Strategies for Developing, Expanding, and Strengthening Community College Engineering Transfer Programs

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Abstract

Broadening participation in engineering among underrepresented minority students remains a big challenge for institutions of higher education. Since a large majority of underrepresented students attend community colleges, engineering transfer programs at these community colleges can play an important role in addressing this challenge. However, for most community college engineering programs, developing strategies and programs to increase the number and diversity of students successfully pursuing careers in engineering is especially challenging due to limited expertise, shrinking resources and continuing budget crises.

This paper is a description of how a small engineering transfer program at a Hispanic-Serving community college in California developed effective partnerships with high schools, other institutions of higher education, and industry partners in order to create opportunities for underrepresented community college students to excel in engineering. Developed through these partnerships are programs for high school students, current community college students, and community college engineering faculty. Programs for high school students include a) the Summer Engineering Institute – a two-week residential summer camp for sophomore and junior high school students, and b) the STEM Institute – a three-week program for high school freshmen to explore STEM fields. Academic and support programs for college students include: a) Math Jam – a one-week intensive math placement test review and preparation program; b) a scholarship and mentoring program academically talented and financially needy STEM students; c) a two-week introduction to research program held during the winter break to prepare students for research internships; d) a ten-week summer research internship program; e) Physics Jam – an intensive program to prepare students for success in Physics; f) Embedded Peer Instruction Cohort – a modified Supplemental Instruction program for STEM courses; g) STEM Speaker Series – a weekly presentation by professionals talking about their career and educational paths. Programs for community college STEM faculty and transfer programs include: a) Summer Engineering Teaching Institute – a two-day teaching workshop for community college STEM faculty; b) Joint Engineering Program – a consortium of 28 community college engineering programs all over California to align curriculum, improve teaching effectiveness, improve the engineering transfer process, and strengthen community college engineering transfer programs; c) Creating Alternative Learning Strategies for Transfer Engineering Programs – a collaborative program that aims to increase access to engineering courses for community college students through online instruction and alternative classroom models; and d) California Lower-Division Engineering Articulation Workshop – to align the engineering curriculum. In addition to describing the development and implementation of these programs, the paper will also provide details on how they have contributed to increasing the interest, facilitating the entry, improving the retention and enhancing the success of underrepresented minority students in engineering, as well as contributing to the strengthening of the community college engineering education pipeline.

I. Introduction

Despite increasingly urgent calls to broaden the participation of underrepresented minorities (URMs include African American, American Indian/Alaska Native, Hispanic, and Native Hawaiian or Pacific Islander) in science and engineering, not much progress has been achieved. Since 2000, underrepresented minorities' shares in engineering and physical science degrees have been flat despite a rapid increase in their representation of the overall US population. In fact, even though URMs currently constitute 39 percent of the US college-age population (18-24 years old), they account for only about 15 percent of baccalaureate degrees awarded in engineering in 2014 [1].

Community colleges play an increasingly important role in educating URMs. Community colleges enroll about 61% of Native American students, 57% of Hispanic students, and 52% of African American students attending institutions of higher education in the US [2]. Almost three-fourths of all Latino students and two-thirds of all African-American students who go on to higher education begin their postsecondary education in a community college [3]. With more than 2.1 million students attending 114 campuses, the California Community Colleges is the largest system of higher education in the United States; one in every five college students in the nation attends a California community college. However, for many of these community college students, the community college gateway does not lead to success. Only one in four students wanting to transfer or earn a degree/certificate did so within six years, according to a recent study of California community colleges. African American and Hispanic students have even lower rates of completion [5].

Cañada College, located in Redwood City, CA approximately 30 miles south of San Francisco in the heart of Silicon Valley, is a member of the California Community College System and is one of three colleges in the San Mateo County Community College District; the other two colleges are Skyline College, and College of San Mateo. During the 2015-16 academic year, Cañada College enrolled 9,940 unique students. The student body is genuinely multi-cultural with Hispanic students as the largest single group at 44.2%; white students comprise 25.8%, Asians 14.2%, African-Americans 2.8%, American Indian/Alaska Natives 0.1%, Filipinos 4.5%, Pacific Islanders 1.3%, multi-ethnic 3.9%. Approximately 16% attend college full time, taking 12 or more units per semester. Like all California community colleges, Cañada is an open-enrollment institution, designed to welcome students of all backgrounds. Cañada College's Engineering Program is a transfer program that offers a comprehensive set of lower-division engineering courses needed to transfer to any four-year engineering program in any field of engineering.

In 2008, the Engineering Department at Cañada College started to develop a number of programs to increase the interest, participation, and success of underrepresented minority students. This paper is an overview of the results of these programs that have been developed for high school students, community college students, and community college STEM faculty.

II. Programs for High School Students

Among the barriers to the participation and success of community college students, especially underrepresented minority students from low-income backgrounds and underperforming school

districts, is their lack of awareness of academic and career options available to them in STEM fields [6]. To address this problem, Cañada College developed two programs for high school students.

A. Summer Engineering Institute

The ***Summer Engineering Institute*** (SEI) is a two-week residential summer camp for high school sophomores and juniors. Designed in partnership with YYYY University School of Engineering, the program's overarching goal is to increase the interest and improve the preparation of female and underrepresented high school sophomores and juniors in pursuing careers in engineering. The partnership with YYYY allowed the program to have access to university housing facilities, advanced engineering labs, and expertise of university engineering faculty. The curriculum for the program, jointly developed and taught by community college and university engineering faculty features lectures, hands-on workshops, demonstrations, panels, field trips, team-building activities, social events, and group projects. The curriculum introduces students to the engineering education system in California, as well as the skills, knowledge, and resources needed to succeed in college, including details on alternative paths to an engineering career. Most mornings of the two-week program are devoted to lectures and presentations, with group activities and hands-on workshops in the afternoon to reinforce concepts learned from the lectures. Some afternoons are devoted to field trips, and most evenings to working on group projects. There are four culminating group projects corresponding to each of the four main areas of engineering (civil, computer, electrical, and mechanical), and each student selects two of the four projects. The first week of the program is devoted to completing the first group project, and the second week is for the second project, with group presentations on the last day of the institute. Project group size varies from 3 students to 6 students depending on student interest and the complexity of the project. Groupings for the first and second projects are different, and are based primarily on student interest as expressed on the opening day of the institute. Groups working on the same project are supervised during project time by either a graduate student, or an upper-division student from YYYY who acts as the project mentor. Each project mentor works closely with YYYY faculty in designing the project and planning daily activities related to project completion.

Implementation of SEI from 2009 to 2016 has been successful in recruiting underrepresented minorities and female students into the program, with more than 50% of participants being women, and over 70% from underrepresented minority groups. Results of SEI implementation show that the program has been successful in promoting interest in engineering among program participants, increasing their self-efficacy in studying engineering, and enhancing success among those who have decided to pursue an engineering degree. A follow-up survey given to the graduates of the first three years of the institute has revealed the long-term positive impact of SEI on its participants. All the survey respondents are still attending school, and a vast majority (greater than 80%) of them are pursuing an engineering major. Years after attending the institute, students have a high opinion of the positive experience they had during the program. SEI graduates who are pursing engineering careers attribute their participation in the program to having a significant influence in their choice of major [7]. Unfortunately, due to funding running out, SEI implementation ended in Summer 2016.

B. STEM Institute

The ***STEM Institute*** a three-week summer program for high school freshmen. The program was developed to increase student knowledge, interest and self-efficacy in STEM by exploring fields through experiential learning using hands-on/real-world projects, classroom/lab instruction, speakers, on-campus field trips and workshops in STEM fields of study. The goals of the Summer STEM Institute program are: to increase student awareness and interest in STEM as possible career options; to increase students' awareness of the tools, skills, and resources they need to be successful college students and those courses and resources available to high school students; and to develop a community of learners and improve self-efficacy among program participants. The curriculum for the program is divided into five modules: Chemistry, Computer Information Science, Earth Science, Engineering, and Mathematics. A college success component is embedded in the program as well. Program staff works closely with local high schools in order to recruit low-income and underrepresented students. The program has been shown to increase student knowledge of skills and resources needed to succeed in college, as well as enhancing student interest and self-efficacy in pursuing STEM careers [8]. Graduates of the STEM Institute, especially those who have expressed interest in engineering, were recruited in subsequent years to participate in the Summer Engineering Institute. Unfortunately, follow-up studies to determine the long-term impact of STEM Institute on participants' educational and career plans were not done. Just like the Summer Engineering Institute, the STEM Institute has been discontinued after the grant project that funded the program ended.

III. Programs for Community College Students

Since 2009, Cañada College has developed a number of programs to address the major barriers to the retention and success of underrepresented minority students in engineering. This section briefly describes the development of these programs, and the results of their implementation.

A. Math Jam

A majority of community college students enter college with low levels of preparation for college-level work, especially in math. For instance, an analysis of math placement test results of incoming students at Cañada College showed that over 75% of underrepresented minority students placed in to math courses that are two or three levels below transfer-level math courses. For students interested in pursuing science or engineering degrees, this may mean up to four or five years of coursework before they are eligible to apply for transfer to a four-year institution. As a result, many of them drop out or change majors even before taking transfer-level STEM courses. To facilitate the entry of these underprepared students, Cañada College developed ***Math Jam***, which is a one-week intensive math placement test review program. Math Jam was developed with the following program goals: a) Help students progress faster through Cañada's math sequence to enable them to transfer to a 4-year university earlier or to complete an associate's degree earlier; b) Increase students' awareness of the tools, skills, and resources they need to be successful college students; and c) Develop a community of learners among program participants. Although originally developed to help students improve the results of their initial math placement tests, Math Jam has evolved a secondary purpose of helping students prepare for a math class that they will be taking. As a result, the program has welcomed repeat participants.

Math Jam participants are grouped into five levels based on students' initial math placement or highest math class completed: one group each for Pre-algebra, Algebra, College Algebra, and Trigonometry/Precalculs, and one group for students in the Calculus 1 level or higher. Each group is assigned a Math Jam instructor who is a math instructor, an instructional aide, or an advanced student. Each Math Jam instructor is assisted by a group of student tutors such that four or five students are assigned per tutor for the Pre-algebra group, and up to ten students per tutor for the higher-level math groups. Math Jam sessions are held from 9:00 a.m. to 3:00 p.m., Monday through Friday. Students study math either in small group workshops or individually using an online math software system. Each day, students have the option of attending one to four mini-lessons and activities that either introduce them to new topics or involve tying previously learned algebraic ideas together so that they can get a bigger picture idea of how they will be using these math skills in their next classes. Although Math Jam was originally developed for the week prior to the beginning of the academic year, the program is now offered three times every year, during the week preceding the start of each term (fall semester, spring semester, and summer term). The program now serves over 500 students a year, with both day (9:00 am to 3:00 p.m.) and evening (6:00 to 9:00 p.m.) sessions.

Years of implementation of the program show success in improving student performance in the math placement test, in preparing students for success, and in creating a sense of community among program participants, as well as significantly higher retention and success rates [9]. The program has also been shown to help close the achievement gap in STEM math classes between minority and non-minority students. Although success rates in math courses are significantly higher for all Math Jam attendees compared to non-attendees, the results are even better for underrepresented minorities. For nonminority students, success rate increased by four percentage points from 70% to 74%. For minority students, the success rate increased by twelve percentage points from 59% to 71% success rate [10].

Math Jam has received multiple awards at the local (J Russell Kent Award from the San Mateo County Board of Education), state (California Academic Senate Exemplary Program Award), and national (Excelencia in Education; White House Initiative on Educational Excellence for Hispanics' Bright Spots in Hispanic Education) levels. The program has been completely institutionalized and has been replicated at many other community colleges and even four-year institutions.

B. Accelerated and Contextualized Foundational Math

Recently, community colleges have identified contextualized teaching and learning as a promising strategy to actively engage students and improve learning in basic skills courses [11] and career/technical education [12]. Another recent trend in community college education, especially in developmental or remedial math and English courses is acceleration, wherein students are given the opportunity to finish a sequence of courses over a shorter period of time through mechanisms for bypassing levels, or compression models that combine levels of an existing sequence. This approach has shown to increase completion in developmental math courses [13], and can contribute to meeting the increasing demand for STEM graduates by accelerating the entry into STEM education among the large number of students who are

interested but are not academically prepared [14].

Combining the two promising practices of acceleration and contextualization, Cañada College developed an accelerated and contextualized ***Pathways to Calculus*** course that combines the existing 4-unit Trigonometry class and the 5-unit Pre-calculus class into a one-semester 6-unit course. This new approach has resulted in significantly higher retention and success rates than the traditional sequence. For instance, for the 2015-2016 academic year, the success rate for the accelerated course was 55.8% compared to the success rate of 31.3% for the traditional Trigonometry and Pre-calculus sequence. For the 2016-2017, academic year, the success rate of 63.1% for the accelerated course was significantly higher than the success rate of 38.8% for the traditional Trigonometry and Pre-calculus sequence. Additionally, pre and post surveys of the students in the accelerated course show that the class has positively impacted their self-efficacy in math and their plans to take higher math courses and pursue STEM degrees. Because of the success of the course, the long-term plan is to eliminate the Trigonometry and Pre-calculus courses at the college and use the *Pathways to Calculus* course to prepare all STEM students for Calculus.

C. Physics Jam

In addition to mathematics, physics is another subject area that is a common bottleneck for STEM transfer students. As a follow-up to the success of Math Jam, and to help students progress through the physics courses, Cañada College developed ***Physics Jam*** – a week-long boot-camp before the beginning of the semester to prepare students for success in first- and second-semester physics courses. The main goal of Physics Jam is to help students develop the necessary study skills and practice working with physics content before they start their physics course. The specific objectives of Physics Jam are to give the participating students the ability to: (a) become familiar with physics concepts; (b) identify, analyze, and formulate physics problems; and (c) apply knowledge of mathematics in general and calculus in particular in solving physics problems. The program is administered by a faculty member assisted by a small group of student tutors. The program's content focuses initially on a math review using an online adaptive math program to get students up to pre-requisite requirements for physics. Students are given a pre-test on key math concepts. The results of the pretest are used to automatically create a customized study plan. Once a student has finished the math review they can continue on to an introduction of core physics concepts, which are introduced though online video lectures and mini-lectures given by the instructor. They then have the opportunity to test their new physics knowledge on practice problems. Since its pilot implementation of Physics Jam in Summer 2012, the program has been institutionalized, and three separate one-week Physics Jam sessions have been offered concurrently with Math Jam every year. The program has increased student retention and success rates in physics courses [15, 16].

D. Embedded Peer Instruction Cohort (EPIC)

Additional academic support services have also been provided by Cañada College to help improve outcomes for STEM students, especially underrepresented minorities. The ***Embedded Peer Instruction Cohort*** (or ***EPIC***) program is a modified *Supplemental Instruction* program designed for STEM courses with high attrition rates. In the EPIC program, EPIC leaders are

selected for targeted courses from students who have previously successfully completed the course. These EPIC leaders attend class with their students and also hold study sessions outside class time each week. EPIC leaders work closely with STEM faculty to ensure that student needs are addressed during study sessions. The program has been proven to be effective in increasing student persistence and success rates, and have been expanded to a wide variety of STEM courses including Mathematics, Physics, Chemistry, and Computer Science [17].

E. Three-Tier Research Internship Program

A growing number of studies document the benefits of research opportunities for undergraduate students [18-22]. Independent research experiences increase student engagement in their education, enhance research and laboratory skills, improve academic performance, increase understanding and interest for their discipline, strengthen oral and written communication skills, enhance problem solving and critical thinking skills, and enhance self-efficacy. For students from traditionally underrepresented groups, the benefits may be even greater when compared to students from majority groups [19]. However, an extensive study of Research Experiences for Undergraduates (REU) programs shows that 91% of these research experiences are provided to junior and senior students [23]. Developing successful research programs is particularly challenging in community colleges, most of which do not have on-going research programs. Establishing collaborations between research universities and community colleges is key to engaging students in research early in college.

To further engage STEM students in their education, Cañada College has developed a three-tier research internship program suitable for community college students at different stages of their academic careers. The first part of the program is a two-week program, the ***Winter Research Scholars Program***, held during the winter break for students in the beginning stages of their studies. The second part is a ten-week ***Summer Group Research Internship*** program for sophomore students who have no previous research experience and have at least one more year of courses to complete at the community college before transfer. The ***Summer Individual Research Internship*** program is a ten-week program for rising junior students who have completed all the required lower-division courses for transfer to a four-year university and are transferring in the fall semester following their participation in the program.

The primary goal of the *Winter Research Scholars Program* is to serve as a stepping stone introduction to the research process and to help develop students' abilities as STEM researchers. The first week is spent working on developing research skills. The second week is devoted to further development of research skills by work on a challenging semi-open-ended research project. Implementation of this program shows positive impact on students' engagement in their academics, confidence in applying for and obtaining further internships, transfer preparedness, teamwork ability, and sense of self-efficacy [24].

The *Summer Group Research Internship Program* is a ten-week program for sophomore students who have no previous research experience and have at least one more year of courses to complete at Cañada College before transferring to a four-year university. In addition to allowing students to participate in the program as part-time interns, the group setting wherein students work with their peers and faculty they know will give students the supportive learning

environment needed to succeed in their first internship experience. A collaborative learning environment has been shown to positively impact minority students—improving cognitive development [25] and reducing students' feeling of isolation [26]. The Group Research Internship program is held at the YYYY University and consists of five research groups, each consisting of one full-time student intern and three part-time student interns supervised by one graduate student and mentored by an engineering faculty. Although the primary consideration for assigning a student to a particular research group is their declared major, student academic preparation (specifically engineering courses completed) is taken into consideration to ensure that students have the recommended background knowledge needed for the research projects.

The third level, *Summer Individual Research Internship Program*, is a ten-week program for rising junior students who have completed all the required lower-division courses for transfer to a four-year university and are transferring in the fall semester following participation in the program. Students in the program work with researchers from San Francisco State University, UC Merced, and NASA Ames Research Center.

Implementation of the Summer Group and Individual Research Internship Programs shows success in helping students in solidify their choice of major, improving preparation for transfer, enhancing student self-efficacy in pursuing careers in engineering, and acquiring knowledge and skills needed to succeed in a four-year engineering program. As a result of their research experience, the participants have also expressed that they are now more likely to apply for other internships and consider pursuing advanced degrees in engineering [27].

F. NSF S-STEM Scholarship Program

Among the major barriers to the success of community college students in STEM, especially those from underrepresented minorities, is the need to work while attending college. For instance, at Cañada College in the 2016-17 academic year, only about 16% of all students are full-time students (i.e., taking 12 or more units per semester). An analysis of student data tracked by the Cañada College MESA (Mathematics, Engineering, and Science Achievement) Program over several years reveals that MESA students work an average of 15-20 hours a week to cover the cost of their education. Because of the need to work while going to college, combined with low initial placement in their courses, the vast majority of these students take at least three years to complete lower-division course requirements before becoming eligible to transfer to a four-year institution.

To assist in providing financial assistance to its STEM students, Cañada applied for and was awarded a five-year National Science Foundation ***Scholarships in Science, Technology, Engineering and Mathematics*** (S-STEM) grant in 2009. To support the students throughout their time at the community college, four different award levels were developed. The first three levels are to support students' three-year tenure at the College, and the fourth to support transfer. Achievement Level 1 scholarship is for students who are eligible to enroll in Trigonometry or Pre-calculus at the time of the award and have three-years of study at Cañada College before transfer. Achievement Level 2 is for students who are registered in Calculus 1, or higher, at the time of the award, and are within two years of completing their Student Educational Plans (SEP) and transferring. Achievement Level 3 is for students who are within a year of completing their

lower-division study at Cañada. The Transfer scholarship is for students who have completed all coursework included in their educational plan and are transferring at the time of the award. Between 30 and 40 scholarship awards were given each year for the five-year duration of the program from 2009-2014.

As a major component of the Cañada College's NSF S-STEM program student support infrastructure, a mentoring program was developed and implemented. Science and Technology Division faculty members were selected as mentors for the scholars. Students and mentors were paired based on academic disciplines. The scholars and their mentors meet as a group through a mentoring lunch at least once every semester. At the fall mentoring kick-off luncheon, new scholars are introduced, and students and mentors are given an orientation to the mentoring program, as well as the benefits of the program, and the expectations and responsibilities of scholars. Mentors are expected to meet with their mentees either individually or in groups throughout the semester to develop and review Student Educational Plans, to discuss academic progress and problem areas, to help devise strategies to improve student performance in their classes, to help students get connected with resources, to provide career counseling, and to help students in completing applications for transfer to a four-year university, as well as applying for scholarships and internships. At the end of the school year, students are asked to evaluate their faculty mentor to assess the mentor's ability to help them with their educational and career endeavors. Transferring students are interviewed about how the program has impacted their academic and professional development. The implementation of S-STEM program from 2009 to 2014 shows that the program has achieved its primary program goals of providing an opportunity for low-income students to focus on their studies and fully benefit from a student support infrastructure that promotes academic excellence, leadership skills, and professional and personal growth among students. The success of the program may be attributed to a well-planned set of activities designed to create a learning community among scholars. Participation among scholars in these program activities has been high, and most of the activities were perceived by participants to be valuable.

As a follow up to the first round of the five-year NSF S-STEM grant, Cañada College applied for and was awarded a second five-year S-STEM grant from 2014 to 2019. Now in its third year of implementation, the program continues most of the activities developed in the first S-STEM program, with additional emphasis on stronger engagement of faculty mentors and additional support from a Retention Specialist to help connect scholars with resources they need to succeed.

G. STEM Speaker Series

The ***STEM Speaker Series*** is weekly event that features local STEM professionals and university faculty in STEM fields in order to provide students with information on the variety of educational and career paths available to them. Of particular interest are presenters who can speak to their experiences as first-generation college students or their community college transfer experience. Speaker Series addresses a critical need for students: lack of awareness about possible major and career options in STEM fields. Since its pilot implementation in Spring 2013, about eight weekly speakers each semester have been featured in the program, and the program has been widely received by the campus community, with weekly attendance of about 150 students per session.

IV. Programs for Community College Faculty

The increasing diversification of transfer requirements among university engineering programs in California has led to 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 [28]. In order to address this problem, Cañada College has developed a number of programs for community college engineering faculty and engineering programs.

A. Summer Engineering Teaching Institute

The ***Summer Engineering Teaching Institute*** is a two-day teaching workshop designed to assist community college engineering faculty in improving teaching effectiveness and productivity through the use of technology in education, online instruction, active learning, flipping the classroom, and applying for grants. The SETI curriculum includes the following components: a) using Tablets for class lectures, b) video capture and sharing, c) classroom formative assessment, d) developing a technology-enabled interactive classroom, e) flipping the classroom, f) synchronous online and face-to-face delivery, and g) developing online labs. For the past seven years, over 160 community college faculty from all over California have attended this workshop. Courses developed and implemented by faculty who attended this workshop have resulted in increased enrollment and improved student outcomes [29]. A survey of SETI participants indicates that the most commonly perceived potential barriers for the adoption of promising teaching practices are a) time required to implement them, b) cost, and c) lack of support from colleagues.

Most of the engineering faculty who attended the Summer Engineering Teaching Workshop are also members of the ***Joint Engineering Program*** – a consortium of 28 community college engineering programs all over California. Led by Cañada College, the main goal of the consortium is to better serve engineering students in California community colleges by aligning engineering curriculum at partner institutions and increasing student access to lower-division engineering courses through distance education. Engineering faculty from these colleges were involved in aligning the lower-division engineering curriculum and developing online courses delivered through CCC Confer, a multipoint videoconferencing system that is available for use free of charge to all faculty and staff of the California Community College system. Engineering courses in the lower-division engineering curriculum were aligned with respect to number of units, prerequisites, catalog description, student learning outcomes, and course outline/topics.

B. California Lower-Division Engineering Articulation Workshop

In order to facilitate efforts to align curriculum and improve the articulation of lower-division courses between community colleges and four-year engineering programs in California, Cañada College organized two workshops. Funded by the National Science Foundation, the ***California Lower-Division Engineering Articulation Workshop*** brought together over 80 engineering

faculty and administrators from community colleges and universities (particularly the California State University system and the University of California system) to align the engineering curriculum by developing state-wide course descriptors for lower-division engineering courses and model transfer curricula for engineering. The overarching goal of the project is to streamline the transfer process for California community college engineering students by: (1) developing a set of lower-division engineering course descriptors that are widely accepted and implemented in the three main segments of the California engineering education system — the community colleges, California State University, and University of California; (2) facilitating the adoption of the course descriptors for a state-wide articulation system to replace the inefficient and costly institution-by-institution articulation system currently in place; (3) developing lower-division model curricula for the most popular engineering majors to allow community colleges to prepare to transfer with minimal loss of units; (4) identifying and addressing significant barriers to the successful transfer of community college engineering students; and (5) creating a vibrant community of engineering educators who work collaboratively to address challenges and opportunities facing the future of engineering education in the state.

The first workshop held at Cabrillo College in Spring 2015 focused on developing the Intersegmental Model Curricula (ISMC) for lower-division transfer programs for four tracks: Mechanical/Aero/Manufacturing Engineering; Civil Engineering; Electrical Engineering; Computer/Software Engineering. The workshop also identified problems, hurdles and challenges in implementing the ISMC, the benefits and rewards of implementing the curricula, and addressing problems and challenges identified. A follow-up workshop, held at University of California, Irvine in Fall 2015, focused on refining the lower-division curricula, training two-year and four-year faculty on the process of reviewing course outlines submitted for state-wide articulation, and the development of upper-division curricula at the four-year institutions to complement the lower-division ISMC.

C. Creating Alternative Learning Strategies for Transfer Engineering Programs

Cañada College is also currently collaborating with three other community colleges, College of ZZZZ.AAAA College, and Skyline College through another NSF-funded grant project titled ***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 Joint Engineering 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 adapting and continually improving the online laboratory curricula and alternative instructional models [31].

In developing the CALSTEP online laboratory courses, consideration was given to the thirteen objectives for engineering educational laboratories defined by the ABET/Sloan Foundation effort

[32, 33]. CALSTEP curriculum development also employs 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. Content is delivered using a variety of formats similar to those used in many existing online and hybrid engineering courses. Curriculum development was done for four lower-division engineering laboratory courses: *Introduction to Engineering* [34], *Engineering Graphics* [35], *Circuits Lab* [36], and *Materials Science* [37]. Implementation of the curriculum indicates its effectiveness in enhancing the capability of small community colleges in supporting the lower-division engineering courses needed by students to be competitive for transfer to four-year engineering programs. Curriculum materials and resources developed through this project have been adopted at many institutions. For the past two summers, dissemination of the CALSTEP curriculum has been promoted through the Summer Engineering Teaching Institute, as described above.

V. Conclusion and Future Plans

Over the past nine years, Cañada College has developed a number of programs that have contributed to strengthening the community college engineering educational pipeline. These programs include efforts that target high school students, community college students, and community college engineering faculty. The programs have resulted in increased enrollments and improved outcomes for students, especially those from underrepresented backgrounds. The programs have also increased access to engineering education by enhancing the capability and capacity of small- to medium-sized community colleges to offer the lower-division engineering courses needed by students to transfer to four-year engineering programs. Despite being a relatively small institution with only one full-time engineering faculty, Cañada has been able to achieve these results by establishing collaborative partnerships with local high schools, with other community colleges, with four-year institutions, and local industry partners. These collaborative relationships can serve as models for other institutions in developing similar programs to help contribute to strengthening engineering education and broadening participation among underrepresented minority students.

Additional programs and support activities are currently in development at Cañada College to further promote the participation and success of underrepresented students. As a follow up to the success of Math Jam and Physics Jam, *Chemistry Jam* is being developed as a week-long boot-camp course at the beginning of the fall and spring semesters for incoming general chemistry students. The *STEM Explorers Program* is a week-long summer orientation for incoming students who have expressed interest in a STEM field. The goals of the program are to: (1) increase student awareness and motivation to pursue a STEM major; (2) engage students with hands-on activities; and (3) develop a community of learners, or STEM cohort. The *Difference Education Intervention* exposes new first-generation students (participants) to continuing students' (panelists) personal experience narratives to teach that academic struggle is a common experience, and that diversity is an asset. The intervention aims to increase help-seeking behaviors and overall well-being of participants, and has shown to result in increased student motivation. It is based on a previous study that has shown that the intervention resulted in statistically significant positive effect on reducing the achievement gap between first-generation students and continuing-generation students [37].

Despite the success of Cañada College in developing programs that promote success of STEM students, sustaining these efforts has been challenging. Because almost all of these initiatives are grant-funded, continuing the activities beyond the life of the grant funding requires additional resources. For instance, the two programs that target high school students (Summer Engineering Institute and STEM Institute) have been discontinued when the grant project funding these programs ended. The decision to discontinue these programs despite evidence showing their effectiveness was influenced by lack or resources, as well as the fact that majority of the participants do not necessarily come to Cañada College to pursue their degrees. For other programs like Math Jam and Physics Jam, institutionalization was relatively easier because these programs are not as resource intensive, and resulting increases in student retention and success (which result in savings and additional revenue for the institution) were significant. Another program that would be relatively easy to institutionalize is the Supplemental Instruction program, EPIC. The program has been shown to be more effective and more cost-effective than the traditional drop-in tutoring that is currently in place. For some of the other programs, especially those that provide direct financial benefit for students (e.g., scholarships and stipends for internships), there is a continued need to seek additional external sources of funds to continue providing the services and benefits of the programs.

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REFERENCES

1. NSF, Division of Science Resources Statistics. 2017. *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Available at https://www.nsf.gov/statistics/2017/nsf17310/.
2. National Center for Education Statistics, *Digest for Education Statistics*, Available at https://nces.ed.gov/programs/digest/d16/tables/dt16_219.70.asp.
3. Joint Venture Silicon Valley (2012). *The 2012 Index of Silicon Valley* p. 36, Available at http://www.jointventure.org/images/stories/pdf/2012index-r2.pdf.
4. NSF, Division of Science Resources Statistics. 2017. *Women, Minorities, and Persons with Disabilities in Science and Engineering*. Available at https://www.nsf.gov/statistics/2017/nsf17310/.
5. Shulock, Nancy & Moore, Colleen (2010). *Divided We Fail: Improving Completion and Closing Racial Gaps in California's Community Colleges*.
6. Camacho, A. M. (2015, June), *Successful Models in Community College STEM Education* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24776.
7. Enriquez, A. G., Pong, W., Ozer, N. M., Mahmoodi, H., Jiang, H., Chen, C., Shahnasser, H., and Rentsch, N. P. (2014, June), *Developing a Summer Engineering Program for Improving the Preparation and Self-Efficacy of Underrepresented Students* Paper presented at 2014 ASEE Annual Conference & Exposition, Indianapolis, Indiana. https://peer.asee.org/20281.

8. Burwell-Woo, C., Lapuz, R., Huang, T., and Langhoff, N. (2015, June), *Enhancing Knowledge, Interest, and Self-Efficacy in STEM Through a Summer STEM Exploration Program* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.23998.
9. Enriquez, A., Hum, D., Price, B, Woo, C., Redding-Lapuz, D., and Camacho, A. (2013)., *Creating Accelerated Educational Pathways for Underprepared STEM Students through an Intensive Math Placement Test Review Program*. Proceedings: 2013 American Society of Engineering Education PSW Conference, Riverside, CA, April 18-20, 2013, pp 314-328.
10. Camacho, A. M., & Hum, D. (2016, June), *Measuring the Effectiveness of an Intensive Math Preparation Program to Enhance the Success of Underrepresented Students in Engineering* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.25700.
11. Hamilton, D. (2013). Contextualized Learning May Redefine Remedial Education, *Community College Journal of Research and Practice*, 37(12), 1016-1020.
12. Curry, K., Wilson, E., Flowers, J., & Farin, C. (2012). E Scientific Basis vs. Contextualized Teaching and Learning: The Effect on the Achievement of Postsecondary Students, *Journ of Agricultural Educ*, 53(1), 57-66.
13. Jaggars, S., Hodara, M., Cho, S.W., & Xu, D. (2015). Three Accelerated Developmental Education Programs: Features, Student Outcomes, and Implications. *Community College Review*, 43(1), 3-26.
14. Business-Higher Education Forum (2011). *Meeting the STEM Workforce Demand: Accelerating Math Learning among Students Interested in STEM*. BHEF Research Brief, October 2011.
15. Hadsell, C. (2016, June), *Physics Jam, a Physics Preparation Program to Increase Student Performance and Success in Introductory Physics Courses* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.25899.
16. Yadak, P., & Enriquez, A. G. (2013, June), *Preparing STEM Students for Success in Physics Through an Intensive Summer Program* Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia. https://peer.asee.org/22363
17. Hadsell, C., Huang, T., and Enriquez, A. G. (2015, June), *Preparation and In-Class Intervention Programs for Barrier Courses for Two-year College Engineering Students* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24581.
18. Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning, *CBE Life Sciences Education* 6: 297-306.
19. Russell, S. H., M.P. Hancock, and J. McCullough. (2007). The pipeline. Benefits of undergraduate research experiences. *Science* 316(5824): 548-9.
20. Kinkel, D. H. and S. E. Henke. (2006). Impact of undergraduate research on academic performance, educational planning, and career development. *Journal of Natural Resources and Life Sciences Education* 35: 194-201.
21. Hunter, A-B., S. L. Laursen, and E. Seymour. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science Education* 91: 36-74.
22. Guterman, L. (2007). What Good is Undergraduate Research, Anyway? *The Chronicle of Higher Education, 53*(50) A12.
23. Russell, S. (2006). *Evaluation of NSF Support for Undergraduate Research Opportunities, Draft Synthesis Report*. SRI International, 1100 Wilson Boulevard, Suite 2800, Arlington, VA 22209-3915.

24. Langhoff, N. P., & Enriquez, A. G. (2017, June), *Development and Implementation of an Introduction to Research Winter Internship Program for Underrepresented Community College Students* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer.asee.org/28155.
25. Cabrera, A., Crissman, J.., Bernal, E.., Nora, A., & Pascarella, E. (2002). Collaborative learning: Its impact on college students' development and diversity. *Journal of College Student Development.* 43(2), 20-34.
26. Swail, W. (1995). *The Development of a Conceptual Framework to Increase Student Retention in Science, Engineering, and Mathematics Programs at Minority Institutions of Higher Education.* Ed.D. dissertation, The George Washington University.
27. Enriquez, A. G., Langhoff, N. P., Pong, W., Mahmoodi, H., Zhang, X., Chen, C., Teh, K. S., Jiang, Z. (2017, June), *Developing a Summer Research Internship Program for Underrepresented Community College Engineering Students* Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio. https://peer.asee.org/28134.
28. Dunmire, E., Enriquez, A., and Disney, K. (2011). The Dismantling of the Engineering Education Pipeline. *Proc. 2011 Annu. Conf. ASEE.*
29. Enriquez, A., Cheung, E., and Reardon, T. (2013). Strengthening the Community College Engineering Pipeline Through Collaboration and Technology. *Proc. 2011 Annu. Conf. ASEE.*.
30. Enriquez, A. G., & Dunmire, E. N., & Rebold, T., & Langhoff, N., & Schiorring, E. (2015, June), *Work in Progress: Creating Alternative Learning Strategies for Transfer Engineering Programs* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.25085
31. Feisel, L., & Peterson, G. (2002). A colloquy on learning objectives for engineering education laboratories. *Proc. 2010 Annu. Conf. ASEE*.
32. Feisel, L., & Rosa, A. (2005). The role of the laboratory in undergraduate engineering education. *J. Eng. Educ.*, 94(1), 121–130.
33. Langhoff, N. P., & Schiorring, E., & Dunmire, E. N., & Rebold, T., & Huang, T. (2016, June), *Developing a Comprehensive Online Transfer Engineering Curriculum: Designing an Online Introduction to Engineering Course* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26715.
34. Enriquez, A. G., & Dunmire, E. N., & Rebold, T., & Langhoff, N., & Huang, T. (2017, April), *Strengthening Community College Engineering Programs through Alternative Learning Strategies: Developing an Online Engineering Graphics Course* Paper presented at 2017 Pacific Southwest Section Meeting, Tempe, Arizona. https://peer.asee.org/29233.
35. Rebold, T., & Enriquez, A. G., & Dunmire, E. N., & Langhoff, N. P. (2016, June), *Toward a Comprehensive Online Transfer Engineering Curriculum: Assessing the Effectiveness of an Online Engineering Circuits Laboratory Course* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.27053.
36. Dunmire, E. N., & Enriquez, A. G., & Langhoff, N. P., & Rebold, T., & Schiorring, E. (2016, June), *Developing Resources to Support Comprehensive Transfer Engineering Curricula: Assessing the Effectiveness of a Hybrid Materials Science Course* Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.26769.
37. Stephens, N.M., Hamedani, M.G., & Destin, M. (2014). Closing the social-class achievement gap: A difference-education intervention improves first-generation students' academic performance and all students' college transition. Psychological Science, 25(4), 943-953.