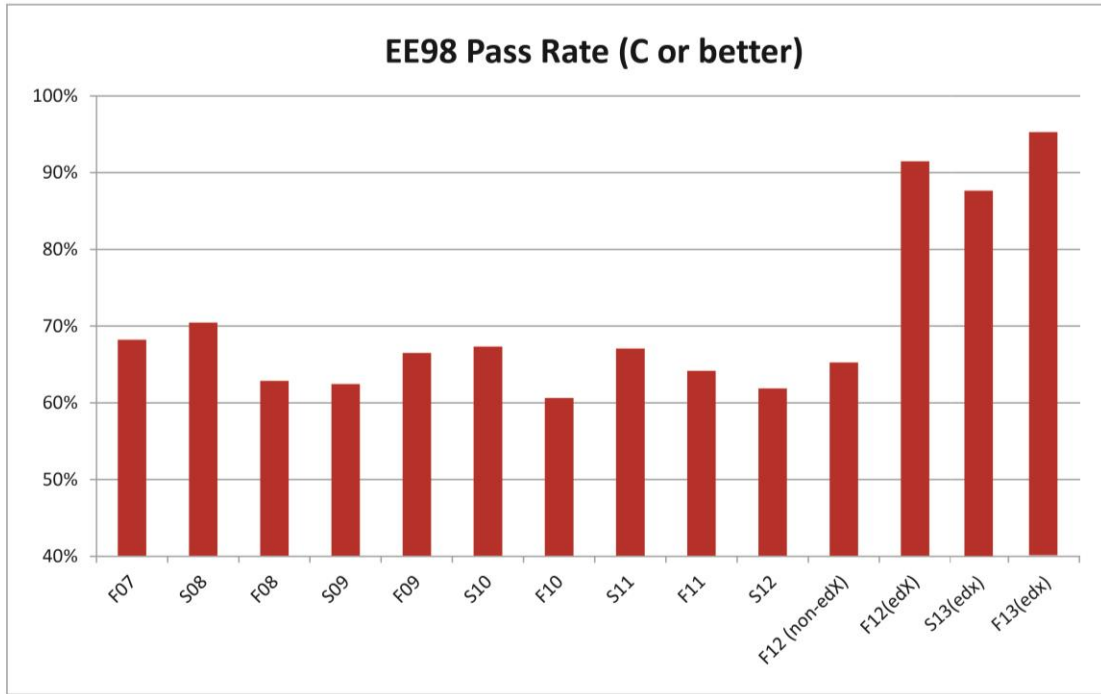


Figure 5. The pass rate of the last seven years of SJSU EE098 students.

Comparison of Student Academic Background

For the last seven years, the success rate for this class has been 65% when taught traditionally. However, with the blended model using the edX MOOC, the success rate increased to 91% (or improved by 26%). To ensure that students were not intentionally assigned to a given section, one-way analysis of variance (ANOVA) was used to compare the means of beginning term cumulative GPAs for all three sections, (see Table I).

Table II provides the Levene test to check the assumption that the variances among three sections are equal for beginning semester GPA. With $p = .109$, the Levene test is not significant and the assumption is not violated. The ANOVA table also provides the overall F (.640) is not significant ($P = .528$), which indicates that there are no significant differences in beginning term cumulative GPAs for all three sections as shown in Table III.

Table I
Descriptive

	No.	Mean	Std. Deviation
Section 1	55	2.611	1.0353321
Section2 (edX)	83	2.701	.8561966
Section 3	86	2.527	1.1032368

Table II

Test of Homogeneity of variance

Levene Statistic	df1	df2	Sig.
2.241	2	221	.109

Table III
ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.282	2	.641	.640	.528
Within Groups	221.451	221	1.002		
Total	222.734	223			

The same implication occurs in Figure 6. It displays no clear separation among three progressive lines of beginning semester GPA (total). These three lines are intertwined across the GPA spectrum.

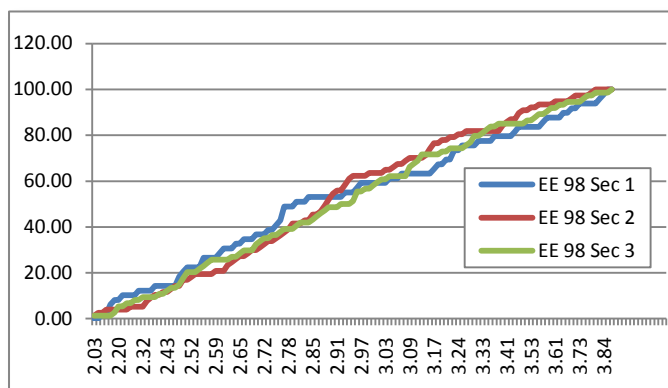


Fig.6. Comparison of Beginning Semester Cumulative GPAs of the EE 098 three sections.

To understand the changes in the official grades of EE 098, a linear multiple regression analysis was performed to examine how well seven predictors used in this study influenced the outcome. The overall models used to examine each section are significant when all predictors are considered together ($p=.013$ for Section 1, $p = .001$ for Section 2; and $p = .001$ for Section 3).

The results in Appendix A - Table X indicate that ending semester grade for Physics 51 is a significant predictor for all three sections. However, the strongest predictor for Section 2 is beginning semester (cumulative) total GPA. The Standardized Coefficients suggested that for an increase in the beginning semester GPA and Physics 51 grade, we expect an improvement in EE 098 grade (0.345 increases in the ordered log odds for beginning semester GPA and 0.253 for Physics 51 grade).

Analysis of the Comments from EE 098 Section 2 (EE 098-MIT6.002x)

Students were asked to describe what aspect(s) of the EE 098 blended class format they liked

most. Table IV suggests that students really liked the online component of the format, quizzes, and the in-class help from their professor, TA's, and peers. The top three responses were: access to resources online, ability to go over material at own pace out of class, and group work/quizzes. Over half the students liked having the resources online because it provided easy access to a variety of learning resources. One student said he liked the fact that "lecture videos can be watched anytime/anywhere." Another student noted the "amount of reference materials online; like sample exams, quiz solutions" available in the EE 098 class format. Students who commented on the ability to go at their own pace out of class referred to the flexibility of viewing lecture videos online on their own schedule and the ability to review the material multiple times.

Support from group members can be considered an additional learning resource as is evident by the 40% of students who felt in-class group work was a helpful component to the EE 098 class format. Groups can be described as helpful because as one student put it, "group quizzes/assignments help stimulate better understanding of concepts." A smaller percentage of students (12%) liked the in-class quizzes. Those students felt frequent quizzes increased their motivation to review lecture and materials regularly before class.

Table IV

What do you like most about the format of class?

Access to resources online	55%
Ability to go over material at own pace out of class	47%
Group work/quizzes	40%
Lectures available online	33%
Professor and TA availability to help	23%
Able to do assignments/problems in class	17%
Quizzes make students become more prepared before class	12%

Students were given an opportunity to provide suggestions on changes the course should make. In Spring 2013, two traditional face-to-face sections with 39 students and 49 students respectively were scheduled. One section of the blended-mode class EE 098-MIT6.002x of 80 students was offered. For better controlled results, a final exam was created and graded by one faculty member. The effect of the class prerequisites and prior GPA of students in the outcome was considered.

We used the edX platform to track students' clickstream data as they access Web instructional materials. This tool will be used to assess students' behavior, study habits, and evaluate their performance in the course. The contribution of different course modules and their statistical regularity of watching the videos and its pattern in success rate will be studied. We are interested to find critical factors (human, organizational, behavioral, and resource) that affect student success.[84-86] The faculty of the blended -mode also is teaching the immediate follow-up class "Circuits and Systems" EE 110 to get some insight information on the student retention rate.

Conclusion

Institutes of higher education are tasked with providing students with a high quality education. At the same time, students are currently saddled with bloated debt and a shrinking job market.[9] Scholars point to a recent but now improving weak economy and skyrocketing education costs. But what can we do to improve student success? Technology can be effectively used to boost student success. This pilot study demonstrated that online material can improve the content of the course and incentivize students to become fully exposed to advanced course content. By doing so student passing rates improved on average over a two-year period to 90% from the traditional 65%. These new instructional stratagems give us hope that multiple safety nets can be cast in our educational system to improve student learning.

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