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Work in Progress: Creating Alternative Learning Strategies for Transfer Engineering Programs

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Eva Schiorring has almost two decades of experience in research and evaluation and special knowledge about STEM education in community colleges and four-year institutions. Ms. Schiorring presently serves as the external evaluator for three NSF-funded projects that range in scope and focus from leadership development to service learning and experimentation with alternative delivery, including online lab courses. Ms. Schiorring is also evaluating a project that is part of the California State University system's new initiative to increase first year persistence in STEM. In 2014, Ms. Schiorring was one of the first participants in the NSF's Innovation-CORPS (I-CORPS), a two-month intensive training that uses an entrepreneurship model to teach participants to achieve scalable sustainability in NSF-funded projects. Past projects include evaluation of an NSF-funded project to improve advising for engineering students at a major state university in California. Ms. Schiorring is the author and co-author of numerous papers and served as project lead on a major study of transfer in engineering. Ms. Schiorring holds a Master's Degree in Public Policy from Harvard University.

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Abstract

This paper presents preliminary results of a collaborative project, *Creating Alternative Learning Strategies for Transfer Engineering Programs (CALSTEP)*. The project aims to strengthen community college engineering programs using distance education and other alternative delivery strategies that will enable small-to-medium community college engineering programs to support lower-division engineering courses that students need to be competitive for transfer to four-year engineering programs. Funded by a three-year grant through the National Science Foundation Improving Undergraduate STEM Education (NSF IUSE) program, CALSTEP will leverage existing educational resources and develop new ones for online lecture courses, as well as core engineering laboratory courses that are delivered either completely online, or with limited face-to-face interactions. The initial areas of focus for laboratory course development are: *Introduction to Engineering*, *Engineering Graphics*, *Materials Science*, and *Circuit Analysis*. CALSTEP will also develop alternative models of flipped classroom instruction to improve student success and enhance student access to engineering courses that otherwise could not be supported in traditional delivery modes due to low enrollment. The project will also evaluate the effectiveness of the curriculum and train other community college engineering faculty in the effective use of the curriculum and resources developed.

1. Introduction

The 2012 President's Council of Advisors on Science and Technology (PCAST) report, "Engage to Excel" indicates that the United States needs to produce one million additional STEM professionals in the next decade in order to retain its historical preeminence in science and technology. To meet this need, the number of undergraduate STEM degrees will have to increase by about 34 percent annually over the current rates. The PCAST report proposes that addressing the retention problem in the first two years of college is the most promising and cost-effective strategy to address this need.[1] The California Community College System, with its 112 community colleges and 71-off campus centers enrolling approximately 2.6 million students—representing nearly 25 percent of the nation's community college student population—is in a prime position to grow the future STEM workforce.[2] However, with shrinking resources and the increasing cost of education, an effective approach is to "more fully exploit the advanced information technology capabilities that science and engineering have produced, which have proven to be valuable in reducing costs and improving productivity in manufacturing and private sector businesses."[3]

Over the past decade there has been an increased interest in online education due to wider acceptance of its potential benefits including increased access and broadening participation of nontraditional students,[4] diversity, potential for individualized and student-centered learning, collaboration, reduced cost, and its potential to be more effective than traditional methods.[5-8] Consequently, although college enrollment declined for the first time in 2011,[9] online enrollment grew by 9.3% so that the 6.7 million online students now represent an all time high of 32.0% of all higher-education students.[10]

In California, the State Chancellor's Office of the California Community Colleges recently committed $16.9 million in 2013-14 and a possible additional $10 million annually for the period 2014-2018 to the California Community Colleges Online Education Initiative (OEI).[11] The purpose of this initiative is to support the development of a statewide online education system that, by increasing access to courses that are in high demand and required for transfer, will accelerate and increase associate degree completion and transfer. The initial focus for the OEI is to use online education to support the courses needed for the Associate Degrees for Transfer.

Numerous studies have been conducted across various disciplines to determine the effectiveness of online teaching and learning.[12-24] A 2010 meta-analysis released by the US Department of Education, which included a systematic search for experimental or quasi-experimental studies of the effectiveness of online learning published in the literature from 1996 to 2008, concluded that "on average, students in online learning conditions performed better than those receiving face-to-face instruction."[4] However, subsequent meta-analysis argued that the report does not pertain to fully online, semester-length college courses.[25] Indeed, as compared to the traditional face-to-face environment, some evidence suggests that not all learners do as well in fully online courses. Using course grade and course completion as dependent variables, a study based on research conducted at community and technical colleges across the state of Washington (on 500,000 course enrollments and 41,000 students) found that in aggregate online students performed worse than their peers, with some student groups—especially males, younger students, students with lower levels academic skills, and African American students—being more negatively affected.[26] It should be noted that the study did not distinguish between different types of online learning environments, faculty preparation, or support services available to students.

A diverse literature is available to document the breadth of online undergraduate engineering courses. Representative examples include engineering graphics,[27, 28] circuits,[29-34] introduction to engineering,[35,36] statics,[37] mechanics of materials,[38] fluid mechanics,[39] power systems,[40] thermodynamics,[41,42] and engineering economy.[43-45] Studies of the effectiveness of these online engineering courses have demonstrated that they are at least as effective as the traditional lecture format.[27-30,33,36-39,45]

Researchers have attributed the challenge of designing effective online engineering laboratory courses as the most significant barrier to widespread adoption of online programs in engineering.[5,7,8,29,46,47] Alternative delivery of traditional campus labs can be implemented using a number of approaches including virtual labs (computer-based simulations of laboratory experiments), remote labs (students control equipment and instruments that are remotely located), hybrid labs (combination of virtual and remote labs), and portable lab kits (either instructor-assembled, or commercially assembled).[8]

In designing laboratory courses (traditional, or otherwise), consideration must be given to achieve the ABET/Sloan Foundation educational objectives of a laboratory experience,[46] to contribute to understanding the role of the laboratory in undergraduate engineering education, and to help guide research on the effectiveness of alternative laboratory formats, including online labs and inquiry-based engineering labs.[48] Just like lecture courses, engineering educators have experimented with distance education for engineering laboratory in a variety of courses. Circuits is one of the most widely explored subject areas for online delivery. Approaches vary from virtual labs[34] to custom-designed kits[31,32] and commercially available kits.[30] Subject areas with remote engineering lab implementation in the literature include circuits,[33] fluid mechanics[39] and manufacturing processes lab.[44] An example of a hybrid deployment of an engineering lab course is the combined use of virtual labs, lab kits, and hands-on labs for a mechanics of materials lab.[38] The above studies of these alternative approaches to lab courses show no significant difference in the performance and outcomes for students in the online and traditional labs.

2. Motivation

The critical role that community colleges play in building a larger and more diverse workforce that is educated in STEM fields has long been recognized.[49] Specifically, community colleges are an important source of prospective engineering students since millions of students attend them, and many women and students from underrepresented minority groups attend community colleges. Yet, significant increases in the community colleges' contribution to the production of STEM graduates could be achieved if more community college engineering students transferred after earning their two-year degree.[50]

For years, the 2+2 concept, wherein students are able to complete all of their lower-division coursework at a community college and then transfer to a four-year institution to complete a bachelor's degree, worked well for community college engineering students in California. In 2002, the California Council on Science and Technology reported that 48 percent of graduates with engineering degrees from the California State University (CSU) and University of California (UC) systems began at community colleges and then transferred.[51] This was made possible by a common set of lower-division courses—commonly referred to as "the core"—required by four-year engineering programs and replicated at community colleges. Students were able to start their engineering coursework at a local community college with the option of transferring to one of the many four-year schools across the state.

Recently, the diversification of transfer requirements among university engineering programs has led to the erosion of the core, increasing the number of courses that community colleges must offer in order to maintain transfer options to different engineering majors and different universities. The diversification includes variability of requirements for students in the same major transferring to different institutions, as well as for students in different majors transferring to the same university, and has resulted in declining enrollments in community college engineering programs. An analysis done by Dunmire, et al., shows that the increasing diversification of the transfer requirements of California university engineering programs, coupled with the lingering budget crisis is threatening the viability of engineering course offerings at many California community colleges. The analysis considered a typical medium-sized San Francisco Bay Area community college engineering program that has approximately 25 students transferring to the four most popular universities in the four most popular engineering majors (civil, computer, electrical, and mechanical) annually. Of the 14 different community college engineering courses included in the analysis, only one (Circuit Analysis Lecture) was projected to have a viable enrollment of about 19 students per year, with 9 out of the 14 courses projected to have an enrollment of less than 10 students per year.[52] With the majority of community college engineering programs not able to offer the lower-division courses needed for transfer, many community college students will not have access to engineering education, and others will be vastly unprepared when they transfer to a four-year program.

One obvious strategy for improving access is to enhance availability of quality online course offerings. Funded by a National Science Foundation grant, the Online and Networked Education for Students in Transfer Engineering Programs (ONE-STEP) project was developed in 2011 to accomplish an important first step toward this objective of increasing the number of California community colleges that now offer online engineering courses. ONE-STEP was developed by Cañada College, a small Hispanic-serving community college in the San Francisco Bay Area to improve community college engineering programs by aligning engineering curriculum, enhancing teaching effectiveness using technology, and increasing access to engineering courses through online education. The project included a Summer Engineering Teaching Institute (SETI) designed to assist community college engineering faculty in developing a Tablet-PC-enhanced model of instruction, as well as developing and implementing online engineering courses. The project also involved a partnership among California community colleges to design and implement a Joint Engineering Program (JEP) that is delivered online. As a result of ONE-STEP, the number of community college students who are able to take these courses and be prepared for upper-division courses upon transfer has increased. However, courses requiring laboratory components are currently not offered online in any of these colleges. As a result many students are not able to complete the required lab courses. For instance at Cañada College, although enrollments in lecture courses have increased 118% due to a dramatic increase in online enrollment (508% over the last four years), enrollments in lab courses have only increased 23%.

3. Creating Alternative Learning Strategies for Transfer Engineering Programs

Inspired by the success of the ONE-STEP program, Cañada College collaborated with College of Marin and Monterey Peninsula College to develop the Creating Alternative Learning Strategies for Transfer Engineering Programs (CALSTEP). The first objective of CALSTEP is to develop laboratory courses that are delivered either completely online, or with limited face-to-face interaction. These courses, together with the online courses already developed through the ONE-STEP Program, will enable more community college students to complete lower-division engineering courses required for transfer to a four-year institution. A second objective of the CALSTEP project is to develop and test whether alternative models of flipped classroom instruction can be used to enhance access to engineering courses that otherwise could not be supported in traditional delivery modes due to low enrollment. The project will also investigate the effectiveness of the alternative instructional models in promoting student engagement, learning, retention, and success. A third objective of the project is to create a community of engineering education practitioners adopting and continually improving the online laboratory curricula and alternative instructional models.

a. Developing Online Laboratories for Core Engineering Courses

The online laboratory courses will be developed to best achieve the thirteen objectives for engineering educational laboratories defined by the ABET/Sloan Foundation effort[46,48]. Echoing the recommendations of the PCAST report,[1] we will employ evidence-based approaches that maximize persistence and learning in a distance environment, including the use of inquiry and design-oriented activities that engage students in authentic engineering experiences. A general strategy in developing the course content and activities will be to provide students with more substantial guidance during the early foundational lab exercises, but as the exercises progress, to offer diminishing support and require more concept formation, experimentation and debugging.

Content Delivery: For all of the lab courses, content will be delivered using a variety of formats similar to those used in many existing online and hybrid engineering courses[5,27,28,29,35,62,63]. In addition to creating standard study guides and laboratory handouts in PDF format, we will produce (e.g., using Camtasia software) short modularized video tutorials from voiced-over PowerPoints, tablet-based "inking", computer animations and simulations, and actual recorded video (e.g., of equipment demonstrations). These course materials will be organized using Moodle as the Course Management System (CMS). To provide structured opportunities for discussions and student interaction, we will hold weekly synchronous sessions using the CCC Confer online conferencing platform (sometimes in conjunction with simultaneous in-person class sessions), and we will archive these sessions for asynchronous reviewing.

Assessments: A series of content-based quizzes and qualitative questionnaires will be developed to assess students' retention of the course material, as well as their perspectives on the remote-based lab experience. The results will be used to assess the effectiveness of the online experience in comparison to the face-to-face laboratory class. Using the Moodle CMS, qualitatively-oriented content assessments will be framed as concept inventories to determine how effectively students have internalized the mental models and reasoning processes that frame the course content, following similar approaches by others.[30,53] Some courses may also include a limited number of proctored assessments (e.g., midterm and final examinations) in order to ensure integrity; students may take these exams either at the college hosting the online course, the student's home institution, or a neighboring JEP partner college.

i. Online Labs for Introduction to Engineering

For the Intro to Engineering lab course, video tutorials will provide basic instruction in the use of: spreadsheet software such as Microsoft Excel for data entry, relative and absolute referencing, arithmetic and logical functions, graphing and curve fitting; FreeMat (an open-source software similar to MATLAB) for introductory programming and data analysis; free modeling software for designing balsawood bridges; and BASIC, in conjunction with a Boe-Bot robotics kit (Parallax, Inc.), to explore microprocessors, basic digital electronics, sensors and motors, program control flow, and proportional control.

We will develop a series of simple experiments that students can perform at home to generate and collect data (e.g. harmonic motion of a pendulum, or evaluating Hooke's law). Students will then apply the spreadsheet and programming tools and methods described above in order to numerically and graphically analyze both modeled and collected data.

Design Projects: A set of design projects will be developed to support learning through doing. A bridge design project will be developed and assigned to both on-site and remote students. Students will design and model their bridge using an open-source bridge modeling software (e.g. Virtual Laboratory: Bridge Designer developed by John's Hopkins University). Students will then assemble their bridges out of balsawood and wood glue, following guidelines outlined in a video tutorial. Students will write a technical report covering the structural and cost efficiencies of their design, in addition to addressing and analyzing failure modes under terminal load. An end-of-term robotic design challenge competition will be developed. The challenge, based around a Parallax Boe-Bot kit, will be to design an autonomous maze navigation vehicle. Design project kits will be distributed to online students each semester for the duration of that semester. Non-disposable materials will be returned at the end of the semester. The kit contents include bridge building materials and a Parallax Boe-Bot Robotics kit.

ii. Online Labs for Engineering Graphics

Lab Activities: Laboratory exercises involving sketching and CAD drawings will be assigned and submitted electronically through the Course Management System. Online students would be able to download student versions of both AutoCAD and SolidWorks for free. The strategy of exposing students to both of these CAD applications is to ensure that students will be prepared when they transfer to a four-year institution. In California university engineering programs, the choice of either AutoCAD or SolidWorks depends on the transfer institution and the major.

Design Projects: The course descriptor (C-ID) for the Engineering Graphics developed through JEP and submitted for state-wide approval includes "Engineering Design Process" as one of the required topics. This topic is usually introduced through a culminating design project that is assigned to students either individually or in groups, and presented at the end of the semester. To facilitate online group dynamics for the design projects, CCC Confer sessions will be organized, and the online "break-out" sessions will be utilized, allowing students to exchange ideas online, and the instructor to go from one break-out room to another to give advice and answer students' questions. For the final project presentations, online students can either come to campus, or deliver their presentations online via CCC Confer.

iii. Online Labs for Circuits

Previous university-based projects have implemented different hardware approaches to online circuit laboratories.[30-33] Several of these involve the NSF-supported Mobile Studio IO Board.[31,34] This integrated hardware/software package, when connected to a PC (via USB), provides functionality similar to that of laboratory equipment (scope, function generator, power supplies, DMM, etc.) typically associated with an instrumented studio classroom.[54] Other efforts have provided inexpensive commercial alternatives to standard bench components, with the most costly item being a Parallax USB scope.[30] A portion of the proposed activity will include evaluation of prior work in this area (hardware, software, labs) for suitability to the learning outcomes of the CA SB 1440 circuit laboratory descriptor.[55] However, our approach is expected to differ from prior efforts in regards to: 1) keeping work with physical components to the minimum level needed to achieve the necessary psychomotor, assembly, and safety outcomes;[30] 2) shifting a greater burden of the design work to virtual circuit simulators; 3) use of the latest web circuit simulators (e.g., circuitlab.com, docircuits.com) over PSPICE to capitalize on their simplified and more intuitive user interfaces, as well as realistic virtual instrumentation; and 4) use of external microcontrollers such as Arduino, Parallax or Raspberry Pi with various sensor components to provide more compelling hands-on experiences that augment the standard laboratory topics for circuits.

Lab Activities: A threefold set of laboratory exercises will be developed to achieve the learning outcomes for an online circuits laboratory[30]: 1) basic hands-on exercises involving inexpensive electronics components and instrumentation, 2) web-based simulators for design and investigation of more complex circuits, and 3) use of open-source software such as FreeMat for developing analytic solutions to complex circuits. We plan to alternate between the three modalities (hands-on, circuit simulation, numerical analysis) throughout the term. Hands-on activities will involve setting up basic circuit law and series/parallel experiments; basic first-order RC and RL step response; building and measuring an audio amplifier using an op-amp; working with diodes and transistors as light emitters and switches as well as in switching circuits for motor control; use of photo, IR and ultrasound sensors in a microcontroller application, with associated conditioning circuits; and characterizing frequency response of first- and second-order circuits. We will use CCCConfer, mobile phones and web cameras to help students troubleshoot their circuits. Circuit simulation activities will involve design of a voltage divider according to specification, nodal and mesh circuits (DC and AC) to verify analytical results, first- and second-order circuits (step and sinusoidal response), and i- v characterization of nonlinear components, among others. While reinforcing the learning outcomes of the circuit theory class (concept formation, analysis and design), it is important that the labs also engage students with intrinsically compelling activities of the kind that initially drew them into engineering.

Design Project: Design activities will be embedded into each week's laboratory exercises. In addition, to engage students more deeply in the design process, and to provide a foundation for further self-guided exploration, a suitable final project will be required. Students will choose from a range of options loosely tied to the content of the laboratories. Projects may involve relatively simple to moderate applications from control theory, communications, mechatronics or audio processing, and the student will be encouraged to keep their project when the class is over.

iv. Online Labs for Materials Science

We will adopt a hybrid delivery approach to the Materials Science labs, incorporating mostly at-home experiments and exercises, but also including several face-to-face experiments late in the course that require use of traditional materials testing equipment. The at-home lab exercises will be of three types: (1) use of physical and virtual models to explore concepts, (2) testing of materials using qualitative and/or crude quantitative methods, and (3) analysis of experimental data supplied by the instructor.

Exercises that involve physical models and virtual simulations employ kinesthetic and visual modes of learning as an aid to concept exploration, and can easily be conducted by students at a distance. For example, construction and manipulation of foam-ball models of crystal structures can help students better understand fundamental concepts of crystallography, and computer simulations can be used to help students better understand abstract concepts such as barriers to slip during plastic deformation of metals. Exercises that involve testing of materials at home, even in a relatively crude manner (e.g., comparing mechanical properties of various candies), allow students to develop abilities in experimental design, creativity, data collection, evaluation of theoretical models, and learning from failure, as they explore important concepts and gain physical intuition about the behavior of common materials. Exercises that require students to analyze supplied data sets from actual experiments (e.g., a standard tensile test or an x-ray diffraction measurement) give them opportunities to refine their quantitative analysis skills and their abilities to interpret results, evaluate theoretical relationships, and defend conclusions.

All of these at-home exercises will develop some foundational laboratory skills that can be applied toward more sophisticated experiments near the end of the course. These face-to-face experiments will emphasize authentic inquiry and/or engineering design, and will require greater independence from the students in designing experimental approaches that aim to achieve objectives that have been defined by the instructor. Students will work in teams, using asynchronous discussion forums and synchronous web conferencing sessions, to design and plan their experiments in advance. Earlier computer simulations and exercises will be used as an adjunct to help prepare students for the in-person laboratory testing, acquainting them with the safety concerns, operational sequence, and effect of process parameters in standard testing methods (e.g., tension test, hardness test, thermal processing, etc.). This should help them to work more effectively through orientation and operation of the laboratory equipment.

b. Flipped/Emporium Models for Low-enrollment Engineering Courses

As part of CALSTEP we will investigate existing educational resources for engineering students that can be used to support flipped classroom methodologies. These resources should ideally include brief modularized video lessons, accompanying formative assessments, and guided-inquiry exercises. For at least the Intro, Graphics, Materials and Circuits courses, many of these resources will naturally be created in support of Objective 1 described above. For other courses, some appropriate content has been created and made available as part of the ONE-STEP project and other online engineering education efforts. For those courses where appropriate content is not available, we will develop additional digital video lessons, as well as accompanying activities, exercises, and assessments for use in a “flipped classroom” approach. In particular, even where online video and exercises are available, we may need to develop different resources that are more appropriate for the in-class portion of the flipped course.

Another important aspect of the project is to coordinate with instructors at other institutions to share resources, align learning outcomes and curriculum, and conduct pre- and post-course assessments for the study. In this way, we hope to compare the efficacy of different delivery approaches across multiple institutions.

We will also implement “small college” pilot study investigating four different approaches to offering classes:

A) Flipped classroom approach with dedicated single-course class session—This will be a “more traditional” approach to flipping the classroom, with each in-person class session composed of students who are all enrolled in the same course. This approach should provide some measure of the effect of flipping the classroom on student outcomes.
B) Flipped approach with simultaneous paired-course lecture class session—This will involve the co-scheduling of two different courses, so that students from both courses meet simultaneously with a single instructor, effectively combining enrollments.

C) Flipped "emporium" approach with required meeting hours chosen from a menu of options—Although students in this model have the normal number of required meeting hours per week, they may choose the in-person days and times from a broader range of scheduling choices. As a result, students meeting at any given time may be enrolled in a broad range of courses, and the instruction will necessarily be of a more individualized nature. These sessions could also be made available for optional drop-in support to online students.
D) Simultaneous paired-course lab sessions utilizing traditional instructor-supervised experiments along with those developed as "online labs"—The lab components of the Circuits and Materials courses will be taught simultaneously, and scheduled such that students in one course will be completing equipment and/or risk-intensive experiments under close instructor supervision, while students in the other course are working more independently to complete experiments designed for the online lab course.

4. CALSTEP Progress Update

This section is a description of the progress that has been made by the CALSTEP program after its initial implementation in fall 2014.

a. Introduction to Engineering Laboratory

Work on the Introduction to Engineering Laboratory portion of this project began in the fall 2014 semester. At this early stage in the project a primary objective was to identify and design a set of experiments that provided hands-on exploration in the major fields of engineering and the engineering design process, and would work well in a remote learning setting. A related objective was to identify and source a set of equipment to support these experiments with minimal travel to a college campus, and would still maintain technical caliber. In addition to exposure and exploration in the major engineering disciplines, emphasis was placed on fostering general experimentation skills, such as how to design an experiment, familiarity with lab instrumentation, how to properly plot, analyze, and interpret data, how to assess and quantify measurement error, and how to report results with honesty and integrity.

<u>Set of Lab Experiments:</u> Table 1 outlines a set of lab experiments for the Intro to Engineering course. The curriculum is intended to address ABET's thirteen lab objectives[46]. The CALSTEP Advisory Board members provided consultation on the laboratory curriculum, all of whom have substantial experience teaching a similar course. The course begins with labs designed to teach students skills in experimentation, measurements, error analysis, along with techniques in a spreadsheet program and MATLAB/FreeMat for data visualization, analysis and interpretations. The course then explores topics in Materials Science, Civil and Mechanical Engineering, and introduces technical drawing in AutoCAD, which was chosen as our CAD tool over Solidworks because students can get a free 3-year license for AutoCAD. Midway through the semester, a bridge competition is held and the students work on a Student Educational Plan that projects their coursework all the way through graduating with the Bachelors of Science degree. Finally, the course finishes up in Electrical and Computer Engineering with topics in electronics and test equipment, sensors and measuring physical phenomena, microcontroller programming and data acquisition, and select topics in robotics with a design competition.

Table 1. Intro to Engineering Lab Experiment Schedule

Week	Lab[1]	Topics
1	1. Introduction to Excel	Data-entry techniques, relative and absolute referencing, arithmetic and logic operations, graphing
2	2. **Introduction to Measurements, Error, and Linear Regression**	Data collection, measurement techniques, precision vs. accuracy, curve-fitting and linearization, quantifying measurement error
3	3. Introduction to Problem Solving in MATLAB/FreeMat	Variables, vectors/arrays, plotting, systems of equations
4	4. Programming in MATLAB/ FreeMat	Scripts, conditional logic, control flow, functions
5	5a. **Exploring Mechanical Properties with Candy** 5b. *__Tension Test of a Metal__	Exposure to common mechanical properties: stiffness, yield strength, resilience, ductility, impact toughness, hardness. Tensile test to measure mechanical properties of low-carbon steel.
6	6. Intro to Technical Drawing in AutoCAD	Units, pan/zoom, geometric objects, precision, layers, object properties, basic editing, 3D drawing, isometric drawing
7	7a. Introduction to Trusses and Structures, Bridge Design	Truss structures, members in compression/tension, bridge modeling software, engineering design. Students use this session to layout their design plan in Autocad prior to construction.
8	8. *Modeling Drag Force in a Wind Tunnel* 7b. Continued work on Bridge project above	Viscous fluids/friction, drag force, numerical modeling/analysis. Bridge construction.
9	7c. ***Bridge Competition/Report**	Static loading, failure analysis, learning from failure. Technical writing, design report.
10	9. 4-yr Student Educational Plan (SEP)	Students identify a university they want to transfer to and develop a SEP that extends all the way up to graduation with a BS degree.
11	10a. **Intro to Electronics and Test Equipment**	Ohm's law, DC circuits, variable voltage sources, AC signals, function generator, oscilloscope, amplification
12	10b. **Intro to Electronic Sensors and Measurement**	IR distance sensors, accelerometers, photo-transistors, sensor resolution, curve fitting and calibration.
13	11. **Intro to Microcontrollers, C- Programming, and Robotics**	Basic microcontroller features, digital IO, PWM and servos, analog-to-digital converters, basic C-programming, conditional logic, control flow.
14	12a. **Robotics: Object Detection**	Sensor calibration, distance estimation, applied microcontroller programming.
15	12b. **Robotics: Autonomous Navigation**	Conditional/sequential programming, program design with flowcharts, engineering design, team-based design.
16	12c. *__Robotics Competition and Report__	Engineering design, technical writing, design report.
17	***Final Exam** (if given)	

[1]Legend for Labs: Plain text = Analysis; *Italic = Modelling (Virtual or Physical)*; **Bold = Experimental**; ***Bold = On-campus expt**.

Over the semester there are only three on-campus lab activities, one for each of the two design competitions, and a third activity to perform a tensile test on low-carbon steel. The Advisory Board agreed that three face-to-face visits over the semester seemed like a reasonable traveling commitment for an online student taking such a course. It was also recognized that for students in circumstances with severely limited travel ability, the tensile test lab could be conducted as a virtual/modeling lab, in which online students would analyze previously gathered stress-strain curves and run a virtual tensile test using an online simulator. The concurrent mechanical properties of candy lab, intended to give further insight into mechanical properties and also give students lab work to do while waiting to use the tensile tester, could be easily done remotely too.

One of the challenges in this phase of the project has been in identifying curriculum examples or materials for an existing online Intro to Engineering course to gain perspective and lessons learned to help guide our efforts in curriculum design, delivery format and logistics, and assessment. While a number of schools have implemented other online engineering lab courses (Circuits having the largest presence), it seems that few institutions have implemented online Intro to Engineering labs yet. Efforts are currently being made to seek out those with direct experience in this area.

<u>Design Projects:</u> Two design project competitions are integrated into the curriculum, with experiments built into the schedule for students to work on their designs leading toward the competition. The first project is a balsawood bridge competition. The project handout and video tutorials provide guidelines on how students can design and layout their bridge using Autocad (for which students can get a 3-year license for free) before they begin construction, in addition to video demonstrations on wood gluing, construction techniques, and safety precautions. We're also developing a tutorial to provide guidelines on how to model static and dynamic loading for students to explore before testing their constructed bridge. On completion of the project, students travel to campus to test their bridges in a load-until-failure process. Students finally compile a technical report covering the structural and cost efficiencies of their design, in addition to addressing and analyzing failure modes under terminal load.

The second design project is a robotics competition, in which students design an autonomous maze navigation vehicle. The development platform for the project is an Arduino-equipped Boe-Bot robot kit (Parallax, Inc.) which contains a robot chassis, continuous rotation servos and wheels, an assortment of different sensors and electronic components, and an Arduino microcontroller board. The laboratory activities leading up the robotics competition at the end of the semester sequentially build students' proficiency in working with electronics, sensors, programming microcontrollers, object detection, and autonomous navigation. Students travel to campus for the final competition, where each team will be scored on time-completion and success rates. In both of the online design projects, we are intending to implement video conferencing for students to help build teamwork skills and collaborate on design approaches.

<u>Assessment and Pilot</u>: A pre- and post-course survey has been developed to assess key concepts in engineering experimentation and the various engineering disciplines, and to gauge students' identity as engineers and their confidence in succeeding in engineering study, along with their perception on the laboratory experience. In addition to the pre- and post-course surveys, a set of content-based quizzes and qualitative questionnaires are being developed to measure retention of

the course material. The multiple choice quizzes are to be administered online the week following each lab exercise, and are not intended to be graded in the course.

The lab activities and assessment tools are currently being piloted in a traditional face-to-face laboratory setting at Cañada College this spring 2015. Some of the questions we're looking to address for the face-to-face control group this Spring 2015 are whether or not the lab activities have helped students gain perspective on the particular discipline, and what importance face-to-face students place on group work to (1) do well in lab experiments, (2) understand the background concepts, and (3) excel in the design projects. We're also interested to learn what importance they place on having an instructor present while they were working. Finally, we're looking to use the aggregate data to measure success on achieving the ABET laboratory objectives and for eventual comparison to future online cohorts.

b. Engineering Graphics

Since the CALSTEP project did not commence until halfway through the fall 2014 semester, and the Engineering Graphics course is taught at Cañada College during fall semesters only, the online version of the course will not be piloted until fall 2015. The first year of the grant will be devoted to reviewing available resources and developing new ones needed to implement the online course.

Fall 2014 was devoted to reviewing available resources and curricula on AutoCAD and SolidWorks that could be adopted for the online Engineering Graphics course. Since AutoCAD and SolidWorks are the two CAD software systems most commonly used by four-year engineering programs, it is important that the community college online course being developed prepares students in using both systems. After reviewing a number of commercially available products, the team decided to develop new resources for the class because of the following considerations:

- Most available teaching resources focus developing proficiency in using the software applications, and considerable customization will be needed in order to blend these resources with simultaneous student exposure to engineering graphics concepts.
- No commercially available products that have well developed resources for both AutoCAD and SolidWorks have been found.
- Costs to students would be prohibitive, especially if they have to pay for both AutoCAD and SolidWorks resources.
- Autodesk products are now available free to students, and free copies the student version of SolidWorks usually come with institutional licenses. As a result online students have access these CAD programs without costs associated with using commercially available curricula.

The development of the online laboratory exercises has commenced. For each online laboratory exercise supporting resources will include written step-by-step instructions that will enable online students to complete the lab with minimal assistance from the instructor. Additionally, video recordings of the laboratory solutions will be available in cases when students have difficulty completing the labs using only the written instructions. Table 2 is a summary of the laboratory exercises for the class, and the timeline for the completion of their development.

Table 2. Summary of online labs to be developed for Engineering Graphics, including the timeline for the completion of handouts with written step-by-step instructions and supporting videos.

Topics	CAD Software	Handouts	Videos
Basic 2D construction	AutoCAD	Fall 2014	Spring 2015
Engineering Geometry; Editing tools	AutoCAD	Fall 2014	Spring 2015
Design Visualization	n/a	Fall 2014	Spring 2015
Orthographic Views	AutoCAD	Fall 2014	Spring 2015
More Orthographic Views	AutoCAD	Fall 2014	Spring 2015
Pictorial Sketches	n/a	Fall 2014	Spring 2015
Pictorials with AutoCAD	AutoCAD	Spring 2015	Spring 2015
Section Views	AutoCAD	Spring 2015	Spring 2015
More Section Views	AutoCAD	Spring 2015	Spring 2015
Basic Dimensioning and Notes	AutoCAD	Spring 2015	Spring 2015
Auxiliary Views	AutoCAD	Spring 2015	Spring 2015
Wireframe Modeling	AutoCAD	Spring 2015	Spring 2015
Solid Modeling	AutoCAD	Spring 2015	Spring 2015
Geometric Dimensioning and Tolerancing	AutoCAD	Spring 2015	Spring 2015
The Design Process	n/a	Spring 2015	Spring 2015
SolidWorks parts	SolidWorks	Summer 2015	Summer 2015
Assemblies	SolidWorks	Summer 2015	Summer 2015
Working Drawings	SolidWorks	Summer 2015	Summer 2015
Advanced construction techniques	Solid Works	Summer 2015	Summer 2015
Advanced Design and Drawings	SolidWorks	Summer 2015	Summer 2015
Animations	SolidWorks	Summer 2015	Summer 2015
Simulations	SolidWorks	Summer 2015	Summer 2015

c. Online Circuits Labs

Work on the circuits labs portion of the project began last year as an exploratory effort in advance of grant funding. A pilot online circuits lab class was provided to six students, working alongside an in-place class of 12. Due to time constraints, the labs were constructed as a work in progress, with the intention of adapting and expanding them in successive semesters with input from the CALSTEP Advisory Committee and the relevant research into desirable outcomes for online laboratories[46].

Previous university-based efforts have implemented a variety of approaches to online circuits laboratories,[30-33] often using inexpensive commercial alternatives to standard bench components. Furthermore, at least two circuits MOOCs[x,y] with labs are now available, one with entirely virtual labs [6.002x], the other using the National Instruments myDAQ [coursera eefunlab], a small, low-cost USB data acquisition (DAQ) device. Finally, companies like National

Instruments, Parallax and Digilent also provide well designed courseware and lab activities to accompany their low cost devices and trainer boards[x,y,z].

A primary question related to online laboratories relates to how much learning can be achieved via software simulators, which are inexpensive and easy to access, and how much needs to involve physical activities, which develop greater psychomotor, troubleshooting and problem-solving skills.

With this in mind, we employed three guiding principles in developing activities for our circuits labs pilot: 1) provide hands-on exercises involving inexpensive electronics components and instrumentation, 2) use web-based simulators (circuitlab.com, docircuits.com), with their highly intuitive user interfaces and sharing capabilities, for design and investigation of more complex circuits, and 3) use numerical software such as FreeMat (a MATLAB-like environment) for developing analytic solutions to complex circuits. The labs alternate between the three modalities (hands-on, circuit simulation, numerical analysis) throughout the semester.

Design of Circuits Kit: Due to the challenge of remote debugging, a concerted effort was made to simplify the kit components and experiments as much as possible. For example, only nine different resistor values, three capacitor values, one potentiometer value, one inductor, and a single op-amp type are provided. In addition, bulky variable DC power supplies are replaced with DC wall adapters connected via breadboard-friendly barrel jacks and varied by adjusting a potentiometer.

Another simplification comes from swapping a 100 ohm audio speaker for the standard 8 ohm speaker, which requires higher current and a more complex amplifier to drive. This provides students an easy path to another sensory modality with which to perceive their circuit operation, and opens up possibilities for further exploration and discovery.

Instrumentation is provided by a low-cost digital multimeter and the Digilent Analog Discovery multifunction USB device, which includes a, voltmeter, +/- 5V power supply, 2-channel oscilloscope, arbitrary waveform generator, spectrum analyzer, logic analyzer, and more.

Finally, inclusion of an Arduino microcontroller provides opportunities for additional context in the use of analog circuits in digital systems and exposes students to the rapidly expanding use of microcontroller technology.

Overview of Lab Activities: Table 3 presents an overview of the activities covered by the pilot online circuits labs, showing topics covered and modalities employed during the lab. The coverage of topics are chosen not only to support the analytical demands of the circuit theory co-requisite course but also to anchor the abstract circuit theory content in concrete experiences.

Additional content, including coverage of diodes, transistors, microcontrollers, as well as simple experiments involving audio signal processing (among others) are included to round out student appreciation of the broad application of circuit theory to the electronics field and provide compelling experiences to encourage deeper exploration.

Table 3. Overview of online circuit lab activities.

Lab	Topics	Modalities
1. Intro to MATLAB/FreeMat	Variables, functions, script files, vectors/arrays, plotting and solving systems of equations	numerical analysis
2. Electrical Safety, Breadboards, Using a DMM	Resistor color codes, circuit topology, translating from schematic to breadboard	hands-on
3. DC Simulation with CircuitLab	Build/simulate modes, DC sweep, dependent sources	simulation
4. Series and Parallel Circuits	Voltage and current dividers, design of a voltage dividing resistive network	hands-on simulation
5. Nodal and Mesh Analysis	Circuits with a) single source, b) super node, c) super mesh, d) dependent source	numerical analysis simulation
6. Thévenin Equivalents	Comparison of two equivalent circuits in CircuitLab Comparison of methodologies to determine	numerical analysis simulation
7. Operational Amplifiers	Comparison in CircuitLab of circuit with non-ideal op-amp model vs circuit with an op-amp Breadboard construction of op-amp circuits Amplification and volume control of audio from media player, audio mixing two channels	simulation hands-on
8. Diodes and Transistors	Ideal diode and transistor models Measuring i-v curves of an LED Measuring current gain of a transistor Dusk to dawn lighting circuit	hands-on
9. First-Order Circuits and Oscilloscopes	Basics, experimental determination of time constant of switched capacitor circuit	hands-on
10. First-Order Time Domain Simulation using CircuitLab	Determining and plotting transient response in CircuitLab and MATLAB/FreeMat	simulation numerical analysis
11. Phasors and MATLAB	Complex valued arithmetic in MATLAB/FreeMat Phasor transforms, AC solution by phasor analysis	numerical analysis
12. Phasor Nodal, Mesh, and Thévenin	Using MATLAB scripts to simplify complex calculations, solving complex values systems of eqns	numerical analysis
13. AC Circuit Measurements	Measuring RMS voltage and phase difference between sinusoids	hands-on
14. Electronic Sensors & Microcontrollers	Initial setup of microcontroller, determining potentiometer position, generating sound, controlling audio frequency with potentiometer	hands-on
15. Frequency Selective Circuits	Measuring frequency response, computing Q of a resonant circuit, exposure to Bode plots, filtering audio signal with mixed audio at different frequencies	hands-on

In order to move beyond the structured activities of the labs, near the end of the semester students are required to choose a final project from a range of options. Project choices are selected from popular electronics sources as well as examples from the theory class.

Content Delivery: Throughout the course, all content in the form of lab handouts and support files is delivered from the class website. Video from class is webcast synchronously and archived online using CCCConfer, with notes and photographs of intermediate steps posted to a social media site for ease of access. The technology and protocols used in streaming lectures and lab content using pen enabled notebook computers has been developed and disseminated by the Summer Engineering Teaching Institute (SETI), offered for the past 4 years by Cañada College in San Mateo, California.

Challenges: Implementing the pilot online circuits laboratories for this grant met with a number of challenges needing to be addressed. The greatest challenge was developing the lab kits and managing the complexity of selecting a large number of components that needed to be compatible with the intended activities, sourced from a multitude of possible vendors. There was insufficient time to test all the activities before shipping the kits, so some exercises were deleted on the go. Also, the online kits differed significantly from the classroom kits, which meant for several labs multiple versions of the handouts needed to be posted. Finally, discovering a desirable USB instrument fairly late in the process required a great deal of reworking of the lab as well as additional shipping charges.

Challenges to delivery of these pilot labs were mostly related to the inability to communicate as effectively as in the classroom. A peripheral web camera was not sufficiently sensitive to be able to webcast a readable image of the breadboard for live demos during the classroom section and was abandoned in favor of stills from a digital camera due to lack of time. The high capability of the cohort of online students in the pilot meant that there wasn't as much debugging needed as expected, but this will not always be the case. Finding ways to assist with troubleshooting will be an ongoing theme for the next iteration.

d. Materials Science

Materials Science at College of Marin is a 3-unit course that traditionally met weekly for one 2-hour lecture session and one 3-hour lab session. In the flipped format, students complete reading assignments and watch lecture videos outside of class time, and use the two-hour lecture session to engage in group discussion and problem-solving exercises. The 3-hour lab session is used for laboratory experiments. However, these labs include inquiry-oriented analysis and modelling activities, as well as more conventional materials testing experiments.

The curriculum design for the Materials course was informed by consultation with CALSTEP Advisory Board members, all of whom have considerable experience teaching a similar course, some in community colleges and others in university settings. One important decision involved the design of the laboratory curriculum, and in particular, the number of required face-to-face labs. Although all of the labs would be performed face-to-face by students during the Spring 2015 flipped format course, some of these labs are intended for at-home completion in future hybrid offerings of the course.

The proposed labs were mapped to the thirteen learning objectives for engineering educational laboratories as defined by the ABET/Sloan Foundation effort[46], in order to ensure that all objectives were addressed in the curriculum. For the spring 2015 course, there are five lab sessions dedicated to experiments that would typically be performed in a face-to-face setting because of equipment requirements and/or safety concerns. The consensus of the Advisory

Board was that five face-to-face visits was a reasonable requirement of students enrolled in such a hybrid Materials course. On the other hand, it was also felt that the course could accomplish all educational objectives at a satisfactory level if two of the proposed experiments were offered in an alternative virtual/analysis format, a potentially attractive option for some institutions, instructors, or students with unique circumstances where five required visits would be impractical. In such a case, the only face-to-face requirement would be a single 3-part brass lab that utilizes tension testing, hardness testing, and annealing treatments to investigate (1) strain-hardening characteristics, (2) recrystallization and grain growth kinetics, and (3) application of the results to achieve a process design objective.

Table 4. Materials Science & Engineering Topic Sequence – Condensed Overview

Week	Major Topic	Activity	Lab[1]
1	Introduction: Overview	Pre-course assessment	1. Intro to Materials Sci & Engin
2	Review of Atoms & Bonding Thermal Properties	Bonding Analysis exercises	2. *Ionic Bonding Spreadsheet Model*
3	Electrical & Chemical Properties	Thermal and Electrical exercises	3. **Corrosion of Metals**
4	Mechanical Properties		4. **Mechanical Props with Candy** 5. (Virtual) Tension Test of a Metal
5	Crystal Structures of Metals	Mech Property exercises	6A. *Crystal Modelling 1: Metals*
6	Crystal Structures: Ceramics Crystallography		6B. *Crystal Modelling 2: Ceramics* 7. X-ray Crystallography
7	Defects and Microscopy	Defects & microscopy exercises	
8	Slip & Strengthening: Metals	Slip & Strengthening Slip & Strengthening	8A. ***Strain Hardening of Brass** 8A. ***Strain Hardening of Brass**
9	Diffusion & Recrystallization	Diffusion exercises	8B. ***Recrystallization of Brass**
10	Binary Phase Diagrams Phase Transformation Kinetics	Phase Diagram exercises	9. ***Phase Equilibrium Lab** (virtual option)
11	Processing of Steel	Alloy Processing exercises	8C. ***Brass Design Evaluation**
12 13	Failure Mechanisms Polymer Structure & Characteristics	Failure exercises	10. ***Heat Treatment & Impact** 11. **DIY Experiment**
14	Chars of Ceramics & Glass	Polymer exercises	11. **DIY Experiment** (cont.)
15	Composites	Ceramics, glass, composite	Report / Presentation Preparation
16			12. Case Study Presentations

[1]Legend for Labs: Plain text = Analysis; *Italic = Modelling (Virtual or Physical)*; **Bold = Experimental**; ***Bold = On-campus expt**.

For the lecture content in the Materials course, online media in a variety of formats and from a variety of sources were selected in order to investigate student preferences. The variables include: (a) publicly accessible versus private or proprietary, (b) modularized content (2 – 20 min) versus full-length lectures (60 – 120 min), (c) Flash presentations of voice-over slides versus MP4 video of tablet PC based presentations, (d) studio recording versus classroom lecture archive, (e) course instructor versus other presenter. Altogether, five distinct combinations of these variables were employed, as summarized by the table below. One additional and important distinction was that Type 2 and Type 3 were of a higher production quality than the others. These lessons were produced by the UC Davis Extension program for their own E45Y course and made available to the community college students for purposes of this study; all other lecture types were produced by individual instructors with little or no additional support.

Table 5. Matrix of variables in formats of online media used to deliver lecture content in Materials Science course.

	Availability	**Duration**	**Style**	**Recording**	**Presenter**
	A = public B = private	A = modular B = full-length	A = voice-over B = video	A = studio B = classroom	A = instructor B = other
Type 1	B	A	B	A	A
Type 2	B	A	B	A	B
Type 3	B	A	A	A	B
Type 4	A	B	B	B	B
Type 5	A	A	A	B	B

All of the content was accessible to students from links in weekly activity blocks of the CMS (Moodle course), as well as from hyperlinks in a single tabular-format course schedule document. Students were asked to regularly indicate their perceptions and preferences regarding the lessons using anonymous survey tools on the course website.

One primary concern about flipped format courses that is often expressed by instructors and supported by data is the inadequate effort by students to complete the assigned reading and viewing before class sessions. This undermines the ability of students to fully contribute to problem-solving and laboratory activities during class sessions, and leads to frustration among the well-prepared students on their teams. As an incentive to ensure that students (a) arrived on time to class sessions and (b) completed reading and viewing assignments, brief multiple-choice quizzes were administered during the first few minutes of each class session to confirm adequate preparation.

During development of the online lecture content for the Materials Science course, it was challenging to locate existing media resources that were simultaneously (1) open and publicly accessible, (2) well aligned with the learning objectives of the course, and (3) in a format optimal for self-directed online learning (e.g., modular, engaging, time-efficient, etc.).

There exist a number of excellent videos, e.g., on YouTube, which satisfy criteria 1 and 3, but such videos address only a handful of the topics covered in the course. Similarly, there exist a number of archived lecture collections for entire materials science courses that satisfy criteria 1 and 2, but the formats may not be optimal for use as surrogate lectures in an online or flipped course. Since most of these are archives of face-to-face lectures, they often drift away from the core learning objectives to tangential topics (e.g., in response to student questions, discussion of homework problems and course administrative details, etc.). Also, most are full-length 1.5-hr to 2-hr videos, making it difficult for students to maintain focus and to locate specific topics of interest. There does exist one complete set of appropriate lecture media resources that was suggested by an Advisory Board member; these lectures are fairly ideal in terms of satisfying criteria 2 and 3, but are proprietary to the UC Davis Extension program, having developed them for their own online version of this course. Fortunately, permission was granted to make two sets of lessons available to students in the study, in order to explore student perception of their relative usefulness in comparison to other format types. However, use of the entire collection for future community college course delivery would, even if permitted, likely require a pay-for-service arrangement that might not be financially viable for most community college students and/or programs.

As a result of these challenges, one of the co-authors developed in-house a number of modular lessons, utilizing presentation software on a tablet PC and Camtasia software for screen capture, editing, and MP4 video production. However, this process was extraordinarily time consuming, requiring many hours of labor per hour of video produced, in order to arrive at a result that was even modestly comparable in quality to the UC Extension lectures described above. Producing a complete set of such lecture modules for the entire Materials Science course would require division of effort over multiple semesters and/or multiple individuals.

e. Flipped Classroom Format for MATLAB Programming

In the fall 2014 semester, resources were also developed for teaching two courses *Programming in MATLAB for Engineers* in a flipped format during the spring 2015 semester at College of Marin. The resources were developed with the concept that they could be used for future implementation in online courses, or in a hybrid fashion. Additionally, future flipped implementations may involve combining students from two or more low-enrolled courses into a single student-centered classroom session, with a single instructor acting as problem-solving coach.

Programming in MATLAB is a 4-unit course that traditionally met for two 3-hour sessions weekly, with time divided equally between lecture and lab. In the flipped format, students complete reading assignments and watch lecture videos outside of class time, and use all 6 hours of scheduled class time for completing hands-on programming laboratory exercises and (formerly) “homework” assignments. Note that any portions of labs or homework that are not completed during class are expected to be completed outside class.

In preparation for teaching the flipped course, existing labs and homework assignments were modified slightly to better align with the new delivery format, and videos were recorded to deliver the lecture content. These lectures were recorded in 1 to 1.5 hour sessions using the CCC Confer webconferencing platform with a live captioner as the only session participant. The presentations utilized a screencasting format on a Tablet PC with prepared PowerPoint images, live "inking," and use of the MATLAB environment. Students are expected to watch one of these lectures before each class meeting (i.e., twice per week), and the content of each lecture directly addresses the topics that will be explored in each lab session. These topics may include general programming or problem-solving concepts, MATLAB syntax, numerical techniques, and in some cases background information regarding contextual applications that may appear in some of the lab exercises. Most of the lectures include presentation of general theory interspersed with examples that demonstrate application of the theory and structures in MATLAB.

The lab exercises involve a combination of guided-inquiry approaches to introduce new concepts or programming structures, together with more complex problem-solving challenges that require application of these concepts. For the latter exercises, students are encouraged to work collaboratively in pairs or in groups of three or four. In contrast, students are encouraged to work alone on completing the homework assignments. Most of these exercises are aimed at reinforcing the skills and knowledge gained during class, using more well-defined problems of narrow scope.

5. CALSTEP Project Assessment

The evaluation includes a formative and summative component that will be implemented through a series of qualitative and quantitative research activities. The two evaluation components are guided by inquiries that were developed by the evaluation team in collaboration with the CALSTEP PI and Co-PIs.

<u>Formative evaluation questions:</u>

1. To what extent did the project team succeed in implementing the proposed project components?
   a) What did the team accomplish in terms of developing, piloting, disseminating and delivering online lab curriculum?
   b) What did College of Marin accomplish in terms of developing, piloting, disseminating and delivering courses using alternative delivery strategies?
   c) How satisfied were students with the alternative delivery?
   d) How effectively did the team promote the alternative delivery models to the CCC and four-year college communities?
   e) How effectively did CAL-STEP leverage inputs and secure additional support?

2. What were the challenges, unanticipated outcomes, and lessons learned?
   a) What did the team learn in terms of how to effectively develop, disseminate and deliver online lab and other alternative delivery strategies?

Summative evaluation questions:

1. To what extent did the project increase course offerings in engineering at the participating colleges?
2. Did students in courses using alternative delivery strategies learn and retain course materials differently than students in traditional lecture style courses?
3. Did access to alternative models of engineering courses increase student enrollment and persistence to transfer?
4. Did students in courses using alternative delivery strategies enjoy higher persistence and success rates than students in traditional lecture style courses?
5. Did faculty trained in alternative delivery strategies adopt the new models at their own college?

The research instruments that will be used by the evaluation team include interviews, focus groups, surveys and analysis of data on student retention and outcomes.

Building Connections: In addition to addressing these areas of inquiry, the evaluation will also attempt to connect CALSTEP with related efforts in progress at other colleges and universities around the US and beyond so that CALSTEP can be informed by lessons learned at other institutions and so that CALSTEP can contribute to the field of research into online and other alternative course delivery in engineering.

Progress Achieved and Very Preliminary Findings: To date, progress has been made in documenting the team's progress in developing online and other alternative delivery strategies. Initial findings underscore the effort that is required to design courses that will be delivered online or flipped and, in particular, the time-consuming and challenging task of identifying from among so many options, an effective combination of video, hardware, text books and in-class activities and experiments. A key question for the CALSTEP faculty has been how much to draw on existing curricular resources and hardware and how much to develop in-house. The result has been many dozens of hours of research into alternative commercial products; review of a large number of alternative videos as well as development of new video material; efforts to determine which text books to use in order to achieve alignment with video material; and time consuming assembly of materials for lab-boxes.

At the same time, the magnitude of this challenge highlights the benefits that faculty in other institutions will derive from having their CALSTEP colleagues use the grant support to engage in these endeavors. Once the curriculum has been developed and the options for delivery assessed by the CALSTEP team, others will be able to draw from this experience as they prepare to deliver their first online or flipped course.

It is also clear at this point that the first several iterations of each class will involve ongoing experimentation to determine what works. As an example, one of the grant Co-PIs is experimenting with four different formats for delivering videos to a flipped course. The faculty member and evaluator will collaborate to collect student feedback on each format, including students' own perception of how effective a particular video was in helping them understand the material.

Initial student interviews in another course that piloted in fall 2014 found that even highly motivated and successful students struggled to adjust to the flipped format. A particularly common challenge for the students was that they could not simply raise their hand and ask a question if they did not understand the video lecture, but had to repeat sections of the video and/or consult a text book to find answers and clarification that the professor would normally have provided in class. In fact, several of the students interviewed noted that one thing that really helped them adjust to the new video format was that they could email their professor with questions that arose as they watched the videos at home and almost always receive a quick response. However, while this kind of support was greatly appreciated by the students, it is not scalable. As the professor himself pointed out, it also does not challenge the students to find the answer on their own.

Upcoming Evaluation Activities: During the coming semester, as the course design and curriculum that CALSTEP faculty developed in Fall 2014 is tested in the classroom, the evaluation team will conduct focus groups, interview and surveys with both students and faculty to document and assess how the new instructional format is working. The evaluation will also include faculty interviews and documentation and assessment of retention in the alternative delivery courses. In addition, students who drop out of the courses will be invited to participate in interviews to explore why they did not persist.

Making Connections: The CALSTEP Advisory Committee was deliberately formed to include national and international leaders in online and other alternative course delivery. At the present, three such leaders are represented on the Advisory Committee and the CALSTEP team will be consulting with each of them throughout the project to incorporate into the CALSTEP curriculum and courses lessons learned elsewhere. The Advisory Committee members who bring to the project this expertise include:

- Dr. Kathleen Mehan who is on the faculty of Virginia Tech, but presently teaching at the School of Engineering in Glasgow, Scotland. An NSF grantee, Dr. Mehan brings to the project many years of experience experimenting with online labs and the development of labs-in-a-box
- Dr. Bonnie H. Ferri from Georgia Tech, who recently taught a flipped circuits course for 450 students with support from nine teaching assistants. Dr. Ferri, also an NSF grantee, advised that when developing an online lab faculty members should consider how to incorporate ABET’s 13 objectives for a successful engineering lab experience.
- Dr. Brock LaMeres from Montana State University, also an NSF grant recipient, who has a particular interest in comparing online to face-to-face student performance.

In addition, the project has reached out to Yacob Astatke from Morgan University and to Prof. Kenneth A Connor, Rensselaer Polytechnic Institute. Both faculty leaders have experimented with alternative delivery formats for many years and have expressed interest in sharing with CALSTEP lessons learned.

During the coming months and years, CALSTEP hopes to draw from the expertise these leaders have developed and to at the same time contribute our own research findings to the emerging field of lessons learned in alternative delivery formats in engineering.

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