The Transformative Potential of Blended Learning Using MIT edX's 6.002x Online MOOC Content Combined with Student Team-Based Learning in Class

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***Abstract*—This pilot implemented a blended model of learning by merging content from an online MOOC (Massive Open Online Course) with in-class, team-based instruction as part of a required undergraduate circuit theory course. The central objective of this pilot was to examine how adaptation 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: (1) improve the department's typical passage rate of 59% for this course; (2) improve students' retention rate; (3) shorten students' time-to-degree; (4) improve the quality of the content of the course; and (5) reduce the prerequisite contribution for successful passage of subsequent courses. Student pass rates from the blended Fall 2012 pilot jumped to 91%, as compared to a 59% passage rate from the previous year's traditional face-to face lecture class. It appears that adaptation of high quality MOOC content using a blended approach and in conjunction with a highly structured in-class team-based approach can produce significant benefits in transforming student learning and success.**

***Index Terms*—Blended model of learning, team-based instruction, MOOCs, flipped class, e-learning, face-to-face traditional instruction, retention rate, pass rate, time-to-degree.**

I. Introduction and Literature Review

Recently, significant media attention [1-4] has focused on the emergence of MOOCs, or Massive Open Online Courses. Indeed, at the time of this writing, more than four million people around the world have enrolled [5] in these free online MOOC courses (e.g., through Coursera, edX, Udacity). However, research on MOOCs is still in its infancy [6]. Furthermore, very few empirical studies have been conducted to test how this new online methodology might affect student learning in actual credit-bearing university courses.

Last summer, San José State University (SJSU) embarked on the first pilot experiment involving faculty interested in adapting online MOOC content for use with students in a university credit-bearing course with the goal of improving student learning. In July 2012, several SJSU Engineering faculty traveled to MIT and volunteered to review and adapt the electronics and circuits MOOC created by Anant Agrawal (MIT edX 6.002x) for use in a similar required upper-division course for SJSU Engineering students.

The first author (a professor of Electrical Engineering at SJSU) agreed to pilot the edX online content by using a blended model of online learning--combining the online MOOC content with highly structured, student team-based, in-class learning in his course last fall. This form of a flipped classroom was employed to replace the traditional face-to-face (F2F) lecture classroom instruction.

Beginning with Chickering and Gamson's (1972) classic summary of principles of student learning, there is ample research documenting the value of active learning in promoting student learning over traditional lecture formats [7] shifting to learner-centered education and inevitability of flexible and online learning in global educational environment. [8-14]

For example, considerable research has documented that collaborative or team-based learning [15-36] engages the students in course content and produces enhanced student learning and course outcomes. [37-46]

More recently, research has been done to examine the benefits of blended or flipped classrooms [47-64], students watch short online video lectures and complete homework at their convenience before class and then come into class to engage in activities traditionally reserved for outside of the classroom (group work, active study, and office hours) in the classroom with the instructor present. [65-94]

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This pilot implemented a blended or flipped model of learning merged online MOOC content to be completed by students *outside* of the classroom with team-based learning *inside* the classroom along with F2F guided support instruction from the professor [95-97].

II. Objectives and Motivations

There were multiple objectives for this pilot: (1) improve students' typical passage rate of 59% for this course; (2) improve students' retention rate; (3) shorten students' time-to-degree; (4) improve the quality of the content of the course; and (5) reduce the prerequisite contribution for successful passage of subsequent courses.

On average forty-one percent of students did not pass with a grade of C or better in the "Introduction to Circuit Analysis" class. Because the course is a "core course," repeating students prolong their time-to-degree, and multiple repeaters are vulnerable to los

The drastic improvement in pass rates shortens the time-to-degree and improves the retention rate. The course prerequisite is university physics course (or equivalent an AP physics class in electromagnetism in high school and an AP advanced calculus course) and co-requisite of university differential equations.

One of the objectives was to marginalize the prerequisite contribution for success. The sometimes uneven background in math and physics of students due to different learning objectives and outcomes from different community colleges can be a challenge for faculty at the four year institution. 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. This is why the customizable content of the course is crucial. If a student is struggling with some prerequisite aspect of the course, other material can be assigned to enable those students to catch up.

Even though EE 098 is a gateway course for all engineering majors at SJSU, the student body for EE 098 includes a diverse enrollment of freshmen, sophomores, juniors, seniors, and even graduate students as shown in Table 1. The diversity is reflected in the fact that students in some non-EE majors postpone take EE 098 until the last minute.

Eighty-six students initially registered for the class. Seventy-eight students took the final exam. One freshman, seven sophomores, thirty-eight juniors, thirty-eight seniors and two graduate students took the class.

III. Case study (EE098 course conttext)

Three sections of Electrical Engineering 098 "Introduction to Circuit Analysis" were offered in the fall 2012 semester at SJSU. Enrollment is typically limited to 90 students for two large sections and 50 students for a third section. The classes met twice a week for 75 minutes each during the 16-week semester.

Students are assigned weekly textbook readings and eight to ten homework assignments. Two midterms and a final exam constitute 75% to 80% of the grade. EE 098 is a required upper-division core course for the College of Engineering and requires a grade of C or better to pass. EE 098 has had a traditionally low passage rate, with 59 percent of the students passing the course in their first attempt.

In this pilot, only one of the large sections was targeted for implementation of this blended model. Because the decision to pilot the blended model occurred over the summer, the 224 students registered for that fall did not have prior knowledge that one of the three sections would be blended. In order to accommodate students who may not want to experience a blended course, another section of EE 098 at the same time and day as the blended class was planned, so that if students wished to withdraw and register for the F2F class they could do so. Students' desire to transfer did not materialize and the need to create another section was cancelled.

The first midterm exam was coordinated very closely with the previous semester's F2F instructor for comparison purposes. The exam results of the blended-mode class as compared with the three other sections offered previous year are shown in Figure 1. The results were encouraging. Most interesting was the disappearance of the lower tail of curve. Not only were the entire class grades higher but also the poor performers in class done better.

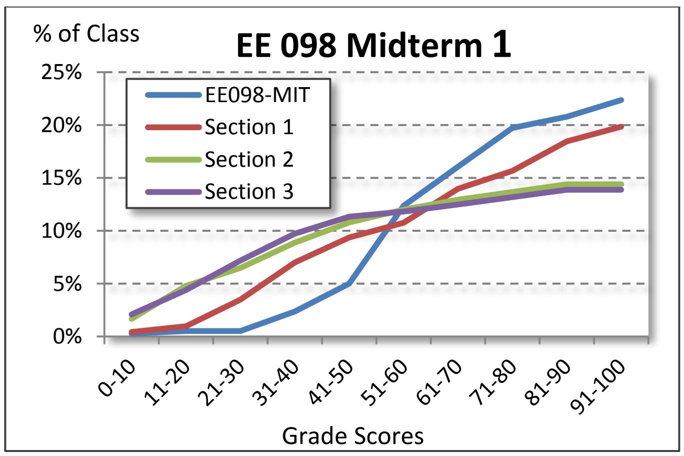

Fig. 1. The EE 098-MIT6.002x first midterm exam results in comparison of three sections of previous year's F2F EE 098 classes

The result of the second midterm exam is shown in Figure 2. Again the results are encouraging. The blended model class performed 10 percentage points better on average compared to the F2F class.

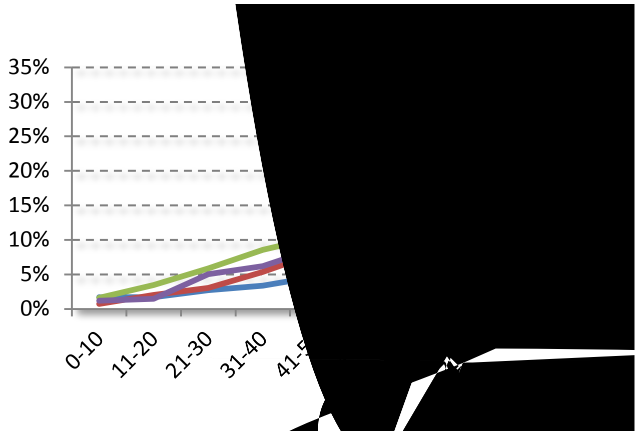

Fig. 2. The EE 098-MIT6.002x second midterm exam results in comparison of three sections of previous year's F2F EE 098 classes

The final exam results of the blended mode class and the three sections of the previous year are presented in Figure 3.

Fig. 3. The EE 098-MIT6.002x final exam results in comparison of three sections of previous year's F2F EE 098 classes

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a) Watch **edX topical mini-lecture videos** of up to 10 minutes each and answer embedded questions online twice a week.
b) Read assigned sections of the **edX online textbook** twice a week.
c) Solve **edX problem sets** and submit answers online for automated grading by edX once a week (for a total of 12 problem sets during the semester).
d) Complete weekly **edX online lab experiments** and submit answers online for automated grading by edX (for a total of 12 lab experiments during the semester).
e) Watch **edX videos of MIT faculty arguing with each other in presenting and modeling competing alternative solutions** to a single problem twice a week.
f) In addition, students were encouraged to submit their questions online in a **SJSU virtual discussion board** that was moderated by the SJSU professor and Graduate Assistants.
g) Finally, after each class session, students were given (or could download) an **assessment handout for the *next* class session** that asked each student to evaluate their understanding or level of difficulty (i.e., "easy", "elementary", "intermediate", "hard", "advanced") for each of the edX topics to be covered in the next class session. If a student rated a topic as "hard" or "advanced", he or she was required to briefly explain what was difficult or confusing. Students were required to complete this survey *before* coming to each class and give it to the Graduate Assistants at the beginning of each class session. The two Graduate Assistants compiled the results of these surveys during the first ten minutes of each class so that the professor could focus on the most difficult topic areas during the F2F mini-review lecture.

2. In-Class Activities (75 minutes, twice a week)

a) **Mental ramp-up period** (10 minutes): Professor asks questions about students' activity to gauge students' understanding while grad students collect weekly "student online activities survey" and summarize results for the professor to be discussed in that day's class session.
b) **In-class mini-review lecture** (20 minutes): Based on the grad students' survey analysis of online topics marked as "difficult to understand" or "hard" by students that week, the professor reviews the more difficult concepts in class. If no topics emerge as difficult, the professor solves a sample problem that embodies the most important concept of that week's topic. In addition, a summary of the online lectures are distributed to all students twice a week.
c) **Group quiz** (15 minutes, 30 quizzes per semester): Students work on a group quiz as a team of three. Professor leads and answers questions on strategies for how to solve different types of problems. The group quiz is collected and graded as part of overall course grade (10%).
d) **Solution of group quiz** (5 minutes): Professor reveals some of the best strategies to solve problem and the solution is distributed among students in class.
e) **Individual quiz** (15 minutes, 30 per semester): The individual quiz is given to each student to gauge their understanding of subject material by ABET criteria and with CLO in mind. The quiz is collected and graded as a part of students' final course grade (10%)
f) **Solution to the individual quiz** (5 minutes) and the best strategy to solve this type of the problem is discussed with the solution distributed to the students in class.
g) **Preview for next class session** (5 minutes): Preview by professor of next class' material.

3. After Class Activities

a) Professor emails absent students with class materials (summary of mini-lecture, individual and group quiz solutions, and words of encouragement for future participation).
b) An optional, Friday, one-hour, F2F walk-in session (i.e., optional recitation office hour) held weekly by the professor.

V. edX E-learning Materials

The rich e-learning content, engaging video presentations and labs, and high-quality production portion of the course was derived from the MIT 6.002x MOOC course. However, all of the course materials for the face-to-face portion of the SJSU class was developed by the first author. It should be noted that MIT6.002x was developed exclusively for MIT students majoring *only* in Electrical Engineering and Computer Science; whereas, SJSU's EE 098 is a required course for all students interested in majoring in *any* Engineering undergraduate program in the College of Engineering. As a result, the degree of overlap between the course content from edX and EE 098 is significant, but not perfect. Therefore, the professor utilized most (85%) of the edX 6.002x e-learning material—assigning students to view eight intertwined modules, and supplemented the remaining 15% with material specific to the SJSU EE 098 course.

In the sections below, a brief summary is provided for how each edX e-learning element was utilized.

1) Video Lecture Sequences

The MIT 6.002x online video lecture sequences are modular interweaved video snippets consisting of a series of short lectures ranging from 30 seconds to 10 minutes narrated by a MIT professor and composed of text, equations and illustrations. The duration of the video snippets are purposefully short, based on studies suggesting that the average attention span of students is roughly 10 minutes (7 to 15 minutes) [98-99]. The lecture pedagogically introduces the basics and fundamentals of circuit theory from physical phenomena to abstraction back to physical phenomena application. All the video lectures were placed in the courseware section as shown in Figure 4. The display page is divided into three panes. The left pane exhibits the time schedule and table of contents, the middle pane contains the lecture videos, and the right pane displays the lecture transcription.

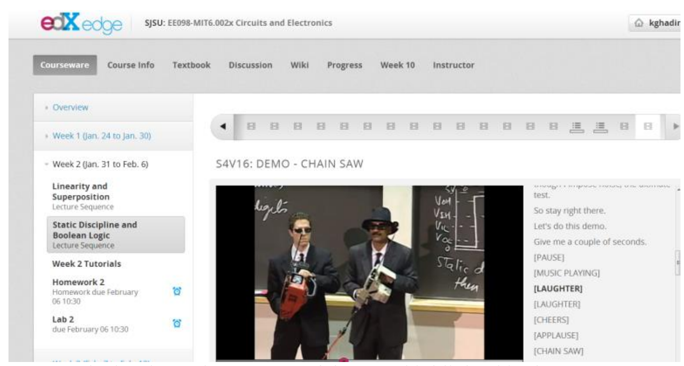

Fig. 4. The header at the very top of the page highlighted in the "Courseware" section, where most of the instructions and assignment are located. The "Course Info" section contains any announcements that the course faculty and TA's would like to share with students including the syllabus, calendar and all of the handouts associated with the course. The online version of the textbook is in the "Textbook" section.

The video lectures are presented on a tablet similar to the Khan Academy style [100] with a Power Point presentation in the background while the slide is being annotated in real time. An example is shown in Figure 5.

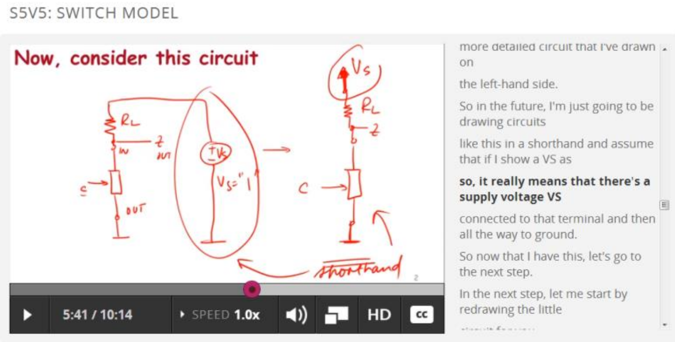

Fig. 5. Another great feature is the transcription alongside of the video snippet which highlights as the speaker talks. Students can also click on any of the words and the video jumps to that part of the lecture.

Lectures can be viewed at four different speeds of .75x, 1x, 1.25x, 1.5x depending on the students' preference. The lecture is transcribed on the right hand side of the screen and highlighted by lecture flow. The students are able to pause and continue as well as change the speed at their convenience anytime as shown in Figure 6.

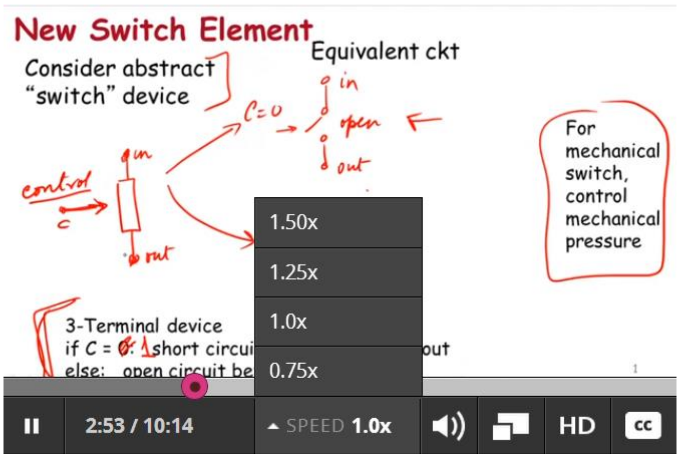

Fig. 6. The navigation tools associated with lecture videos are some standard video buttons, like the play/pause button on the bottom left and the time-elapsed button. Something new is the ability to speed up and slow down lectures with the video speed button.

The 28 lectures are online as shown in the table I with their time durations

TABLE I
NUMBER OF STUDENTS OF DIFFERENT MAJORS

Lecures	Hour	Min.	Sec.	Lecture	Hour	Min.	Sec
Lec. 1	1	8	15	Lec. 15	2	29	26
Lec. 2	0	43	25	Lec. 16	1	19	15
Lec. 3	0	59	04	Lec. 17	1	45	50
Lec. 4	1	16	29	Lec. 18	3	11	25
Lec. 5	1	31	52	Lec. 19	1	29	52
Lec. 6	1	22	41	Lec. 20	1	17	39
Lec. 7	1	35	14	Lec. 21	1	43	40
Lec. 8	1	12	18	Lec. 22	0	33	40
Lec. 9	1	43	15	Lec. 23	2	07	34
Lec. 10	0	47	39	Lec. 24	1	14	49
Lec. 11	1	9	19	Lec. 25	1	51	59
Lec. 12	1	27	25	Lec. 26	1	17	10
Lec. 13	0	39	15	Lec. 27	1	29	43
Lec 14	1	25	49	Lec 28	1	10	19

2) Embedded Exercises

The embedded exercises are online exercises interspersed among video lectures to enable students to gauge their understanding and ability to apply concepts covered in the lecture videos. Each of the lecture video sequences is embedded with three-to-six questions that require students to verify and elaborate on the concepts covered.

3) Textbook

In this pilot, students may access an e-book version of the textbook [101] electronically free of charge on the edX website. The textbook is accessible from a navigation bar on left or with a forward and backward arrow as shown in Figure7.

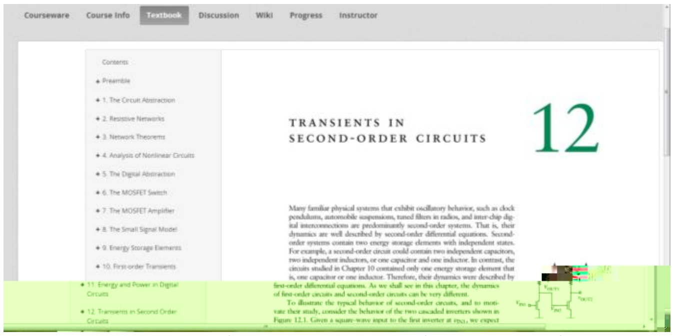

Fig. 7. Screen capture from ebook version of Foundation of Analog and Digital Circuits by Anant Agarwal and Jeffery H. Long, with navigation bar on left.

3) Homework Assignments

The edX video lecture is frequently followed by an application problem, which is solved by students and then the answers submitted online and graded automatically. Students were asked to solve twelve homework assignments through the semester. These homework assignments consist of three problems with several parts and were due at beginning of the next biweekly class meeting as shown in Figure 8. The homework assignments were carefully chosen to cover fundamental principles and materials that the student should retain and was a tool to motivate students to watch the edX lecture video sequences and explore the Web to encourage lifelong learning. Completion of the homework and activities solidify the student's understanding of the materials covered in the course. The homework assignment also was a bridge between the online activities and in-class discussion. The student can enter algebraic expression such as $Ax^2 + \sqrt{y}$ in the answer box. The entry is case sensitive. The product must be indicated with an asterisk, and the exponential with a caret, so the above algebraic expression must be written as "A*x^2+sqrt(y)".

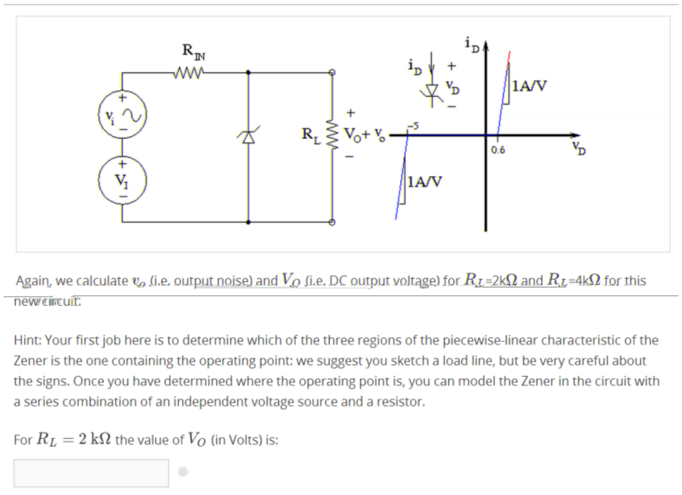

Fig. 8. The edX platform is able to check the students' answers and provide immediate feedback. When students "check" a problem, it is automatically submitted for grading purposes. The course logistics require that if students get an answer wrong, they can simply try again until they get it right. Depending on the type of the problem, they may have access to the "show answer" button. In many self-assessment questions, this option will appear after their first attempt at answering the question, while in most graded assignments; this option will appear only after the due date has passed.

5) Tutorial on Problem-Solving Techniques

A key feature of the MIT edX video discussion section is an innovative approach to problem-solving by having two of the MIT faculty argue alternative ways to solve a particular problem, having them ultimately reach the same solution, but in different ways. The solutions are provided in copy board style as shown in Figure. 9.

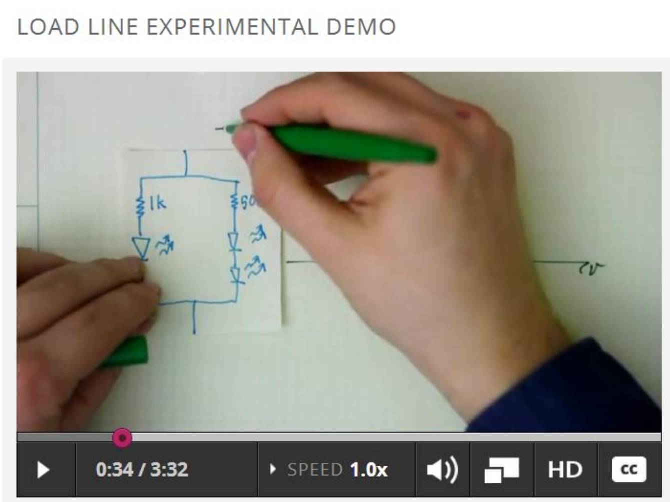

Fig. 9. The copy document technique is used to demonstrate critical thinking through different problem solving techniques and. The videos demonstrate how different problem solving approaches can provide the same result, but a particular approach is preferable among others.

6) Virtual Laboratory

The edX sandbox is a virtual lab. Students can place virtual components together and create circuits with different functionality and observe their behavior by creating a simulation. The components can be selected from the parts bin and dragged onto a gridded screen as shown in Figure 10. The students connect the components together and easily assign a numerical attribute to them. After a circuit is made, any relvent measurement can be conducted. For example, a DC analysis will determine the voltage of every node in the circuits at time equal to zero as the current flows through the various components. The transient anlysis provides osciloscope plots of voltage and current waveforms over time using the numeric simulation techniques. The small signal AC circuit analysis tool enables students to figure out how their circuits behave with different frequency signals by appyling sine waves at a particular nodes in the cicuits.

Students complete twelve edX laberatory's experiments during the semster. Experiments are graded automatically and the scores are available to students and faculty in the performance portals. The laboratory score is 7.5% of the final course grade.

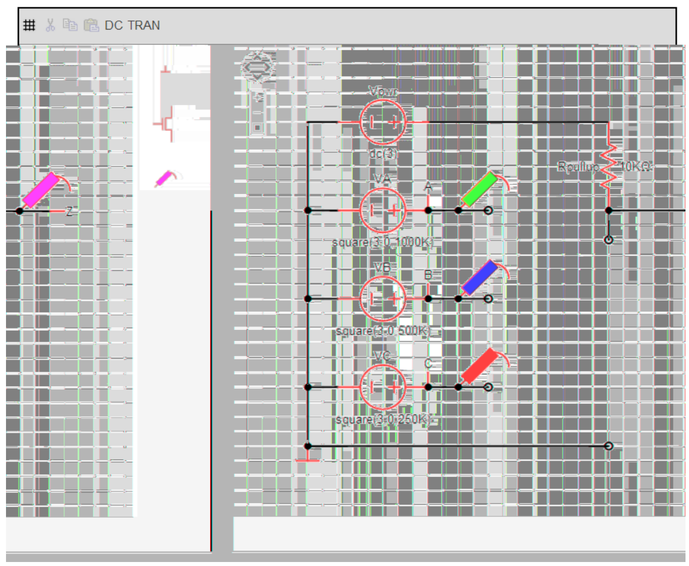

Fig. 10. The edX circuit sandbox is a virtual laboratory that can be used in order to enter circuits online and explore their behaviors using a simulation. The sandbox has tools for both editing and simulating a circuit. The entire component that can be used to build a circuit can be found in the parts bin on the right side of the sandbox. The selection of available components differs from assignment to assignment.

7) Online Discussion Forum

The students may start or participate in online discussion sections at any time. The faculty and TA's will frequently answer questions, but other students may jump in with answers.

8) edX Wiki

Edx wiki is for posting a persistent and organized reference and additional information. These postings are collaboratively collected and edited by the students and faculty.

VI. LIVE PORTON

Budgeting the invested student and faculty time in classroom and proportionating it appropriately to seeking objectives was an important step. A system of intervention catches students that need help at the early stages of the course quickly. The in-class portion of the course is divided into six distinct periods. Each period is designed to promote the learning objectives and desired outcomes.

1) The mental ramp-up period

The first 10 minutes of class is a mental ramp-up period. We dubbed this time the mental ramp-up because we gradually engage the student to the content of the lecture. The TA's gather the e-learning surveys which students took before class and compile the results identifying common on-line difficulties for the faculty to address. Meanwhile, the faculty lead a question and answer session reflecting the material covered in e-learning to gauge the level of understanding of the students. Careful consideration is needed in this segment of the class period. The student surveys, which identify the majority of lecture as hard to understand, result in 75 minutes of F2F classroom teaching. The solution is for the faculty to challenge each student to be sure the edX videos are watched.

2) Mini-Lecture or Quiz During Class (20 minutes)

This short mini-review lecture based on the results of the student survey or a question and answer period clarifies in depth any troublesome concepts. The mini-lecture goal is to stir effective classroom discussions and encourage questions, clarifying learning objectives and identifying areas of focus. The in-class lecture is not a reiteration of the content of the online edX lectures. There are two reasons for this. First, a simple repetition of what students already know to be difficult to understand may not be helpful. Second, such reiteration turns the in-class activities into review of the online lecture, and in turn encourage students' motivation to make an effort to understand the content of the online lecture by themselves. Therefore, students are encouraged to ask questions about particular video snippets for class discussion. If there are no troublesome concepts, no lecture is needed but a quiz is given to verify understanding. The quiz is presented on the board and the professor coaches students in the methodology of an answering the question and then provides the solution. Then the summary of key points of the lecture is distributed to students.

3) Group quiz (15 minutes)

The group quiz is designed to spark class discussion and enhance students' collaborative critical thinking. During this period, the students exercise their verbal and written communication skills, as well as develop the spirit of team work while stating and defending positions with evidence and sound arguments. This period's objective 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 grad assistants act as facilitators and mentors, rather than a source for solutions during this segment of the class. [5,6]

4) Solution to Group Quiz (5 minutes)

A short review of the different solutions and possible approaches enables the class as a whole to share their findings and develop technical skills in a team-supported context. A hard copy of the solution to the quiz is provided to students at the end of this period. The content of the quiz is chosen based on the ABET criteria and the course learning objectives (CLO).

5) Individual quiz (20 minutes)

The individual quiz develops students' ability to use course concepts and problem solving techniques. It also evaluates the technical skill and performance of students on their own merit and identifies the areas of excellence and weakness. The excellence is rewarded by recognition in class, and shortcomings are overcome by specific student tailor-made material and tests to be done outside of the classroom.

6) Next Meeting Agenda (5 minutes)

The last 5 minutes of the class is devoted to reviewing the key points for the upcoming class and other announcements. It always concludes with some words of encouragement from the professor.

VII. After Class support

The student participation on the web and classroom is closely monitored by faculty.

1) Student Follow-Up

The professor sends an email to absent students immediately after every F2F class meeting to encourage their participation in the following class meeting. A summary of class activities including the team and individual quizzes, their solutions and the lecture summary hand-out is emailed to students. Student attendance in this blended pilot was exceptionally high nearly 100%.

2) Weekly Recitation

A weekly one-hour recitation is scheduled by the professor to help the students understand the difficult topics, unravel misconceptions, and tailor an algorithmic procedure for different application of the topics. Some words of advice for allocation of time and attention over different components of the course is given.

3) Students' Progress Reports

A summary of student progress reports summarizing their online and in-class activities are sent to students electronically every two weeks.

VIII. Grading Policy

The student course grades are based on online activities (twelve homework assignment and twelve laboratories) (15%), thirty team quizzes (10%), thirty individual quizzes (10%), two midterm exams 20% each (40%) and a final comprehensive exam (25%).

Letter grades will be assigned based on the distribution curves for each exam. These will be converted to numerical scores using the following equivalencies listed in table II:

TABLE II
Conversion Table of Equivalence

Grade	A+	A	A–	B+	B	B–	C+	C	C-	D+	D	D–	F
Score	14	13	12	11	10	9	8	7	6	5	4	3	0

The overall grade will be ascertained from these numerical scores, as, using appropriate weights for all three exams and other course activities.

IX. Findings and Results

Student Overall Reactions During the Pilot Course

Three distinct phases of student reactions to the blended course evolved over the semester: initial resistive mode, guarded skeptic mode, and final receptive mode. These phases coincided with the start of the class, the first midterm after 10 weeks, and the second midterm 10 weeks after that.

During the resistive period, students complained about the extensive hours required weekly to study (minimum of 12 hours per week), the fast pace of the course, constant testing, complaints that their peers did much less for the same class and number of units. Student complaints during this resistive face were sufficient to cause initial concern that the pilot program might fail.

However, after the results of the first exam became known, the resistive phase changed to the guarded skeptic phase when students were informed that the blended class did on average 11 percentage points higher on the exam compared with midterm scores from the prior three semesters. This finding changed students' attitudes from resistive mode, to guarded skeptic mode and students to consider the blended approach as rewarding and possibly beneficial. The second midterm results showed an average 10 percentage point higher on the exam compared with midterm scores from the last three semesters. Sudents became much more appreciative and enthusiastic about the blended model.

In the third part of the semester, the students became very comfortable with the class flow and activities, and were receptive and became ambassadors of the new blended approach.

Fifty students took the final exam in the first face-to-face traditional class and the mean was 50% with a 23% standard deviation as shown in Figure 11.

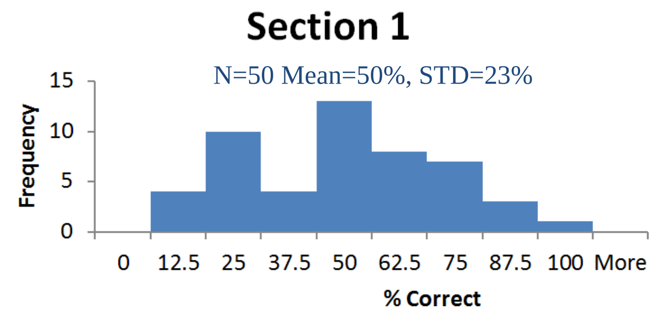

Fig. 11. The EE 098 section 1 of 50 students taking common final exam results with mean of 50% and standard deviation of 23%.

Seventy-eight students took the final exam in the blended mode class with the mean score of 62% and with a standard deviation of 20% as shown in Figure 12. The results were encouraging. Most interesting was the disappearance of the lower tail of curve. Not only were the entire class grades higher but also the poor performers in class did better.

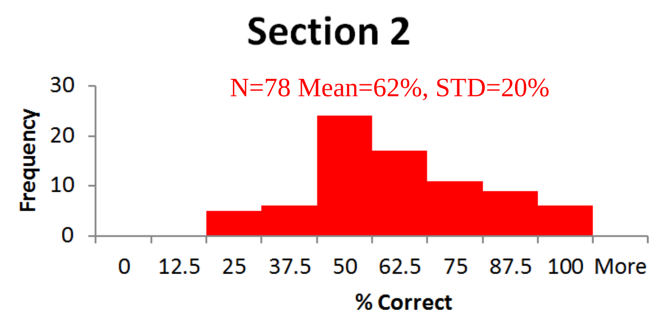

Fig. 12. The EE 098 section 2 of 78 students taking a common final exam with mean of 62% and standard deviation of 20%.

Seventy-five students took the final exam in the third section of EE 098, which was a face-to-face traditional class with a mean of 45% and a standard deviation of 19% as shown in Figure 13.

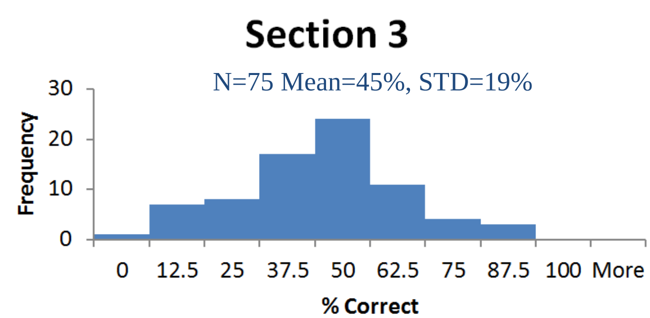

Fig. 13. The EE 098 section 3 of 75 students taking common final exam results with mean of 45% and standard deviation of 19%.

Conclusion

In conclusion 91% of the blended class passed the course with grade C or better compared with previous semester of 59%.

Comparison of Student Academic Background

For the last three 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 III.

Table IV 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 no significant (P = .528), which indicates that there are no significant differences in beginning term cumulative GPAs for all three sections as shown in Table V.

TABLE III
DESCRIPTIVES

	N	Mean	Std. Deviation
Section 1	55	2.611	1.0353321
Section 2	83	2.701	.8561966
Section 3	86	2.527	1.1032368

TABLE IV
TEST OF HOMOGENEITY OF VARIANCES

Levene Statistic	df1	df2	Sig.
2.241	2	221	.109

TABLE VI
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 14. It displays no clear separation among three progressive lines of beginning semester GPA (total). These three lines are intertwined across the GPA spectrum.

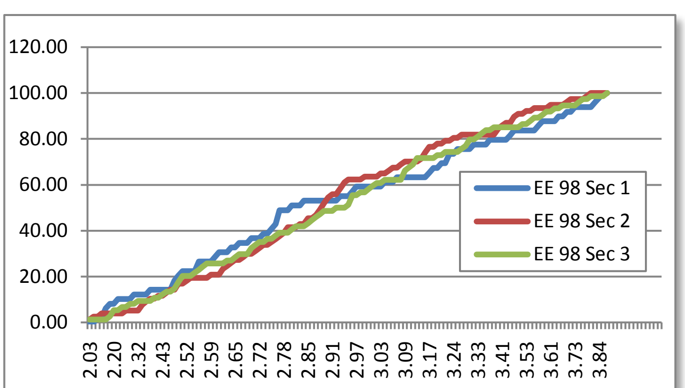

Fig. 14. Comparison of Beginning Semester Cumulative GPAs of the EE 098 three sections.

To understand the changes in the official grades of EE 098, a linear multiple regression 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 Table VII in Appendix A indicate that ending semester grade for Phys 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 Physic 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 Physic 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 VII 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 helps 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 VII
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 prepare	12%

before class	

There were aspects of the EE 098 class format students did not like, shown in Table X below. In general, in order of frequency, students reported that they were not happy: problems with some of online edX material which did not appear to aligned with the in-class material; edX online lectures and homework not helpful/long/difficult; the amount of time required for completing the course; and not having sufficient time for in-class reviews.

In general, students felt that the material provided to them online (lectures, assignments, and other resources) and the in-class work (quizzes, assignments, and reviews) were out of sync. One student felt the "discrepancy between online and actual class schedule, this contributed to arguably useless HWs for some weeks."

Forty eight percent of students reported disliking the online lectures because they were out of sync with in-class material, required too much time to watch, were a source of confusion rather than clarity, or focused on theory and provided very few applicable examples. This is an interesting finding because 33% of students reported liking the online lecture component of the EE 098 class format (see table above). These findings suggests that providing online lectures can be helpful, but may not be the best option for all students when it is the only source of lectures.

One reason online lectures may not be convenient for all students is that they are time consuming. Thirty six percent of students felt the EE 098 class format in general was time consuming. Some students simply stated that "the online HW/labs are very time consuming," while others explained why they disliked "Watching lectures online .I had 2 jobs on top of school so I never had time to spend watching left alone understanding the lectures. Everything I learned was from example problems or book."

TABLE VIII
WHAT DO YOU DISLIKED MORE ABOUT THE FORMAT OF THE CLASS?

Material not correspond to outclass material	71%
Online lectures not helpful/long/difficult	48%
Time consuming	36%
Difficulty of material did not match course level/difficult in general	24%
Online homework in general/too frustrating/too much	28%
Homework is difficult	35%
Homework is irrelevant	22%
Homework is too frequently	22%
Insufficient reviews	14%

Students were given an opportunity to provide suggestions on changes the course should make for the next semester. Table IX indicated that modifications for **Homework**, **Online Content**, **Content Focus**, and **Quizzes/Exams** were the concern. The top three suggestions were *remove online and replace with more sample problems (show step by step to solve problems)*, *align class and online content*, and *class lectures (to supplement online materials)*.

The top suggestion, under the **Homework** category, was the removal of online homework because it was not considered to be helpful. Instead, students suggest replacing online homework with sample problems showing step by step solutions. Another student was concerned with the grading aspect of online homework and suggested that participation credit be given for completing example problems.

In the previous table, data showed that 71% of students did not like the aspect of the class format in regards to the online material and in-class material being out of sync. Not surprisingly, students suggested "make sure the online lectures go along with in class materials." Other suggestions included "cut some of the online section that are not in class curriculum," "make online works more relevant to course or assign HWs that are relevant to problems that would be on final," and "please talk more about relevant topics and not take class time to talk about theory that is not relevant to our course."

Another **Content Focus** suggestion which is one of the top three suggestions for future changes to the course is that of *class lectures (to supplement online materials)*. Students would like in-class time to include more lectures either as a review and clarification of the online lectures. One student recommended "go over video lectures in class (keep lectures up to speed with videos)." Other students suggested more in-class lectures for the most complex topics/chapters. These suggestions show that students may find the online lectures helpful, but there is still a need to for traditional in-class lectures.

Although not one of the top three suggestions, students also recommended changes in regards to **Online Content** and **Quizzes/Exams**. Changes students would like to see made to the materials provided online includes providing fewer lecture videos or making them shorter and easy to understand the material, focusing lecture videos on practice and less on theory, and removing labs. As was discussed previously, students felt the class format was time consuming, especially the online lectures. These changes would lead to a decrease of time spent outside of class on online material.

In regards to **Quizzes/Exams**, students simply suggest providing fewer quizzes and/or exams. Specifically, students recommend "less quizzes, go over materials more in depth" and "less quizzes but more problem solving as a whole class." Again, it appears students require more practice and in-class time going over the material as a class.

TABLE IX
IF YOU COULD OFFER ONE SUGGESTION FOR A CHANGE NEXT SEMESTER, WHAT WOULD IT BE?

Homework	
Remove online and replace with more sample problems (show step by step to solve problems)	33%
Align online homework with class	24%
Make relevant to final/exams	14%
Assign from EE98 book	10%
Online Content	
Less/videos shorter in length	24%

Less theory based	16%
Fix/edit videos (for EE98 not MITx)	12%
Remove labs	12%
Lecture videos need to be clear & concise	8%
Content Focus	
Align class and online content	30%
Class lectures (to supplement online materials)	27%
More problem solving techniques/practice problems	21%
Focus on tested material only	6%
Quizzes/Exams	
Fewer	54%

Students were not aware of their assignment to enroll in the blended section. The beginning term "SJSU GPA" of EE 098 students shows no significant difference as shown in Figure 13.

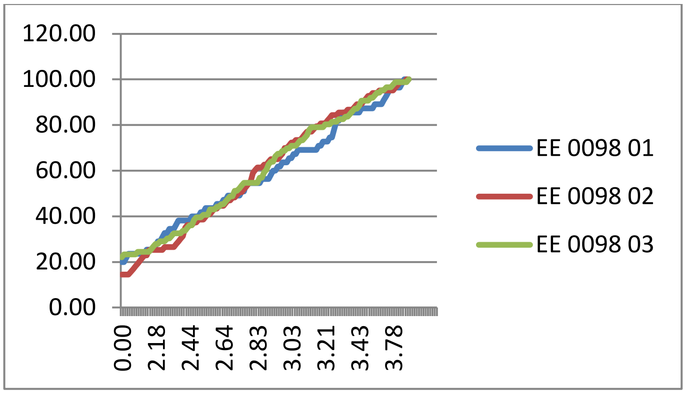

Fig. 13. Beginning term (SJSU GPA) of EE 098 three different sections.

In spring of 2013, two traditional face-to-face sections with 39 students and 49 students respectively are scheduled. One section of the blended-mode class EE 098-MIT6.002x of 80 students is offered. For better controlled results a final exam is created and graded by one faculty member. The effect of the class prerequisites and prior GPA of students in the outcome will be considered.

We will use 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 lead to more or less 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.

X. Conclusion

Striving for better and more effective instructional delivery models is a sincere desire 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 significantly reduce student failure rate.

This is even more critical today with millennial students because keeping their attention for a traditional 50 minutes in the lecture hall and passively listen is not realistic.

Currently in the U.S. only six percent of the 24-year-olds attain a first degree in a STEM field. The U.S. is ranked in the bottom quartile (20^{th} among 24) among the comparative nations. According to the Higher Education Research Institute at UCLA, roughly 26 percent of the college students enter in a STEM area; roughly 18 percent of them graduate in these fields in five years, in other words, less than 40 percent of students who aspire to get a STEM field, Moreover, the disparity among ethnic groups is also very concerning. For instance, while 42 percent of Asians, 33 percent of Caucasians earn a STEM degree within five years, less than 22 percent of Latino, and 18 percent of African-Americans achieve this.

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 and address our national security needs. Our experiment at San Jose State University bears a lot of hope as an effective approach that can enhance the success of engineering students in a major gateway course. Our plan is to continue our assessment with future students groups along many campuses and share our results as they become available.

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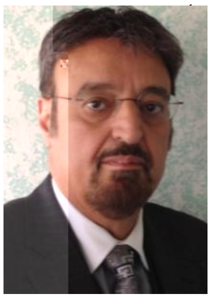

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Appendix A.

TABLE VI

MULTIPLE REGRESSION MODEL RESULTS

	EE 98 Section 1		EE 98 Section 2 (edX 6002x)		EE 98 Section 3	
	Overall = Significant**		Overall = Significant*		Overall = Significant*	
Research model relationship	Standardized Coefficients Beta	Significance Level	Standardized Coefficients Beta	Significance Level	Standardized Coefficients Beta	Significance Level
PHYS 51 Ending Semester Grade Points	.612	.000	.253	.023	.291	.010
PHYS51 Time Difference	-.139	.363	.044	.701	-.050	.637
PHYS51 Enrolled (at SJSU)	.068	.760	-.002	.990	-.394	.012
Total Attempted Units	-.028	.840	.191	.112	.080	.483
Beginning Semester (Cumulative) GPA	.074	.609	.345	.006	.114	.375
Under Representative Minority (URM)	-.115	.426	-.065	.570	-.266	.015
Freshman Starters	.067	.751	.012	.931	.100	.471

* significant at 0.01; ** significant at 0.05; *** significant at 0.10