Developing a Comprehensive Online Transfer Engineering Curriculum: Designing an Online Introduction to Engineering Course

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Abstract:

Access to lower-division engineering courses in the community college substantially influences whether or not community college students pursue and successfully achieve an engineering degree. With about 60% of students from under-represented minority (URM) groups beginning their post-secondary education in the community colleges, providing this access is critical if the US is to diversify and expand its engineering workforce. Still many community college lack the faculty, equipment, or local expertise to offer a comprehensive transfer engineering program, thus compromising participation in engineering courses for underrepresented groups as well as for students residing in rural and remote areas, where distance is a key barrier to post-secondary enrollment. An additional obstacle to participation is the need for so many community college students to work, many in inflexible positions that compromise their ability to attend traditional face-to-face courses. Through a grant from the National Science Foundation Improving Undergraduate STEM Education program (NSF IUSE), three community colleges from Northern California collaborated to increase the availability and accessibility of the engineering curriculum by developing resources and teaching strategies to enable small-to-medium community college engineering programs to support a comprehensive set of lower-division engineering courses that are delivered either completely online, or with limited face-to-face interactions. This paper focuses on the development and testing of the teaching and learning resources for Introduction to Engineering, a three-unit course (two units of lecture and one unit of lab). The course has special significance as a gateway course for students who without the role models that their middle class peers so often have readily available enter college with very limited awareness of the exciting projects and fulfilling careers the engineering profession offers as well as with apprehension about their ability to succeed in a demanding STEM curriculum. To this end, the course covers academic success skills in engineering including mindset and metacognition, academic pathways, career awareness and job functions in the engineering profession, team building and communications, the engineering design process, and a broad range of fundamental and engaging topics and projects in engineering including electronics, basic test equipment, programming in MATLAB and Arduino, robotics, bridge design, and materials science. The paper presents the results of a pilot implementation of the teaching materials in a regular face-to-face course which will be used to inform subsequent on-line delivery. Additionally, student surveys and interviews are used to assess students' perceptions of the effectiveness of the course resources, along with their sense of self-efficacy and identity as aspiring engineers.

1. Introduction

Efforts to remain competitive internationally in engineering and technology require a significant increase in the number of STEM graduates in the United States. A recent report prepared by the President's Council of Advisors on Science and Technology states that currently less than forty percent of students entering college to pursue a STEM career end up completing a STEM degree, citing that students typically leave the STEM field in the first two years of their program.[1] One of the primary barriers for students to persist is access to lower division engineering courses. 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 help address the need for the future STEM workforce.[2] However, many community college lack the faculty, equipment, or local expertise to offer a comprehensive transfer engineering program, thus compromising participation in engineering courses for underrepresented groups as well as for students residing in rural and remote areas, where distance is a key barrier to post-secondary enrollment. An additional obstacle to participation is the need for so many community college students to work, many in inflexible positions that compromise their ability to attend traditional face-to-face courses.

Working toward widening access to education for engineering students, The "Online and Networked Education for Students in Transfer Engineering Programs," or ONE-STEP is a collaborative project among California community college engineering programs to improve engineering education by aligning engineering curriculum, enhancing teaching effectiveness using technology, and increasing access to engineering courses through online education. The project includes 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 involves a partnership among California community colleges to design and implement a Joint Engineering Program (JEP) that is delivered online.

The ONE-STEP project accomplished an important first step toward widening engineering education access, increasing the number of California community colleges that now offer online engineering courses. As a result, the number of community college engineering 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 first four years of JEP), enrollments in lab courses have only increased 23%[3].

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 primary 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. The project will also investigate the effectiveness of the alternative instructional models in promoting student engagement, learning, retention, and success.

Although the CALSTEP project aims to develop a comprehensive lower-division curriculum that is delivered completely online, the focus of this paper is the development of the course materials for the online Introduction to Engineering course and the testing of the teaching and learning materials in a traditional face-to-face pilot implementation at Skyline College in Fall 2015.

2. Developing an Online Introduction to Engineering Course

Within the first two years of an engineering program, the Introduction to Engineering course is one of the most important courses students take. This gateway course is an ideal forum and opportunity for a rich, engaging, and empowering experience allowing students to become oriented to engineering disciplines, job functions, and overall career awareness in addition to begin developing the growth mindset and success strategies needed to be a successful college student in a rigorous technical field. As such, many of the activities developed for the lecture and laboratory Introduction to Engineering curriculum are designed to help students grow in these vital areas.

Set of Lab Experiments

In developing the lab experience for this course, 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, which would also 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, without compromising the caliber of technical skillset typically gained in a lab with a comprehensive set of equipment. 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.

Table 1. Introduction to Engineering Online 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. ***Stress-strain problem set**	Exposure to common mechanical properties: stiffness, yield strength, resilience, ductility, impact toughness, hardness. Problem set to explore stress vs. strain curves.
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 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. 4yr 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 Report Due	Academic success project (discussed below)

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

Table 1 outlines the set of lab experiments developed for the Introduction to Engineering course. As part of the CALSTEP online laboratory curriculum, the Introduction to Engineering course is developed to best achieve the thirteen objectives for engineering educational laboratories defined by the ABET/Sloan Foundation effort[4,5]. The course begins with labs designed to teach students skills in experimentation, measurements, and error analysis, along with techniques in a spreadsheet program and MATLAB/FreeMat for data visualization, analysis and interpretations. The course then progresses to explore topics in Materials Science, and Civil and Mechanical Engineering. 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 concludes with Electrical and Computer Engineering 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.

Over the semester there are only two on-campus lab activities, one for each of the two design competitions. The development team agreed that two 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 students in circumstances with severely limited travel ability could potentially complete the robotics competition at home, synchronously participating in the final design competition via live web-enabled video conferencing.

Design Projects

Two design project competitions are integrated into the curriculum, with experiments built into the schedule for students to build the required skillsets and work on their designs leading toward the competition. The design projects are intended to provide an experience for students to gain confidence and ability in teamwork, communication, scheduling, and leadership. To this end, lab teams are assigned in an effort to group students that reside geographically close to one another to help facilitate in-person project work sessions whenever possible. Students will also use a web-conferencing tool (blackboard collaborate, google hangouts, etc.) to connect with their teammates remotely and share design ideas and strategies, work on reports, delegate responsibilities and schedule deliverables.

The first project is a balsawood bridge competition. Project handouts and video tutorials have been developed to 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. A tutorial is also currently being developed 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. The teams are scored on load supported and cost efficiency in the design. 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 is an Arduino-equipped Boe-Bot robotics 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 to 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. Each online student has their own robot in their lab kit, and students can share code techniques through the web-conferencing tools. Students travel to campus for the final competition, where each team is scored on time-completion and success rates.

Laboratory Hardware

Toward developing a project-based online engineering course, with hands-on engaging labs and hardware that students could easily implement remotely, special attention was given to functionality and robustness when choosing laboratory hardware. An effort was made to keep equipment costs relatively low, while still providing an experience with professional grade tools and a comprehensive set of functionality. One mechanism for helping reduce costs was to utilize free software available. The programming labs were all done using FreeMat, an open-source intended replica of MATLAB, the latter of which typically costs $100 per year for a student license. The computer-aided-drafting (CAD) activities are implemented with Autocad, which is now offered in full version free for three years.

Table 2. Lab kit components and cost (tax not included)

Lab Kit Components	Cost
Analog Discovery USB lab-in-a-box	$159.00
Arduino Boe-Bot robotics kit	$149.99
Various sensors and electronics	$20.00
Assorted balsawood	$10.00
Balsawood saw and glue	$5.00
Candy	$3.00
Total	*$346.99*

Table 2 lists the lab kit components and their associated costs. The electronics labs and measurement applications in the robotics experiments are designed around the Analog Discovery lab-in-a-box made by Digilent, Inc. This relatively low-cost USB tool, together with a computer running the developer's free interface and data acquisition software, provides a comprehensive set of electronics test equipment including a two-channel oscilloscope, two-channel function generator, voltmeter, +/- 5v power supply, and serial protocol decoder, each of which prove highly useful for hands-on engaging electronics experiments and insightful measurement, analysis, and data visualization in the labs and robotics activities. The Analog Discovery boasts further tools including a 16-channel logic analyzer, spectrum analyzer, and a network analyzer; all of which were not used in the Introduction to Engineering lab curriculum, but are useful to have on hand for use in other courses (circuits for example) and student club design projects.

The robotics labs and design project are based around the Arduino Boe-Bot made by Parallax, Inc. The kit includes a C/C++ programmable microcontroller board, vehicle chassis with continuous rotation servo motors, a small variety of sensors, and a set of basic electrical components (resistors, capacitors, leds, etc.). To expand the possible activities in sensors, measurements, and robotics experiments, the decision was made to purchase a few extra sensors for each kit including an accelerometer, infrared (IR) distance sensor, and a hall-effect sensor.

The laboratory kits are to be picked up or mailed out to students at the beginning of the semester and returned at the end of the semester. The net cost of each kit is just under $350. While this is a considerable startup cost per student taking the course online, engineering departments who do not offer the Intro to Engineering course every semester (which is a common course offering sequence for many community college engineering departments) can utilize the equipment in other courses during other semesters. As an example, the Analog Discovery and the Arduino Boe-bot are excellent tools to integrate into the sophomore level Circuits Laboratory course. It should be noted that the online Circuits Laboratory curriculum being developed under the CALSTEP project also utilizes the Analog Discovery tool. Community colleges adopting both the Introduction to Engineering and Circuits online laboratory courses can use the hardware for both courses (scheduling permitting), thereby helping alleviate equipment costs.

Metacognition and Reading Apprenticeship in Engineering

It is widely agreed that engineering study is a rigorous endeavor, and students need to acquire and develop skills, tools, and resources needed to be successful students. Yet in a typical engineering curriculum, there is often very little time and effort spent to help students develop the skills they need to succeed academically[6]. Some of these skills include mindsets and attitudes, metacognition, time management, working with others, seeking help, and utilizing one's peers and professors. The Introduction to Engineering course is a prime venue and opportunity to help cultivate many of these skills for students.

Two main resources were used in helping students develop these skills. One of these resources is the textbook for the course "Studying Engineering: A Road Map to a Rewarding Career" by Dr. Raymond B. Landis[37]. This book covers many of the topics listed above in the context of beginning and pursuing engineering study. Receptivity to change and personal growth are strong underlying themes in the text and the assignments based around the readings. The Introduction to Engineering course integrates weekly reflective writings to prepare students for a final term paper on designing their process to become a "World-class" engineering student. This project has been implemented by a number of community college and four-year university faculty to show large gains in student retention, persistence, and academic performance in engineering study[7,8,9,10,11].

The second resource used is the Reading Apprenticeship framework. Reading Apprenticeship, or RA, has been used in high school for many years now, and has been gaining traction by faculty in community college STEM disciplines[12, 13]. RA is a general set of tools and pedagogy used to bring students further along the continuum towards thinking and problem solving like a discipline expert. To this end, discipline expert faculty strive to expose their strongly developed thought processes to their students about reading, thinking, and problem solving in their discipline. Many of the student routines in RA can be done as active learning exercises in which students start to become aware of their own thought processes and begin to practice new strategies in reading and problem solving. The exercises draw on students' real-world and prior learning experiences to kindle and promote knowledge transfer and integrative, deep learning.

Of the RA toolset, two primary RA teaching and learning techniques were leveraged in this course. The first is a set of metacognitive techniques. One of the stronger themes in RA, metacognitive conversation is centered around bringing awareness to how we think when engaged in reading a book, listening to a professor lecture, discussing lab data with a peer, or sitting down to approach a brand new problem. The goal is toward ultimately cultivating techniques to be in greater control of one's thought process and become a more self-regulated learner. In the Introduction to Engineering curriculum, students are exposed to the metacognitive conversation and given opportunities to practice it in varied scenarios.

The second RA technique utilized in the course is the think-aloud paired problem solving (TAPPS) strategy. The TAPPS activity focuses on metacognitive conversation and forming an internal dialogue applied to problem solving. In this exercise students work in teams of two and each adopt a unique role. "Student P" takes the role of the problem solver, while "Student L" adopts the role of the listener. Student P is responsible for solving the problem and explaining their thought process and approach in each step of the problem, thereby effectively practicing peer instruction to student L while also exposing their own thought processes in problem solving. Student L only listens and does not help solve the problem, even if they know the answer. Student L holds student P accountable for keeping them on task and on track with Student P clearly conveying their thought process and reasoning every step of the way. Two students then get a different problem and switch roles to experience the other position, thereby learning from each other different ways of thinking about and approaching a problem.

The Introduction to Engineering class at Skyline College

Skyline College, located in the San Francisco Bay Area, CA is a member of the California Community College System and is a federally-designated Hispanic-Serving Institutions. During the 2014-15 academic year, the college enrolled 20,787 unique students, with white students as the largest single group at 20.6%, followed by Asian students at 20.3%, and Hispanic students at 18.1%. Like all California Community Colleges, Skyline College is an open-enrollment institution, designed to welcome students of all backgrounds. Skyline College has just begun to offer engineering courses to support transfer pathways to four-year engineering programs in most fields of engineering.

The Introduction to Engineering course at Skyline College is a three-unit course (corresponding to 32-36 lecture hours plus 48-54 lab hours) designed to satisfy the introduction to engineering requirement for students intending to transfer to a four-year program in any field of Engineering. The course was designed for articulation with the state-wide approved course descriptor for Introduction to Engineering as published in the course identification numbering system (c-id) website at https://c-id.net/view_final.html.

3. Traditional Pilot of the Introduction to Engineering Teaching and Learning Materials

The teaching and learning materials developed for the online Introduction to Engineering Curriculum were piloted in a traditional face-to-face setting at Skyline College in the Fall 2015 semester. The semester course enrollment was 29 with 5 female (17%) and 24 male (83%) students. The student population included Asian students at 34%, Filipino students at 24%, Hispanic students at 21%, Pacific Islander at 3%, multiracial students at 10%, and white students at 7%.

The classroom format was one two-hour lecture and one three-hour lab session each week. The first hour of the lecture meeting was generally utilized to discuss and explore academic success strategies covered in the Landis text and related reading and video assignments, and metacognitive exercises. Weekly homework assignments were reflective writings on the reading or video assignments that prompted students to think about concepts and strategies for success in what they read or watched, reflect on new knowledge they gained, and how these strategies applied to their own journey through engineering education.

The second hour of the lecture meeting was generally used to explore engineering careers and conceptual background and applications for the lab activities and design projects. Topics included measurements and error analysis, computational methods and analysis with MATLAB, mechanical properties of materials, trusses and structures, fundamental electronics, sensors and signal conditioning, Arduino programming, and robotics and simple control scenarios.

All of the lab activities and design projects listed in the curriculum were piloted in the face-to-face traditional laboratory classroom. The lab meetings were also used to practice the Reading Apprenticeship metacognitive paired problem solving exercises. The stress-strain problem set was done as a metacognitive paired problem solving set (TAPPS), and students were encouraged to practice the technique in a concurrent STEM course and report their results. As listed below in the results section of this paper, many students placed a high value on the metacognitive activities.

Table 3. Highest level of math completed with passing grade

Highest level of math completed	# of students (N = 29)	%
College Algebra	1	3.4
Trigonometry	2	6.8
Pre-calculus	4	13.8
Calculus 1	6	20.7
Calculus 2	6	20.7
Calculus 3	1	3.4
Linear Algebra	5	17.2
Differential Equations	4	13.8

Table 3 shows the highest level of math completed by students in the Fall 2015 Introduction to Engineering course at Skyline College. The distribution brings up a troubling issue regarding what point in the academic path students are taking the Introduction to Engineering course. While the course is called "Introduction to Engineering" and intended by community college engineering departments to be one of the first courses students should take if they are considering pursuing an engineering degree (and want to transfer to university), many students take the course several semesters after they have begun their path toward transfer in engineering – in fact, we often see students taking the course during their last semester prior to transfer. The primary motivators for students to take the course early are to build the requisite study skills early on before taking more advanced coursework and to help contextualize later math, physics, and engineering courses through hands-on application and design projects and career awareness in the engineering profession. In the student population of the Fall 2015 course, 24% of students were in Pre-calculus or below, 21% in Calculus 1, and 55% were in Calculus 2 or higher – a clear indicator that students are taking this course much later than they should.

4. Results of the Pilot Run

One of the primary objectives for the Introduction to Engineering course is for students to build success skills and increase self-efficacy, identify more strongly with science and engineering, and further define and discover their academic path with regard to an intended major, the transfer process, and academic life post-transfer. To this end, much of the data captured in the traditional face-to-face pilot focused on these areas. Pre- and post-course surveys were developed and administered to gauge students' identity as engineers and their confidence in succeeding in engineering study, along with their perception of the laboratory experience. In addition the surveys were used to assess to what extent the lab activities and design projects helped students gain insight into the engineering disciplines, increase their understanding and appreciation of fundamental math and physics, and help solidify their intended major. The surveys were developed by the CALSTEP external evaluator, with input from the instructor and the institution's Research Office.

Comparison of Students' Self-Efficacy in Pre- and Post-Surveys

The pre-course survey was conducted on October 1, 2015, several weeks into the fall semester, while the exit survey was conducted on December 17, 2015. Questions concerning students engineering self-efficacy were asked in the pre- and post-survey. Key findings from a comparison of the responses found that students' confidence in their ability to complete math requirements for transfer did not change much over the course of the class. By contrast, there was a positive shift in the number of students who experienced an increase in confidence that they can complete the physics requirements for transfer.

Table 4. Attitudes: *"I am certain I can complete the physics requirement for transfer in engineering"* Response Scale: 0 – Strongly Disagree, 5 – Strongly Agree.

"I am certain I can complete physics to transfer"	Pre	Post	Change
High agreement (responded 4 or 5)	68%	82%	+14%
Low agreement (responded 2 or 3)	33%	19%	-14%

Table 4 shows the pre- and post-course survey results to how confident students feel in their ability to complete the physics requirement for transfer. The number of students who were the most and the least confident did not change much over the duration of the course, but more students shifted from the low end to the middle of the spectrum of confidence.

Table 5. Attitudes: *"I can cope with doing poorly on a test in a math class"* Response Scale: 0 – Strongly Disagree, 5 – Strongly Agree.

"I can cope with doing poorly on a math test"	Pre	Post	Change
High agreement (responded 4 or 5)	29%	56%	+14%
Low agreement (responded 2 or 3)	–	11%	–
Disagreement (responded with a 0-2)	36%	–	–

Table 5 shows the pre- and post-course survey results of students' assessment of their ability to cope with getting a bad grade on a math test. Near the beginning of the course, only 29% of the students felt comfortable with this notion, while at the end of the course 56% felt they could pick themselves back up again after receiving a poor grade.

Gains were also made in students' assessment of their knowledge about which courses to take in the first two semesters after transfer and in where to go for help with transfer questions. By contrast, there was little change in students' assessment of their knowledge about which courses to take to be ready for transfer. It is possible that these students knew this well before they started the class. There was also little change in students' assessment of their ability to find help with difficult material in their math classes. This finding may relate back to the students' response to the question about how confident they are in their ability to complete the math requirements for transfer.

Table 6. Pre- and post-course survey number of students who knew which engineering degree they wanted to pursue

Knew which engineering degree wanted to pursue	Pre	Post	Change
Yes	57%	78%	+21%
No	7%	4%	-3%
Uncertain	36%	15%	-21%
Decided to no longer pursue engineering	N/A (0%)	4%	+4%

Table 6 shows the pre- and post-course survey results of the number of students who knew which engineering degree they wanted to pursue. With a 21% increase to 78% by the end of the course, the number of students who knew which engineering degree they wanted to pursue increased markedly.

Table 7. Post-survey responses categories in response to the question: "*Please explain in one or two sentences how the class has influenced the way you think about yourself as a student.*"

Response categories to: ***"How has the course influenced how you think of yourself as a student"***	# of responses (N = 28)	%
Importance of being a team player/how to work in teams	5	17.8
Finding/being motivated	4	14.3
How to fully engage and succeed as a student	13	46.4
Time management	6	21.4
Importance of active engagement beyond classroom	3	10.7
Range of engineering fields	3	10.7
Importance of planning	2	7.1

(note several students identified responses in more than one category)

Table 7 shows categories of the themes that surfaced in responses from the post-course survey to a question asking students to describe how the class has influenced the way they view themselves as a student. Nearly half of the class (46.4%) provided responses that conveyed they feel more confident in how to engage and succeed as a student in college. Another common response (21.4%) were students who indicated they felt they had better time management. Note that several of the responses contained elements that fit more than one category.

Table 8. Post-survey responses categories in response to the question: *"Please explain how/if the metacognitive problem solving approach (used for the mechanical properties of materials group problem) helped you understand the mechanical properties of materials."*

Response categories to: *"How the metacognitive problem solving approach helped you"*	**# of responses (N = 27)**	**%**
Helped problem solving/establish a process of problem-solving that the student used in this class	9	33.3
Generally helped student develop techniques/approaches to organize ideas and solve problems	10	37.0
Increased self-awareness for students on how they tend to approach a problem	5	18.5
Helped student develop/use different types of problem solving approaches (e.g., visual)	5	18.5

(note some students identified responses in more than one category)

Table 8 shows response categories to students' assessment of how the metacognitive problem solving approach helped them understand mechanical properties of materials. In this problem set, students were asked to use a Reading Apprenticeship TAPPS metacognitive problem solving approach. Almost 90% of respondents, 24 of 27 students, felt the metacognitive approach has helped them think through problems before they try to solve them, organize their thoughts, understand their own thought process, break down complex problems, and establish a problem-solving process.

Table 9. Post-survey responses categories in response to the question: "*Please explain in one or two sentences how/if you used the metacognitive approach in other courses (for example to compare your learning style to the teacher's teaching style -- or to annotate and talk to the text)?"*

Response categories to: *"How you have used the metacognitive approach in other courses"*	**# of responses (N = 27)**	**%**
Used to develop problem solving approach/organize thoughts	7	25.6
Used knowledge of different learning styles	5	18.5
Used note-taking approach	1	3.7
Used communication skills for team work	1	3.7

(note only some students identified responses in a category)

One of the main objectives in introducing Reading Apprenticeship and metacognitive techniques was to see if students would use these approaches in their other courses. Table 9 shows the response categories of how students used the metacognitive approach in their concurrent courses. More than 70% of survey respondents (19 of 27) noted they have used metacognition in other courses, including physics and chemistry. While many students focused their response on where they have used metacognition, about half of the respondents provided examples of how they used the approach in other courses they took during the Fall semester.

Table 10. Post-survey responses categories in response to the prompt: "*Please explain in one or two sentences what you have learned from the design projects. For example, did they help you understand the application of math and physics and/or increase your interest in a particular field of engineering?"*

Response categories to: *"What you have learned from the design projects*	**# of responses (N = 27)**	**%**
Helped understand application of math and physics	7	25.6
Increased motivation/interest in engineering	5	18.5
Helped learn how to write code	1	3.7
Helped build skills working in teams	1	3.7

(note only some students identified responses in the above categories)

A huge goal in the course was to provide engaging design projects to enhance students' interest in and motivation to continue engineering. Table 10 shows categories to the responses of what students gained from the design projects. The responses to this question were the most enthusiastic of all responses collected. In addition to underscoring how the projects contributed to increase students' understanding of math and physics, many students spoke of how working on the projects increased their interest, motivation and overall enthusiasm about engineering. Also, in the "what can be improved" section of the survey one –third of respondents (9 students) said they wanted more projects.

5. Conclusions and Future Plans

A traditional pilot of the teaching and learning materials for the CALSTEP Introduction to Engineering curriculum has yielded key results that show progress in meeting curriculum objectives, point to issues in student pathways, and help encourage further development in delivering the course online. The curriculum has been successful in enhancing students' identity as engineers as indicated by pre- and post-program surveys. The lab activities and design projects were well received by students and allowed them to explore the major fields of engineering, increase their knowledge of specific engineering topics and disciplines, as well as understand a variety of job functions in an engineering career. The course has helped students decide which particular field of engineering is most intriguing to them. The course has also shown to provide context to fundamental physics and math concepts—a strategy that has been proven to increase student motivation and persistence, especially during the potential struggle through the first two years of their engineering studies.

The Introduction to Engineering course also shows success in increasing students' self-efficacy and skills needed to succeed in college, as well as provide insight into the university transfer process and academic pathway post-transfer. As a result, students expressed increased self-efficacy in succeeding in their courses and increased ability to cope with and overcome doing poorly on a math exam.

With regard to pathways and course sequencing, even though most students were more than one year into their community college journey and had completed many units and semesters, many found that the course broadened their view of the wide range of career opportunities available in engineering – Students reported choosing a different engineering path as a result. For several students the change in direction was also linked to the opportunity they had a chance to "do engineering" in the design projects and labs activities. This potentially raises the question of whether a student can actually choose a career with confidence if they only have a theoretical knowledge of what the career choice involves—a situation many of our aspiring engineering students begin. This clearly points to a need to create early on-ramps for students to begin the Introduction to Engineering course at the appropriate time to best leverage the study skills gained in the course.

With the measured gains in student success, self-efficacy, and identifying with their path in engineering, the curriculum shows success in achieving these main outcomes for students. From here the path forward is to continue developing resources to create an equally engaging, motivating, and empowering educational experience for students taking the course online. Special attention will be given to getting students connected to each other and continue building the teamwork and communication skills essential to strong academic success, rewarding careers, and fulfilling lives.

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