121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #10207

Improving Engineering Curriculum and Enhancing Underrepresented Community College Student Success through a Summer Research Internship Program

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Abstract

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. One of the Council's recommendations to address this issue is to engage students with research experiences in the first two years. Recently there has also been an increasing awareness of the important role that community colleges play in educating STEM professionals, especially in broadening participation among students from underrepresented groups. This paper presents the results of a collaborative project between a small Hispanic-serving community college and a large urban university to address the retention and completion problems among community college students through a summer research internship program that provides opportunities for freshmen and sophomore community college students to participate in engineering research under the supervision of a university professor and a graduate student mentor. Developed through a grant funded by the NASA Curriculum Improvements Partnership Award for the Integration of Research (CIPAIR) program, the summer internship program integrates research with curriculum improvements by providing the framework for students to use their research experiences to develop instructional materials to improve the engineering curriculum. The paper highlights the results of the research done by the mechanical engineering student group who helped develop a novel haptic apparatus and associated curriculum for teaching upper division mechanical engineering laboratory courses in control systems, mechatronics, and haptics. Over the ten-week program the group made significant design improvements to the apparatus, manufactured a set of the devices to outfit a laboratory classroom at the university, and helped define instructional methods and learning outcomes for a mechatronics laboratory curriculum. In addition to developing research skills among participants, three years of implementation of the program have also been successful in strengthening students' identity as engineers, in increasing student interest to further engage in research activities, and in enhancing student self-efficacy for successfully transferring to a four-year university, completing a baccalaureate degree in engineering, and pursuing a graduate degree.

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. One of the Council's recommendations to address this issue is to engage students with research experiences in the first two years. 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]

Recent reports on student achievements at California community colleges show disappointing results. Key findings indicate that only one in four students wanting to transfer or earn a degree/certificate did so within six years.[3] African American and Hispanic students have even lower rates of completion; only 14% of African American students and 20% of Latino students completed a degree or certificate within six years, compared to 29% of white students, and 24% of Asian students. These low success and completion rates among underrepresented students at community colleges are even more crucial since almost three-fourths of all Latino and two-thirds of all African-American students who go on to higher education begin their postsecondary education in a community college.[4]

In California's Silicon Valley, the distribution of high school graduation rates reveals that some ethnic groups are less prepared to enter college. The graduation rate is lowest for Latinos at 78% and African Americans at 83% compared to 96% for Asians and 94% for Whites.[5] Located in Silicon Valley, Cañada College is a member of the California Community College System, and is one of three colleges in the San Mateo County Community College District. It is one of only two federally-designated Hispanic Serving Institutions in the San Francisco Bay Area. The College opened in 1968, and is located in Redwood City, California. During the 2012-2013 academic year, the College enrolled 10,271 students, with Hispanic students comprising 45.8% of all full time equivalent (FTE) enrollments, Caucasians 30.4%, Asians 7.6%, African-Americans 3.7%, American Indian/Alaska Natives 0.3%, Filipinos 3.1%, Pacific Islanders 1.8%, multi-racial 2.9%, unknown 4.5%. [6]

At Cañada College, the discrepancy in the levels of preparation among different ethnicities is manifested in student persistence. During a recent planning initiative led by the College President, a cohort study of newly enrolling students at Cañada was performed. Table 1 shows a summary of one-year and two-year persistence rates of students by ethnicity. Among Hispanic students the one-year persistence rate was 59.4%, and the two-year persistence rate was 28.8%. The one-year persistence rate of African American students was 46.7%, and the two-year rate 20%, significantly lower than those of white students whose one-year and two-year persistence rates were 72.5% and 54.4%, respectively. Given these low patterns of persistence for Hispanics and African Americans, low transfer and completion rates for these students are not surprising. Clearly, much needs to be done to improve the retention and success of underrepresented students, especially in STEM areas.

Persistence by Ethnicity				
Percentage	**Fall Yr1**	**Spring Yr1**	**Fall Yr2**	**Spring Yr2**
Hispanic	N/A	59.4%	38.9%	28.8%
Caucasian	N/A	72.5%	59.7%	54.4%
Asian	N/A	76.2%	52.4%	40.5%
African American	N/A	46.7%	33.3%	20.0%

Table 1. Semester-to-semester two-year persistence rates of Cañada students by ethnicity.

Improving the post-secondary student retention and success has been the subject of many studies. For example, Kuh's multi-phased study identified high-impact practices including first-year seminars and experiences, common intellectual experiences, learning communities, writing-intensive courses, collaborative assignments and projects, undergraduate research, diversity/global learning, service learning/community-based learning, internships, and capstone courses and projects.[7] Another study published by the California State University Chancellor's Office shows that "Participation in high-impact practices has been shown to improve both learning and persistence for all students, but especially for the historically underserved."[8] This study also indicates that participation in more than one high-impact practice increases the benefits for these students. Other specific strategies that have been proven effective in improving student outcomes for minority students include mentoring programs,[9,10] introducing context in introductory courses,[11] alternative instructional strategies,[12] summer programs,[13,14] and peer mentoring.[15]

In 2008, to increase the participation, retention, and success of underrepresented, underprepared and educationally disadvantaged students interested in pursuing careers in STEM fields, Cañada College developed a program titled Student On-ramp Leading to Engineering and Sciences (SOLES). Funded by the US Department of Education through the Minority Science and Engineering Improvement Program (MSEIP), SOLES addressed some of the barriers to the successful transfer of community college engineering students to a four-year institution including low success rates in foundational math courses, lack of practical context in the traditional engineering curriculum, and inadequate relevant internship opportunities for lower-division engineering students. The program employed strategies that have been proven effective in increasing the retention and success of minority students. Among the specific programs developed through SOLES are the Math Jam and the Summer Engineering Institute. Math Jam is a two-week intensive summer mathematics program designed to improve students' preparation for college-level math courses. The Summer Engineering Institute (SEI), a two-week residential program held on campus at San Francisco State University, aims to introduce students to the engineering educational system and the engineering profession, recruit students into an engineering field, increase student awareness of resources and skills needed for college success, and increase student knowledge of specific engineering topics. These two programs have contributed to a significant increase in enrollment and success of underrepresented minority students in transfer-level math, science and engineering courses.[16,17]

With the resulting increase in the enrollment of underrepresented students intending to transfer to a four-year engineering program, additional programs need to be developed in order to ensure the success of these students and facilitate their successful transfer and completion of their academic goals. In 2010, in response to this need, Cañada College collaborated with San Francisco State University to develop the Creating Opportunities for Mathematics, Engineering, Technology, and Science (COMETS) program. Funded by NASA through the Curriculum Improvements Partnership Award for the Integration of Research (CIPAIR) program, the COMETS program involves collaboration among math and engineering faculty of a community college and engineering faculty of the closest neighboring four-year institution that has an established relationship with a NASA Ames Research Center. This paper summarizes the results of the first two years of implementation of the COMETS program.

2. Overview of COMETS Program Objectives and Activities

Building upon the activities previously developed through the SOLES program, the COMETS program introduced three new strategies to improve the retention and success of underrepresented community college students. The first strategy involves curriculum enhancements through contextualized teaching. The second strategy is the intersegmental cross-enrollment program that allows community college students to participate in upper-division university laboratory and capstone design courses. The third strategy is the development of a research internship program specifically designed for community college students.

<u>Strategy 1: Curriculum Enhancements through Contextualized Teaching and Learning</u>

Recently, the California Community Colleges Basic Skills Initiative has identified contextualized teaching and learning as a promising strategy to actively engage students and improve learning in basic skills courses and career/technical education.[18] Contextualized learning has been defined as a "diverse family of instructional strategies designed to more seamlessly link the learning of foundational skills and academic or occupational content by focusing teaching and learning squarely on concrete applications in a specific context that is of interest to the student."[19] Contextualized learning promotes critical thinking and creative problem solving by connecting math to real-life situations, thereby making it easier for students to transition from concrete, hands-on examples to more abstract mathematical concepts.[20]

Part of the COMETS strategy is to use contextualized teaching and learning to improve retention and success of underrepresented students in foundational math, science and engineering courses. NASA-related themes and content using research and real-life data as contextualized science-based, hands-on activities and exercises have been introduced in a variety of math courses. Among the modules developed and implemented in trigonometry include electricity consumption, Coronal Mass Ejections, NASA STEREO Spacecraft, solar probes, and using actual tide observations to explore sinusoidal functions. For precalculus, modules on exponential and logarithmic functions using Moore's Law on the increasing complexity of computer microchips, sinusoidal functions using actual tide height observations, Law of Sines and Law of Cosines using data from two NASA STEREO satellites, calculating earth-sun distance from Venus transit, and earth-moon distances have been developed. For calculus, modules on solar wind, stellar stereography, radiation from stars, and parameterization of a moon's orbit around a planet have been developed.

NASA-themed content has also been introduced in other foundational courses in computer science and engineering. For example, a module on solving the problem of launching a satellite by numerical solution of the governing differential equations using Euler's Method has been introduced in programming courses. Curricular enhancements using contextualized approaches have also been introduced in foundational engineering courses at Cañada College including a course module on introduction to robotics and programming using LEGO Mindstorms in Introduction to Engineering, designing and building a Mars rover in Engineering Graphics, and a module titled "How do you launch a satellite?" in MATLAB Programming.

Strategy 2: Intersegmental Cross-Enrollment Program

A common phenomenon that is widely observed among transfer students is transfer shock, which refers to "the tendency of students transferring from one institution of higher education to another to experience a temporary dip in grade point average during the first or second semester at the new institution."[21] It has been suggested that, in order to enhance success in their academic adjustment at the four-year institution, students must begin seeking assistance and information about admissions, academics, and social and academic expectations while still in the two-year institution.[22] To enhance the preparation of Cañada College students for a smooth transition to their four-year transfer institution, reduce the effects of transfer shock, and enhance their academic success at the baccalaureate institution, the COMETS program provides opportunities to participate in the Intersegmental Enrollment Program. Every fall semester for each year of the grant, four Cañada College sophomore students—one each from the areas of civil, mechanical, electrical, and computer engineering—are selected to participate in upper-division courses or senior design capstone courses at San Francisco State University.

For the 2010-2011 academic year, the civil engineering student participated in the design and construction of a timber bridge. The mechanical engineering student participated in a project on Materials and Manufacturing. Both the computer engineering and the electrical engineering participated in projects on Microelectronics. For the 2011-2012 academic year, the civil engineering student participated in the design and construction of a concrete canoe. For fall 2011, the mechanical engineering student participated in a Linear Systems Analysis Lab while the computer engineering and the electrical engineering students participated in projects on Microelectronics. For spring 2012, the mechanical, electrical and computer engineering students participated in research on miniaturized, minimally-invasive remote powering systems for biomedical implants. A post-program survey administered to student participants shows that the program has improved student preparation for transfer and increased their confidence in succeeding in a four-year institution. The students also indicated that the program has helped solidify their choice of major.

Strategy 3: Summer Research Internship

Among the commonly recognized high-impact practices for improving student retention and success in STEM is experiential learning, such as internships, apprenticeships, field experience and community-based projects.[23] Although research courses have been widely implemented by universities in a wide variety of undergraduate STEM curricula,[24- 31] such programs have been relatively difficult to develop in community colleges, which do not have on-going research programs. The 2012 President's Council of Advisors on Science and Technology (PCAST) report, "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics," recommends that federal agencies should encourage collaborations between research universities and community colleges to engage students in research early in college.[1]

The benefits of internship and research opportunities for undergraduate students have long been recognized.[32, 33] Independent research increases student engagement in their education. Successful research experiences among undergraduate students often lead them to seek even greater challenges that elevate their educational experience to higher levels.[34] The unexpected problems that arise in doing research "force the students to troubleshoot for solutions, which catapult students in undergraduate research past cookbook-style experiments with step-by-step instructions and outcomes."[35] Among community college students, research experiences often lead to strengthened oral and written communication skills, enhanced self-confidence, and enhanced problem solving and critical thinking skills.[36]

One of the main goals of the COMETS Program is to develop a model summer internship program that encourages collaboration between community colleges and four-year institutions to provide a research experience that is suited to the needs and qualifications of community college students.

3. COMETS Summer Research Internship Program

In 2010, a focus group of engineering students at Cañada College identified common barriers to a successful research internship program for community college engineering students. For most undergraduate research internship positions, community college students are in competition with upper-division students who have taken more advanced and specialized courses, and are from four-year institutions that have provided students with exposure and access to research-quality laboratory facilities. Perhaps an even bigger barrier is the need for many of these community college students to attend summer session in order to fulfill the various transfer requirements of the institutions and programs to which they intend to apply. Due to the diversification of requirements of different majors and different institutions, community college students often take more classes compared to their counterparts in four-year institutions.[37] Since most summer research internship positions are full-time, community college students who are interested in participating in internship programs are often faced with the difficult choice between accepting a summer internship position or taking summer courses to ensure their timely transfer.

One of the major objectives of the COMETS program is to develop a research internship program that is especially designed for community college engineering students. The ten-week NASA CIPAIR Summer Research Internship Program has been designed to include full-time positions for students who have completed all lower-division course work, and half-time positions for students who have another year in a community college before transfer, in order to allow them to take courses they need for transfer while participating in the internship program. Three research groups were formed for the 2011 and 2012 internship programs, while four research groups were formed for the 2013 internship program with each group consisting of one full-time intern and three to four half-time interns. Each group is mentored by a half-time graduate student under the supervision of a university faculty.

3.1 Demographics of Program Participants

Selection of interns is done through an online application process that takes into consideration student GPA, intended major, STEM courses completed (minimum requirement is completion of first semester physics class), extracurricular activities, statement of academic and professional goals, statement of research interest, and a recommendation letter from a STEM instructor. Table 2 summarizes the demographics of the community college students who participated in the COMETS summer research internship program in 2011, 2012, and 2013. Interns were predominantly male and Hispanic. For both 2011 and 2012 only two of the interns were female, while in 2013 there were three female interns. The program has been successful in recruiting underrepresented minorities (African American, Hispanic, and Pacific Islanders); 83.3% of the interns were minority students in 2011, 92.3% of the interns were minority students in 2012, and 81.25% of the interns were minority students in 2013.

Demographics	**2011**		**2012**		**2013**	
	# of Students	**(%)**	**# of Students**	**(%)**	**# of Students**	**(%)**
Gender						
Male	10	83.3%	11	84.6%	13	81.2%
Female	2	16.7%	2	15.4%	3	18.8%
Total	12	100.0%	13	100.0%	16	100.0%
Ethnicity						
American Indian	0	0.0%	0	0.0%	0	0.0%
Asian	2	16.7%	0	0.0%	1	6.25%
Black	0	0.0%	1	7.7%	1	6.25%
Hispanic	10	75.0%	9	69.2%	11	68.75%
Pacific Islander	0	0.0%	2	15.4%	1	6.25%
White	0	8.3%	1	7.7%	2	12.5%
Total	12	100.0%	13	100.0%	16	100.0%

Table 2. Demographics of 2011, 2012, and 2013 Summer Research Internship Program participants.

One difficulty encountered during the first two years of the program was that despite the fact that mechanical engineering is the most popular major at Cañada college, there was no mechanical engineering research group in the program. As a consequence, the mechanical engineering students were distributed evenly to each of the research groups. Table 3 shows the distribution of student majors for each of the research groups in 2011 and 2012. For 2011, there was only one computer engineering student and 6 mechanical engineering students. For 2012, the number of interns majoring in the four main fields are slightly more evenly distributed with two in computer, three in mechanical, and four each in civil and electrical.

Student Majors	**Civil Group**		**Computer Group**		**Electrical Group**		**Total**	
	2011	2012	2011	2012	2011	2012	2011	2012
Civil Engr	2	4	0	0	0	0	2	4
Computer Engr	0	0	1	2	0	0	1	2
Electrical Engr	0	0	1	0	2	4	3	4
Mechanical Engr	2	0	2	2	2	1	6	3

Table 3. Declared majors of 2011 and 2012 summer interns.

2013 was the first year the program was able to support a mechanical engineering research group. This improved the possibility for each student to join a research group that more closely matched his or her intended major. Table 4 shows the distribution of student majors for each of the research groups in 2013. Three of the five mechanical engineering students joined the mechanical engineering research group, while the other two joined the electrical engineering research group. Four of the six civil engineering students joined the civil engineering research group, and all three computer science students along with the one computer engineering student joined the computer engineering group.

Student Majors	**Civil Group**	**Computer Group**	**Electrical Group**	**Mechanical Group**	**Total**
	2013				
Civil Engr	4	0	1	1	6
Computer Engr	0	1	0	0	1
Electrical Engr	0	0	1	0	1
Mechanical Engr	0	0	2	3	5
Comp Science	0	3	0	0	3

Table 4. Declared majors of the 2013 summer interns.

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 they have the recommended background knowledge needed for the research projects. Table 5 summarizes the distribution of courses completed by students in each of the research groups. Ideally, students in the Civil Engineering research group have completed statics, students in the Computer Engineering research group have completed at least one programming class, students in the Electrical Engineering research group have completed the Circuits Analysis course, and students in Mechanical Engineering group have completed dynamics and a Circuits Analysis course. As can be seen from the highlighted cells of Table 5, the ideal minimum requirement for courses completed were satisfied for each group except for the 2012 Civil Engineering and the 2013 Electrical Engineering research group, wherein only 75% of the students had completed Statics and Circuits Analysis, respectively. In addition, only 50% of the 2013 Mechanical Engineering research group had completed Dynamics. It should be noted that, due to a combination of factors (availability to participate full time, overall academic performance, and maturity level) the only student in the group who has not completed Statics was also selected as the full-time intern. Despite not having any background in statics, this student did a good job in leading the group and felt academically prepared for the task.

Completed Courses	**CE Group**			**COMP-E Group**			**EE Group**			**ME Group**
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2013
Statics	100%	75%	100%	75%	100%	25%	75%	60%	50%	75%
Dynamics	25%	25%	50%	25%	75%	25%	50%	60%	100%	50%
Circuits	50%	75%	50%	100%	75%	25%	100%	100%	75%	75%
Intro to Programming	50%	50%	0%	100%	100%	100%	0%	80%	75%	50%
Programming in C++	50%	50%	0%	75%	75%	75%	0%	60%	75%	25%
Matlab Programming	25%	0%	50%	0%	25%	25%	25%	9%	50%	25%

Table 5. A summary of engineering courses completed by students in each research group

3.2 Research Topics

The research topics and research activities assigned to the internship program participants were decided by the San Francisco State University faculty mentors based on students' level of preparation, existing research initiatives in the university, and the availability of graduate student mentors in these areas. The 2011 Civil Engineering group conducted research on seismic systems, structural design, and time history analysis. Much of the research focused on moment-resisting frames; students relied on building codes to ensure the safety of the structure, and used the Equivalent Lateral Force Procedure (ELFP) to determine the loads and stresses of the structure. The interns also conducted research on time history analysis, which involves dynamic analysis of structures. Four sets of earthquake data – Landers, Loma Prieta, Kobe, and Northridge Earthquakes – were integrated into the simulation. Using Structural Analysis Program, SAP2000, students were able to examine story drift, and the bending of the structure's members. In addition to learning about Earthquake Engineering, the interns also developed and facilitated an interactive presentation to high school students to encourage them to pursue careers in math, science and engineering. Lastly, the interns created tutorials and videos to help improve community college and university engineering curriculum.

The 2012 Civil Engineering group focused on performance based seismic analysis of moment-resisting frames, and applied them to the design of a five-story steel moment-resisting frame in the earthquake-prone San Francisco Bay Area, California near the Hayward fault. SAP2000 and MS Excel were used to design, simulate and analyze the structure. These analyses techniques were also applied to the design of space structures (such as the space station) against similar seismic activities on other planets for human space exploration.

The 2013 Civil Engineering group worked on the design of a lateral-force resisting system for a three-story building in the earthquake-prone San Francisco Bay Area, California. Their design utilized steel plate shear walls as the structure's lateral-force resisting system, exploring how to implement current seismic technologies into a cost-efficient and environmentally friendly design. In addition to computer based analysis with SAP2000 and MS Excel, the students gained early exposure to governing building codes through the use of structural engineering and seismic design specifications such as ASCE 7-10 (American Society of Civil Engineering) and AISC 341-10 American Institute of Steel Construction). The students used SAP2000 to simulate and evaluate the response of their designed structure to selected ground motions from past earthquakes acquired from the USGS Pacifica Earthquake Engineering Research Center.

The 2011 Electrical Engineering group completed research on creating a data logger from a printed circuit board that records pressure and temperature changes due to magnets implanted inside of a patient with a hollow chest condition. The magnets gradually pull the sternum outwards to realign with the ribcage, and the data logger is designed to monitor subtle changes within the patient in real time. Creating the data logger required the use of software such as OrCAD Capture and PCB Editor. The group's responsibility was to construct the data logger so it can be manufactured into either a two-layer, or a six- layer printed circuit board. This involved gathering all the necessary datasheets and information on manufacturing capabilities, creating footprints for the components used, generating a bill of materials and a netlist, drawing a board outline and placing parts within the board outline, routing the board, producing the artwork, and generating the necessary manufacturing files.

The five interns in the 2012 Electrical Engineering group were involved in designing a world's smallest power harvesting apparatus for implantable medical devices (IMDs). Two of the five students engaged in circuit simulation using LT-SPICE to predict the device's performance. Two students were involved in programming the micro-controller, which controls the operation of the power harvest apparatus, and characterizing its performance. Another student designed and winded spiral coils used to harvest time-varying magnetic field. After students became familiar with the system, they were asked to improve the existing device by re-designing the electronic circuitry using the printed circuit board (PCB) technology altogether.

The four interns in the 2013 Electrical Engineering group worked on the optimization of the wirelessly powered AC-DC boost circuit for power harvesting in IMDs. The students again utilized LT-SPICE to model the device's performance, and conducted significant tests to maximize power transfer through adjustment of the microcontroller-based transmitting circuitry and careful measurement of the device performance. Emphasis was placed on completely redesigning a PCB layout, and the group went through extensive revisions to finally arrive at an optimal and minimally sized design.

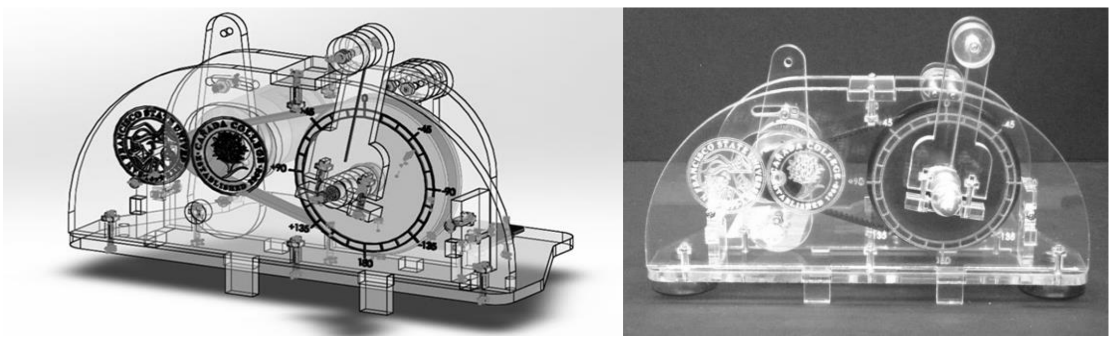
The 2011 Computer Engineering group worked on developing curriculum on Embedded Systems for graduate courses at San Francisco State University using an educational development board called Altera FPGA to understand embedded systems utilizing the Quartus II design software and the Verilog programming language. Additionally, instructional materials on using the educational development board were developed for upper-division and graduate courses in computer engineering. Despite the participants' limited prior knowledge of embedded systems, and limited previous experience or course work in computer engineering, the participants were able to achieve the program's major goals. Among the materials produced were instructional videos and laboratory manuals on a variety of topics including an Introduction to the DE2-115 Development and Education Board, Hardware Design Flow Using Verilog in Quartus II, and Hardware and Software Codesign Flow.

The focus of the 2012 Computer Engineering research group was on the analysis of performance degradation of integrated circuits due to transistor aging effects in nano-scale. In this research, analysis of transistor breakdown was performed through computer simulations to understand effects on circuit power and performance. A ring oscillator circuit was utilized as a generic logic circuit for this research. The breakdown was modeled by resistors placed between the transistor terminals. The value of the resistor represents the severity of the breakdown; large resistors represent fresh transistors, whereas low resistors represent a fully broken transistor. In addition to computer simulations, real ICs were studied by taking power measurements experimentally. This research aims to offer better insight into the impact of transistor breakdown and to improve IC design in nano-scale. Through this internship program, the undergraduate students not only contributed to research and discovery, but also gained valuable experience and knowledge of nano-scale circuits that could have not been achieved in traditional educational methods. Their research results show that the performance of integrated circuits degrades and the power consumption increases by transistor aging effects. They verified this observation by not only simulations but also experiments on an actual test chip.

The 2013 Computer Engineering group worked on the modeling and implementation of a brain-inspired neural network for edge detection and object recognition. Their system collected and analyzed data from a computer webcam with a software model of photo-receptive retinal cells to simulate the biology of the object recognition brain process. Each student in the group worked on a separate software module of the design. The various modules developed included functions to collect data from the webcam, a set of different eye cell stage functions, and an overall program to tie all the function modules together. Their system was able to consistently detect rotating objects at a resolution of 45 degrees.

New Mechanical Engineering Research Group

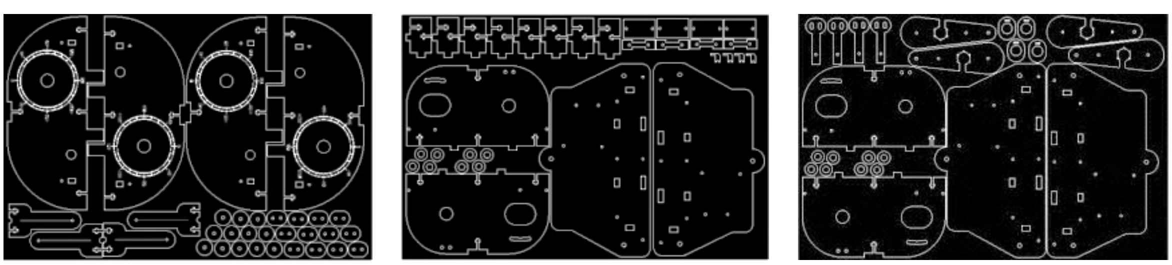
In 2013 the COMETs program hosted its first Mechanical Engineering group. The four interns in the Mechanical Engineering group worked on the development of a low-cost dynamic plant and data acquisition Haptic Paddle laboratory apparatus for use in teaching upper division topics in control theory, mechatronics, and haptics at San Francisco State University. The Haptic Paddle is a single degree-of-freedom force-feedback joystick that is well suited to be used as a test bed for exploring both basic and advanced topics in systems and control theory, mechatronics and haptics.[38] Figure 1 shows the San Francisco State University Haptic Paddle. The device demonstrates a modular design using laser-cut acrylic that is easily and inexpensively manufactured. It incorporates a timing belt-drive transmission, and includes an Arduino-based solution to data acquisition and motor drive electronics. It is powered by a standard computer power supply (not shown).



(a) (b)

Figure 1. The Haptic Paddle design finalized by the Mechanical Engineering group. (a) SolidWorks model. (b) Manufactured unit.

The group made significant improvements to the mechanical design, enhancing robustness, operational safety, and ease of manufacturing. To simplify manufacturing, thereby increasing the opportunity for wider dissemination of the device, the interns developed novel ways to change the design such that all machining (drilling holes, and cutting edges) could be performed by the laser cutter. This effort greatly improved the ability to easily fabricate the device, furthering accessibility and adoption of this Haptic Paddle design as a teaching tool.



(a) (b) (c)

Figure 2. Haptic Paddle parts for four Paddles arranged on three 12”x18” sheets, each containing: (a) Front plates, accessory washers, and handles. (b) Base and back plates, stabilizers, accessories. (c) Base and back plates, sensor board holders, motor mounts, and accessories.

In addition to finalizing the design, the group manufactured and assembled a full set of Haptic Paddle lab stations to outfit the Mechatronics laboratory at San Francisco State University. They oversaw the manufacturing process from start to finish, beginning with developing SolidWorks layout files to cut on the laser cutter (Figure 2), calibrating and configuring the laser cutter to process the acrylic sheets, quality checking cut pieces, and final assembly and mechanical calibration of thirteen Haptic Paddles (Figure 3).

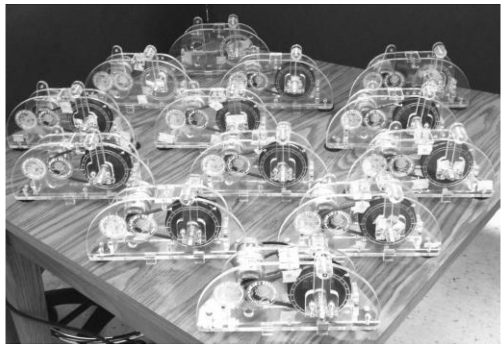


Figure 3. A full complement of Haptic Paddles to outfit a mechatronics lab has been manufactured and assembled.

Towards aiding dissemination of the Haptic Paddle, the Mechanical Engineering students were responsible for designing two sets of instructions, one for manufacturing and the other for assembly of the device. The manufacturing instructions provided a detailed account of the laser cutter used and specific settings for each manufacturing stage. One of the Mechanical Engineering students took up the task of developing a set of assembly instructions for the Haptic Paddle. The student worked through five revisions of the instructions, each time improving clarity of the procedure. It should be noted that this student had the least course preparation in his group, only having completed Calculus I, but showed the strongest dedication of his group. This student also sought assessment of his work and recruited two students from the Civil Engineering group, who had no familiarity with the Haptic Paddle hardware, to test the effectiveness of his assembly instructions. Figures 4a and 4b show these two students following the assembly instructions and completing the Haptic Paddle.

a) b)

Figure 4. (a) Civil Engineering intern students testing the Mechanical Engineering group's assembly instructions. (b) Happily finished with their assembled Haptic Paddle.

Throughout the summer research Haptic Paddle project the Mechanical Engineering group was exposed to advanced concepts like analog to digital conversion, data acquisition and sensor calibration, motor control techniques, and closed loop control topics such as proportional and derivative position control and step response behavior. This exposure to such advanced concepts significantly reinforced their interest and motivation in their current coursework, and additionally provided insight and perspective on the courses they would be taking in their junior and senior years. Each student intern chose a Haptic Paddle to calibrate and run tests with. During this time the interns used a Matlab-based GUI (designed by their graduate student mentor) that communicates with the Haptic Paddle to adjust its control gains and settings. Using this GUI the students explored various position control architectures, captured step response data, and analyzed their findings. In doing these exercises, the interns also provided valuable feedback to their mentor on improvements to make to the Matlab interface, thereby further improving future curricula based on the interface.

3.3 Results

The internship program was successful in achieving its goals of developing students' skills needed for academic success. Table 6 shows a summary of student perception of how much they have learned from participating in the internship program, as determined from a post-program survey. Note that for each of the categories, the average response is between "Quite a bit" and "A lot."

Question: How much did you learn about each of the following?	**Average Rating**		
1 – Nothing; 2 – A little; 3 – Some; 4 – Quite a bit; 5 – A lot.	**2011**	**2012**	**2013**
Performing research	4.7	4.8	4.9
Designing/performing an experiment	4.7	4.9	4.9
Creating a work plan	4.5	4.8	4.8
Working as a part of a team	4.8	4.8	4.8
Writing a technical report	4.5	4.8	4.6
Creating a poster presentation	4.7	4.7	4.7
Making an oral presentation	4.7	4.6	4.8

Table 6. Summary of student responses to the post-program survey measuring the perceived benefit of participating in the research internship program.

Table 7 summarizes the results of the post-program student survey designed to measure perception of over-all usefulness of the research internship program. Results show that the research internship program was successful in achieving its goals of helping students prepare for transfer, solidify their choice of major, increase their confidence in applying for other internships, and enhance their interest in pursuing graduate degrees. Overall, students were satisfied with the program, and would recommend it to a friend.

Question: Tell us how much you agree with each statement. 1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree.	**Average Rating**		
	2011	**2012**	**2013**
The internship program was useful.	4.8	4.9	4.9
I believe that I have the academic background and skills needed for the project.	4.2	4.1	4.6
The program has helped me prepare for transfer.	4.3	4.5	4.9
The program has helped me solidify my choice of major.	4.6	4.3	4.8
As a result of the program, I am more likely to consider graduate school.	4.7	4.6	4.1
As a result of the program, I am more likely to apply for other internships.	5.0	4.8	4.9
I am satisfied with the NASA CIPAIR Internship Program.	4.7	4.8	4.8
I would recommend this internship program to a friend.	4.8	4.8	4.9

Table 7. Summary of student satisfaction with the summer research internship program.

Figure 5 is a summary of student responses to the open-ended question: "What did you like most about the program?" For the 2013 interns, the challenge of the work they did during the program was the most popular response (25%), followed by a three-way tie of doing research, gaining teamwork experience, and being able to apply theory to real-world engineering problems, with 19% of students selecting each response, followed further by the advanced nature of the work they did during the program (13%), and working with the graduate student mentors (6%). For 2012, doing research was the most popular response (38%), followed by being able to apply theory to real-world engineering problems (23%). In 2011, doing research and the advanced nature of the work they did during the program were tied as the most popular responses, with 25% of students selecting each response.

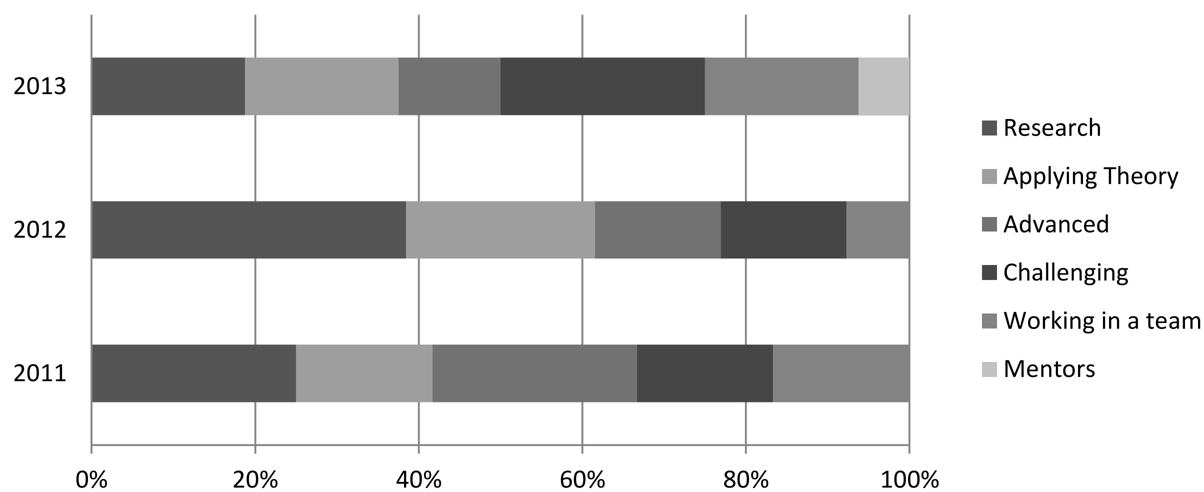


Figure 5. Summary of student survey responses: "What did you like most about the program?"

When asked to give one suggestion for improving the internship program, the most popular suggestion among the 2011 interns was to provide more structure to the program (58%), followed by adding a Mechanical Engineering research group (38%), and increasing the duration of the internship program (17%). As a response to student feedback, more structure in the form of weekly group meetings and bi-weekly progress reports were incorporated in 2012. As a result of these programmatic changes, the student responses to the 2012 post-program survey completely reversed; the most popular suggestion was to increase the duration of the program (42%), followed by adding a Mechanical Engineering group (33%), and providing more structure to the program (25%). As a response to the student feedback, the 2013 internship program included a mechanical engineering research group, and continued to implement frequent group meetings and progress reports to maintain the level of program structure reached in 2012. As a result, the 2013 post – program survey student responses showed the most popular suggestion was to provide methods to better manage teamwork and time on task for the interns (31%), followed by a tie for adding more structure and providing more resources, with 19% of students selecting each response. Other suggestions were to provide more involvement at the NASA AMES research campus (13%), and find a way to reduce the commute time for students (13%). None of the 2013 students recommended extending the length of the program.

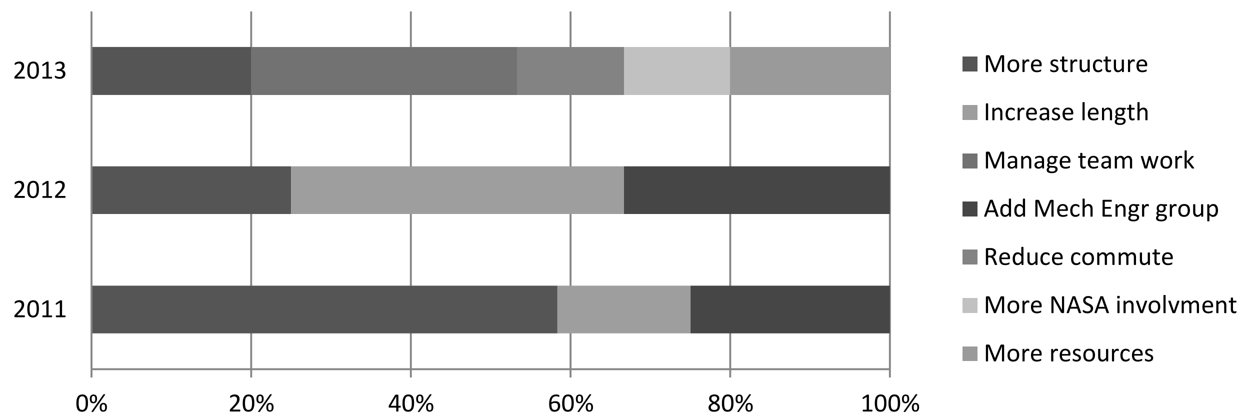


Figure 6. Summary of student survey responses: "Give one suggestion for improvement."

4. Conclusion

The first three years of implementation of the COMETS project have been successful in carrying out all the planned activities as scheduled. The project has resulted in a number of curricular enhancements in foundational math and engineering courses developed collaboratively by math, computer science, and engineering faculty, as well as curriculum developed by students as part of their summer research activities. Further curricular enhancements are planned for math, engineering, and computer science by incorporating NASA-related content as in-class demonstrations, projects and hands-on exercises.

The intersegmental cross-enrollment program that allows sophomore community college students to participate in upper-division and capstone design courses in a four-year school has been successful in its goal to improve student preparation for transfer and increase their confidence in succeeding in a four-year institution. The student participants also indicated that the program has helped solidify their choice of major.

The Summer Research Internship program has been successful in creating opportunities for students to engage in advanced work that develops research skills and applies concepts and theories learned from their classes to real-world problems. The program has also helped students in solidifying their choice of major, improving preparation for transfer, and acquiring knowledge and skills needed to succeed in a four-year engineering program. As a result of their research experience, all of the participants have expressed that they are now more likely to apply for other internships and consider pursuing graduate degrees in engineering. The research internship has also resulted in a number of student conference paper and poster presentations including paper and poster presentations that were selected as the only community college finalists in the undergraduate paper and poster presentation at the 2011 Society of Hispanic Professional Engineers National Conference. Papers and posters were also presented by students at the following conferences: 2012 and 2013 Interdisciplinary Engineering Design Education Conference (IEDEC), 2012 and 2013 American Society for Engineering Education Pacific Southwest (ASEE PSW) Conference (3 posters, and 3 papers), and the 2012 and 2013 Society for the Advancement of Chicanos and Native Americans in Science (4 posters, and 4 papers).

The collaboration between Cañada College and San Francisco State University through the COMETS program that has created opportunities for community college students has been mutually beneficial to both institutions. At Cañada College, curriculum enhancements that were directly developed by COMETS program participants together with the enriching academic experiences of its students have strengthened the engineering transfer program. Curriculum enhancements have also improved several undergraduate and graduate courses at San Francisco State University, including the most recent laboratory hardware development work done by the 2013 Mechanical Engineering group. Research contributions of the community college students and lessons learned from the program have strengthened faculty research and increased undergraduate student engagement in research. The success achieved through the partnership has also been instrumental in securing additional funding—both individually and collaboratively—to further strengthen the partnership, better promote STEM education and improve the programs and services offered at both institutions, and serve as a model of collaboration for improving STEM education in public institutions of higher education.

Acknowledgements

This project was supported by the National Aeronautics and Space Administration (NASA) Office of Education through Curriculum Improvement Partnership Award for the Integration of Research into the Undergraduate Curriculum (CIPAIR), Grant No. NNX10AU75G.

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