Developing a Summer Engineering Program for Improving the Preparation and Self-Efficacy of Underrepresented Students

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(Research to Practice) Strand: Other

Abstract:

In order to meet current and future demands for engineers needed to retain economic competitiveness and innovation capacity of the United States, there is an increasing need to engage students from traditionally underrepresented groups in engineering, including women and ethnic minorities. To be successful in expanding the pool of potential engineers, the needs of these underrepresented students have to be addressed. A majority of these students have low-levels of preparation for college-level course work, especially in math and science, and most have little or no pre-college exposure to the engineering profession. This paper is a description of a collaborative effort between a small community college, a comprehensive urban university, and a highly diverse high school district in the San Francisco Bay Area to increase the interest and improve the preparation of female and underrepresented high school students in pursuing careers in engineering through a two-week residential summer camp. The Summer Engineering Institute provides participants an insight into the engineering profession and the engineering educational system through a combination of lectures, hands-on laboratory activities, field trips, workshops, panels, and projects. Among the strategies employed in developing the program are emphasizing all the major fields of engineering and the various paths to an engineering career, including the role of community colleges; targeting first generation students and underrepresented minorities; collaborating with high school faculty and staff through a nomination process to identify and select potential students; collaboration among community college and university faculty in developing and implementing the curriculum; engaging industry partners and engineering professionals; and encouraging family involvement in program activities. Program outcomes assessments include pre- and post-program student surveys that measure student interest in pursuing an engineering degree, academic self-efficacy and motivation, attitudes and enthusiasm of participants towards the program activities, knowledge of specific engineering topics, and awareness of resources and skills needed for success in engineering. A follow-up survey has also been developed to track changes in student attitudes, interests, and educational plans years after participating in the program. The paper presents the results and lessons learned from five years of implementation of the SEI, and how the program has succeeded 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.

1. Introduction

Despite increasingly urgent calls for investment in science and technology education to meet current and future demands for more engineers needed to retain economic competitiveness and innovation capacity of the United States, trends in engineering enrollment show that, over the last decade, undergraduate degrees awarded in the fields of engineering have declined from 6.3 to 5.4 percent of the total degrees conferred.[1] An important strategy for increasing the number of future engineers is to engage students from traditionally underrepresented groups in engineering, including Latinos and African Americans. 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.[2] Yet for many of these 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. According to the study, 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.[3]

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," indicates that the United States needs to produce one million additional STEM professionals in the next decade in order to retain its historical preeminence in science and technology.[4] Among the strategies that have been proven effective in increasing the participation, retention and success of minority students in science and engineering include summer programs.[5-12] Although proven to be a successful strategy particularly for traditionally underserved students,[13] most residential summer bridge programs focus on incoming college students with primary goals of providing students with an orientation to the campus, building a community among the students, delivering remedial instruction, and providing knowledge and skills for college success. This paper focuses on the Summer Engineering Institute, which is a summer residential program for high school students that is developed collaboratively by a community college and a large, comprehensive urban university to provide students from underrepresented groups the opportunity to explore alternative paths to an engineering career.

In addition to providing high school students an exposure to the engineering profession to increase their interest, it is important to also enhance their self-efficacy to pursue careers in engineering, especially those from underrepresented groups. Bandura, defined self-efficacy as the "the belief in one's capabilities to organize and execute the courses of action required to manage prospective situations[14]." In other words, self-efficacy is one's belief in their ability to succeed in specific situations, and such belief can influence how one approaches goals, tasks, and challenges. As a result, educational research has linked student persistence with self-efficacy.[14-17] Self-efficacy theory hypothesizes four factors affecting self-efficacy: mastery experience, vicarious experience, social persuasion, and physiological factors. Mastery experiences, prior experiences resulting in positive outcomes results in increased self-efficacy, and lead to increased confidence, resilience, perseverance.[14,18] Vicarious experience, or observing others succeed, can also lead to an increased sense in one's own ability to similarly succeed.[18,19] Social persuasion, i.e., as direct encouragement or discouragement from another person, also influences one's feelings of confidence and judgment of personal capabilities. Physiological factors pertain to emotional reactions to stressful situations and perceptions of these reactions, which can heighten or diminish confidence, and impact performance.[18,19]

In studies of persistence and retention of students in STEM fields, self-efficacy frequently arises because students' perception of their self-efficacy and responsibility for learning are linked to persistence and performance.[20-23] For instance, students having higher mathematics self-efficacy also had higher mathematics achievement.[24] Similarly, science positive self-efficacy beliefs are positively correlated with persistence.[25]

This paper will detail the development and implementation of the Summer Engineering Institute, which was designed to increase the interest and improve the preparation of female and underrepresented high school students in pursuing careers in engineering while providing opportunities to positively impact student efficacy for college success, particularly in an engineering field. The paper will also highlight the results from the last five years of implementation of the program.

2. The Summer Engineering Institute

In 2008, Cañada College, a Hispanic-Serving community college in Redwood City, CA, was awarded a Minority Science and Engineering Improvement Program (MSEIP) grant by the US Department of Education. The project, entitled Student On-ramp Leading to Engineering and Sciences (SOLES), aims to maximize the likelihood of success among underrepresented and educationally disadvantaged students interested in pursuing careers in STEM fields by incorporating strategies that address challenges and barriers to recruitment, retention and success of these students. Among the strategies developed for this project is a summer engineering camp developed collaboratively with San Francisco State University, a large comprehensive urban university in San Francisco. The Summer Engineering Institute (SEI) is a two-week residential program held on campus at San Francisco State University. The goals of the program are to introduce students to the engineering educational system and the engineering profession, to recruit students into an engineering field, increase student awareness of resources and skills needed for college success, and to increase student knowledge of specific engineering topics. The first year of implementation of SEI was done through a collaboration with the California Department of Transportation (Caltrans), with the curriculum adopted from previous years of implementation of Caltrans' engineering institute. This curriculum focused mostly on engineering fields that are relevant to Caltrans missions, and does not provide students the opportunity to explore the many different pathways to the various engineering career options.

In 2010, the SEI curriculum was drastically revised in order to present a more balanced curriculum that introduces participants to the major areas of engineering. This revised SEI curriculum—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 details on alternative paths to an engineering career including concurrent enrollment in high school, community college engineering transfer programs, and state universities, as well as private and independent institutions. Appendix 1 shows a summary of the typical schedule of the Summer Engineering Institute. This schedule has been adopted with a few minor modifications for the last four years of the program. Most mornings 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.

Group Projects

One of the most effective factors in enhancing self-efficacy is through mastery experiences. To provide those experiences to SEI participants, four culminating group projects corresponding to each of the four main areas of engineering (civil, computer, electrical, and mechanical) were designed. Each student selects two of the four projects based on their initial interests. The first week 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 San Francisco State University who acts as the project mentor. Each project mentor works closely with San Francisco State University faculty in designing the project and planning daily activities related to project completion, and to ensure the success of students in completing their selected projects. Below is an overview of each of the SEI group projects used for the last three years.

The computer engineering project is to design and create an iPhone App that has an academic application (e.g, unit conversion, periodic table of elements, math formulas). The goals of this project are to (1) attract high school students into the field of computer engineering, (2) demonstrate the fundamentals of computer engineering, and (3) encourage innovations on designing human-computer interface. The project is carried out in the following four phases:

- Introduce xcode and its emulator: The programming tool, xcode, an object-oriented programming language developed by Apple, is presented to students in a lecture mode. Meanwhile, its emulator, which is used to test the xcode program, is demonstrated.
- Design the App: Each group, which consists of 3-4 students, brainstorms the possible best design for their App. Students will come up with the sketch of the "look" of the App and the flow chart of the program. This process could inspire students' creativity.
- Program and Validation: In this phase, students focus on programming the App using xcode and validate the program using its emulator. Students will be exposed to the real-life computer engineering: programming and debugging.
- Documentation: Students are asked to report their design and experience. Students are asked to write a clear document on the App their created. Like any engineering project, concise and clear documentation is an integral part of the project.

The SEI Civil Engineering group project has the following objectives:

- Understand the basics of statics and equilibrium of forces.
- Understand static and dynamic loads on structures.
- Understand the basics of truss bridges; use computer applications and simulations to design truss bridges.
- Build a truss bridge using available materials in the PASCO Scientific kit (http://www.pasco.com/).
- Calculate the bar forces of truss bridge under static loads.
- Measure the bar forces of truss bridge under static loads.
- Measure the bar forces of truss bridge under dynamic traffic loads.
- Compare the bar forces under static and dynamic loads.
- Prepare project report and presentation.

The Electrical Engineering group project uses the BASIC Stamp Activity Kit from Parallax, Inc. (http://www.parallax.com/) to achieve the following objectives:

- Understand basic circuits principles.
- Understand circuit elements, symbols and diagrams.
- Design, build and test simple circuits.
- Understand the basics of microcontrollers.
- Learn concepts of computer hardware and programming.
- Write and debug BASIC programs.
- Prepare project report and presentation.

The Mechanical Engineering illustrates a practical application of heat engines and demonstrates the magnitude of losses that occur during energy conversion processes. The project uses an off-the-shelf Stirling engine kit to achieve the following objectives and activities:

- Understand the fundamentals of heat engines and how they convert energy in the form of heat to mechanical work output.
- Understand the thermodynamic processes in the Stirling engine cycle.
- Work in teams to build a Stirling engine from a commercially available kit, and optimize its operation to provide electrical power output (using a small generator).
- Conduct experiments on the Stirling engine generator to determine energy conversion efficiency (conversion from stored chemical energy in the fuel to electrical energy from the generator).

Workshops Developed and Led by Community College Students

For the last three years of implementation of SEI, community college students have been engaged in developing curriculum for the program. Four groups of XXXXXXXXXX students who are participating in a 10-week summer research internship funded by NASA through the Curriculum Improvement and Partnership Awards for the Integration of Research (CiPair) Program were asked to develop a two-hour workshop for SEI participants focusing on the four major areas of engineering, and including a short presentation on the research project they are doing and hands-on demonstrations or activities that involve the application of engineering. The motivation to involve the CiPair interns in SEI is two-fold. First, this gives the interns the opportunity to practice their presentation skills. Secondly, and perhaps more important for SEI, having the interns present their research and lead the activities provides “vicarious” experiences to SEI participants to help enhance self-efficacy. The student interns are mostly from underrepresented backgrounds very similar to the SEI students, and in some cases, even graduated from the same high schools they are currently attending. Seeing successful community college students who are only a few years older doing advanced engineering research can be very effective in enhancing self-efficacy of high school students, convincing them that perhaps, they too could succeed.

The Civil Engineering group presented their research project that is related to earthquake engineering. Two hands-on workshops have been developed: one on designing truss bridges,[28] and another on designing a spaghetti tower.[29] The Computer Engineering group presented their research project on a variety of topics (embedded systems in 2011, nano-scale circuits in 2012, and modeling brain-inspired neural networks in 2013). The two hands-on workshops were based on developing algorithms for making a peanut-butter-and-jelly sandwich,[30] and introduction to programming through RoboZZle.[31] The Electrical Engineering group presented their research projects on biomedical applications of circuit design. The hands-on workshops developed were based on making a simple electric motors,[32] and building a variety of circuits based on a commercially available electronic lab kit.[33] The Mechanical Engineering Groups presented their research on haptics, and developed hands-on workshops on designing a balloon-powered vehicle,[34] and designing a mechanically powered contraption to transport a ball across a gap.[35]

Other Workshops

In addition to the above culminating projects and the student developed workshops, SEI also held a variety of other workshops related to academic, personal, and professional development. One such workshop provides participants with an overview of renewable energy. Specifically, students learn about the various forms of renewable energy (solar, wind and hydro power), how these forms of energy can be converted into useable (mechanical or electrical) energy, and their pros and cons. Using the Invicta Plastics Renewable Energy kits (http://www.fisher.co.uk/), students observe for themselves the energy conversion processes in action. Students are asked how they would represent the amount of useable energy (mechanical or electrical) as a function of input energy (speed of the wind turbine, or angle of the PV panel with respect to the sun), and then correlate increased output as a result of increased input. Additionally, there were workshops on résumé writing, public speaking, and robotics, as well as team-building exercises.

3. Results from 2009-2013 SEI

This section is a description of the results of the first five years of implementation of SEI.

3.1 Recruitment

Recruitment of SEI participants includes class visits to local area high school math and science courses, presentations to high school math department and counseling department meetings, recruitment tables at college night events for high school students and their parents, and presentations during high school student campus visits and tours. Additionally, program brochures and fliers are sent to high school math and science teachers and to local youth organizations. Program information and application materials are also made available at the program website (http://canadacollege.edu/STEMcenter/highschoolstudents.php).

Table 1 is a summary of the results of the recruitment efforts showing a steadily increasing number of applications, and consequently drastically decreasing acceptance rates. For instance, the acceptance rate in 2009 was 86.2%, compared to only 18.2% for 2013. The selection process is based on a number of factors including academic performance, extracurricular activities, statement of interest, participation in high school programs for underrepresented students (e.g., MESA Schools Program [http://mesa.ucop.edu/programs/schoolprogram.html], AVID Program [http://www.avid.org/abo_whatisavid.html]), and letters of recommendation from a math or science instructor, or a counselor. It should be noted that in 2009, all application materials were submitted by mail. Starting 2010, all applications were completed and submitted online. The online submission process has significantly increased the number of applications received and has also simplified the review and selection processes. Although a handful of applications are received from out of state (and even out of the country), the vast majority of applications are from California residents.

Table 1. Summary of applications received and acceptance rates for SEI.

SEI Applications	2009	2010	2011	2012	2013
Number of Applicants	29	46	77	121	143
Number of Participants	25	26	26	26	26
Acceptance Rate	86.2%	56.5%	33.8%	21.5%	18.2%

3.2 Profile of SEI Students

Since the Summer Engineering Institute was originally funded through the US Department of Education Minority Science and Engineering Improvement Program (MSEIP) whose primary goal is broadening the participation of traditionally underrepresented students in STEM, the project team has made a conscious effort to give priority to minority, female, and first-generation college students, and those from underserved communities. Table 2 shows a summary of the demographics of students selected to participate in the program. The percentage of students from underrepresented minority groups is above 60% for each year, with Hispanics constituting the largest ethnic group. The percentage of students who are the first in their families to go to college was 44.0% in 2009 and has stayed above 50% for subsequent years. More than half of the participants from each year were female students.

Table 2. Demographics of Summer Engineering Institute participants for 2009 to 2012.

	2009		2010		2011		2012		2013	
Demographics	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Gender										
Female	13	52.0%	14	53.8%	15	57.7%	14	53.8%	13	50.0%
Male	12	48.0%	12	46.2%	11	42.3%	12	46.2%	13	50.0%
Total	25		26		26		26		26	
Ethnicity										
African Amer	3	12.0%	1	3.8%	3	7.7%	3	11.5%	3	8.8%
American	0	0.0%	0	0.0%	1	3.8%	1	3.8%	2	5.9%
Asian American	5	20.0%	2	7.7%	1	3.8%	4	15.4%	4	11.8%
Caucasian	2	8.0%	3	11.5%	2	7.7%	3	11.5%	5	14.7%
Hispanic	12	48.0%	20	76.9%	18	69.2%	14	53.8%	17	50.0%
Pacific Islander	1	4.0%	0	0.0%	1	3.8%	1	3.8%	3	8.8%
Other/Unknown	2	8.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	25		26		26		26			
First in Family to Attend College?										
Yes	11	44.0%	14	53.8%	16	61.5%	19	73.1%	13	50.0%
No	14	56.0%	12	46.2%	10	38.5%	7	26.9%	13	50.0%
Total	25		26		26		26		26	

3.3 SEI Students' Intended Major

One of the main goals of SEI is to increase the interest of participants in pursuing careers in engineering. To evaluate the success of SEI in achieving this goal, pre- and post-surveys of students' intended major in college were done. Table 3-A summarizes the results of the pre-program survey of students' intended major, while Table 3-B summarizes the post-program survey results. Cumulative results for the five years (column labeled "Total") indicate that the largest increase in the number of students' intended major is in Civil Engineering (+2), followed by Electrical Engineering (+6), and Mechanical Engineering (+4). The largest decrease is in Engineering (-19), followed by Undecided (-6). The large decrease in the number of students who initially declared a "general" Engineering major shows that after participating in SEI, these students have been able to identify a specific engineering field of interest to them. These results also indicate that after participating in the program and gaining an understanding of the different engineering fields, several students changed from one area of engineering to another. It is worth noting that, despite a heavy focus on Civil Engineering due to the Caltrans' SEI curriculum used in 2009, the only change in student intended major is one student changing from Civil Engineering to a non-engineering major.

Table 3-A. SEI Pre-Program Student Survey: Intended Major in College.

Pre-Program Intended Major	**2009**	**2010**	**2011**	**2012**	**2013**	**Total**
Aerospace Engineering	0	3	1	1	2	7
Biomedical Engineering	1	0	1	4	3	9
Chemical Engineering	0	0	0	1	0	1
Civil Engineering	4	3	2	2	4	15
Computer Engineering	2	8	7	5	3	25
Electrical Engineering	0	2	0	0	0	2
Mechanical Engineering	3	3	4	1	4	15
Engineering	7	0	5	9	9	30
Other (non-engineering)	0	2	1	3	0	6
Undecided	8	5	5	0	1	19
Total	*25*	*26*	*26*	*26*	*26*	*129*

Table 3-B. SEI Post-Program Student Survey: Intended Major in College.

Post-Program Intended Major	**2009**	**2010**	**2011**	**2012**	**2013**	**Total**	**Change**
Aerospace Engineering	0	3	0	1	2	6	-1
Biomedical Engineering	1	0	1	4	2	8	-1
Chemical Engineering	0	0	0	0	0	0	-1
Civil Engineering	3	2	7	8	7	27	12
Computer Engineering	2	7	7	4	5	25	0
Electrical Engineering	0	2	0	3	3	8	6
Mechanical Engineering	3	5	6	2	3	19	4
Engineering	7	0	2	1	1	11	-19
Other (non-engineering)	1	5	0	3	3	12	6
Undecided	8	2	3	0	0	13	-6
Total	*25*	*26*	*26*	*26*	*26*	*129*	**

Another indication of initial student interest in the different areas of engineering is their selection of the culminating projects during SEI. Recall that starting 2010, SEI participants are given a choice of participating in two of the four projects. Table 4-A shows the number of students who selected each of the four projects, while Table 4-B shows the number of students who declared each of the four major engineering fields as their major after the program. Note that although only 21.6% of students indicated initial interest in Civil Engineering by selecting it as one of their SEI projects, 33.8% of students selected Civil Engineering as their intended major after participating in SEI.

Table 4-A. Summary of the number of SEI students who selected a particular project in 2010, 2011, 2012, and 2013.

Project Selected	2010	2011	2012	2013	Total	Percentage
Civil Engineering	7	12	9	17	45	21.6%
Computer Engineering	19	18	18	13	68	32.7%
Electrical Engineering	8	8	11	7	34	16.4%
Mechanical Engineering	18	14	14	15	61	29.3%
Total	*52*	*52*	*52*	*52*	*208*	*100.0%*

Table 4-B. Summary of post-SEI intended majors (only includes the four major areas of engineering).

Post-SEI Intended Major	2010	2011	2012	2013	Total	Percentage
Civil Engineering	2	7	8	7	24	33.8%
Computer Engineering	7	7	4	5	23	32.4%
Electrical Engineering	2	0	3	3	8	11.3%
Mechanical Engineering	5	6	2	3	16	22.5%
Total	*16*	*20*	*17*	*18*	*71*	*100.0%*

3.4 Student Survey Results: Student Attitudes Towards SEI

To assess the effects of participation in SEI on student attitudes about engineering, their confidence in succeeding in college, and SEI's impact on their selection of an engineering major, pre- and post- program surveys were administered. The surveys include items in which students responses are in the following Likert scale: 5 – Strongly Agree, 4 – Agree, 3 – Neutral, 2 – Disagree, 1 – Strongly Disagree. Averages of responses were calculated and results are summarized in Table 5-A for 2009, Table 5-B for 2010, Table 5-C for 2011, and Table 5-D for 2012.

With respect to the prompt “I feel excited about participating in the Summer Engineering Institute,” student responses were highly positive, with averages between “Agree” and “Strongly Agree.” Statistically significant increases from pre- to post- program responses were measured in 2009 and 2011. With respect to students' confidence in succeeding in college, statistically significant improvement in the post-program student responses is observed in 2011. With respect to the prompt “I am confident that SEI will help me in selecting an appropriate Engineering major," a decrease in the average student response is observed for each of the four years, with the largest (and the only statistically significant decrease) observed in 2009. This is perhaps due to the nature of the 2009 SEI curriculum, which focused mostly on Civil Engineering, and hence failed to be help students in selecting an appropriate major.

Table 5-A. 2009 SEI Student Survey: Attitudes towards SEI. Response Scale: 5 – Strongly Agree, 4 – Agree, 3 – Neutral, 2 – Disagree, 1 – Strongly Disagree.

Attitudes	Pre	Post	Change
I feel excited about participating in the Summer Engineering Institute.	4.24	4.58	0.34*
I am confident that I have the skills and academic preparation to be a successful college student.	4.32	4.42	0.10
I am confident that SEI will help me in selecting an appropriate Engineering major.	4.16	3.63	-0.53*

* The change is statistically significant ($p < 0.050$).

Table 5-B. 2010 SEI Student Survey: Attitudes towards SEI.

Attitudes	Pre	Post	Change
I feel excited about participating in Summer Engineering Institute.	4.35	4.23	-0.12
I am confident that I have the skills and academic preparation to be a successful college student.	4.00	4.12	0.12
I am confident that SEI will help me in selecting an appropriate Engineering major.	4.19	3.81	-0.38

For the 2011, 2012 and 2013 student surveys, the prompt "As a result of SEI, I am now more likely to consider science or engineering as a major in college," was added. Responses to this have been very positive, with average values above 4.0 (last row of Table 5-C and Table 5-D).

Table 5-C. 2011 SEI Student Survey: Attitudes towards SEI.

Attitudes	Pre	Post	Change
I feel excited about participating in Summer Engineering Institute.	4.38	4.83	0.45*
I am confident that I have the skills and academic preparation to be a successful college student.	4.35	4.71	0.36*
I am confident that SEI will help me in selecting an appropriate Engineering major.	4.42	4.38	-0.04
As a result of SEI, I am now more likely to consider science or engineering as a major in college.	--	4.54	--

* The change is statistically significant ($p < 0.050$).

Table 5-D. 2012 SEI Student Survey: Attitudes towards SEI.

Attitudes	Pre	Post	Change
I feel excited about participating in Summer Engineering Institute.	4.35	4.50	0.15
I am confident that I have the skills and academic preparation to be a successful college student.	4.31	4.29	-0.02
I am confident that SEI will help me in selecting an appropriate Engineering major.	4.31	4.17	-0.14
As a result of participating in the SEI, I am now more likely to consider science or engineering as a major in college.	--	4.63	--

Table 5-E. 2013 SEI Student Survey: Attitudes towards SEI.

Attitudes	Pre	Post	Change
I feel excited about participating in Summer Engineering Institute.	4.62	4.44	-0.18
I am confident that I have the skills and academic preparation to be a successful college student.	4.15	4.40	0.25
I am confident that SEI will help me in selecting an appropriate Engineering major.	4.58	4.40	-0.18
As a result of participating in the SEI, I am now more likely to consider science or engineering as a major in college.	--	4.24	--

3.5 Student Survey Results: 20010-2013 Program Activities

In order to establish a more direct comparison of the SEI activities in 2010, 2011, 2012 and 2013, the results of the post-program survey of their usefulness are summarized. The post-program survey had the prompt: "How useful is each following?" and the Response Scale was: 5 – A Lot, 4 – Quite a Bit, 3 – Some, 2 – A little, 1 – Not at All Useful. Note that survey results from 2009 are not included in the present analysis because the curriculum in 2009 (and consequently the activities) was very different because it was based on the curriculum previously developed by Caltrans.

Table 6 is a summary of the average student ratings of the usefulness of the projects. From 2010 to 2012, steady improvements of the ratings of the projects are observed over the past three years, with the exception of the 2012 iPhone Project. Yearly increases in student ratings of the project can be attributed to the program improvements made as a result of lessons learned from previous years. For the 2012 iPhone project, the low student average rating is brought about by the combination of technical difficulties (old computers not working properly with the software) and a last-minute switch to a graduate student mentor who does not have a solid background in iPhone Apps. The drop in student average rating of the Sterling Engine project in 2013 may again be attributed to the new student mentor in charge of the project.

Table 6. Student Ratings of the Usefulness of SEI Projects. Response Scale: 5 – A Lot, 4 – Quite a Bit, 3 – Some, 2 – A little, 1 – Not at All Useful.

Projects	2010	2011	2012	2013
Bridge design	4.00	4.33	4.70	4.65
Designing a Timer	4.27	4.33	4.72	4.36
iPhone project	4.10	4.65	3.81	4.20
Sterling Engine	4.26	4.60	4.75	4.06

Table 7 is a summary of the average student ratings of the usefulness of the SEI lectures and presentations. It should be noted that the morning lectures/presentations on the four main fields of engineering are the least favorably viewed by students. On the other hand, afternoon sessions which are either more focused in content, or involving some hands-on demonstrations, or involving more than one presenter are more favorably viewed.

Table 7. Student Ratings of the Usefulness of Lectures and Presentations. Response Scale: 5 – A Lot, 4 – Quite a Bit, 3 – Some, 2 – A little, 1 – Not at All Useful.

Lectures	2010	2011	2012	2013
Lecture on Civil Engineering	3.65	4.21	4.26	3.88
Lecture on Computer Engineering	3.69	4.25	3.74	3.52
Lecture on Electrical Engineering	3.23	4.00	3.87	3.68
Lecture on Mechanical Engineering	3.69	4.08	4.22	3.64
Overview of Engineering Curriculum and Profession	3.46	4.33	4.17	4.08
Top 10 Things Engineering Students Need to Know	4.35	4.46	4.39	4.40
Wheel Chair Lab presentation	3.88	4.38	4.17	4.36
Professionalism and Ethics	3.73	4.50	4.52	4.08
Panel of Engineers	3.58	4.25	4.26	4.24

Table 8 shows a summary of average student ratings of the usefulness of the workshops. Note that not all of the workshops were offered during each of the years. With only a few exceptions, student ratings for most of the workshops have improved significantly from 2009. Student ratings of the field trips have shown steady improvements of the years, and have become some of the most highly rated activities in the institute, with the exception of the 2013 when the planned field trip had to be changed at the last minute due to unexpected closure of the facility originally scheduled to be visited.

Table 8. Student Ratings of the Usefulness of Workshops. Response Scale: 5 – A Lot, 4 – Quite a Bit, 3 – Some, 2 – A little, 1 – Not at All Useful.

Workshops	2010	2011	2012	2013
Guaranteed 4.0 workshop	3.96	*	*	*
Civil Engineering Workshop	3.77	4.33	4.09	2.76
Egg Drop	4.12	4.25	4.17	4.68
Secret Codes with Tic Tacs	4.12	4.17	4.04	4.36
Renewable Energy	2.54	4.04	3.91	3.36
Robotics Workshop	4.08	4.38	4.43	4.44
Math Review using MyMathTest	4.15	4.07	3.88	*
Resume Workshop	3.46	*	4.04	3.04
Vision Board	4.00	*	*	*
Toast Masters	*	*	3.92	4.32
Robotics Challenge	4.19	4.17	4.38	4.56
NASA CIPAIR Interns (Civil Engineering)	*	4.42	4.13	4.28
NASA CIPAIR Interns (Computer Engineering)	*	4.38	4.13	4.36
NASA CIPAIR Interns (Electrical Engineering)	*	4.33	4.04	4.40
NASA CIPAIR Interns (Mechanical Engineering)	*	*	*	4.20
Field Trip: Shipyard (2010), PG&E (2011-12), downtown SF (2013)	3.96	4.42	4.43	3.84**
Field Trip: Exploratorium	4.31	4.50	4.52	4.60
Field Trip: Bay Bridge	3.91	4.75	4.79	4.80

*Workshop was not offered.

**The planned field trip was changed at the last minute because of unexpected closure of facility.

3.6 Student Survey Results: Self-Efficacy

One of the goals of SEI is to improve student self-efficacy in succeeding as an engineering student. To determine the impact of SEI on student self-efficacy, the Baldwin Confidence Survey Form was used in 2013.[36] In this survey, which was created to measure self-efficacy in STEM, participants respond to statements on a five-point scale, ranging from strongly disagree to strongly agree. Statements are phrased both positively and negatively (items 4, 7, 9, and 14 of the survey) to increase reliability and reduce apathetic answers. Table 9 shows a summary of the results of the pre- and post-SEI self-efficacy survey. Among all 15 items in the survey, a statistically significant favorable change in student responses is observed only for item 8. For all the other items, the change is not statistically significant.

When compared to results of other STEM self-efficacy studies using the Baldwin Confidence Survey, the SEI participants have very high self-efficacy based on both the pre- and post-surveys. For instance, the mean responses of SEI students are about one full point more positive than those reported from a survey of 23 engineering and computer science students who were participants of the ACE Scholarship Program at California State University, Fullerton.[37] When compared to the responses of 216 Anatomy & Physiology students at Chippewa Valley Technical College in Eau Claire, Wisconsin, the mean responses to the survey for the SEI students are on the average about 1.68 points more positive.[38] Because of the initially high levels of self-efficacy among the SEI participants, a significant increase in their self-efficacy is difficult to achieve. Among the possible contributors to high self-efficacy of these students are the SEI selection procedure, which involved a nomination process initiated by a math or science instructor. Furthermore, during the SEI Orientation Program, the students and their parents were informed of the highly competitive nature of the SEI selection process, with less than 20% of the applicants being selected. This sense of being one of the few selected to participate in the program may have boosted the participants' self-efficacy.

Table 9. SEI Student Self-Efficacy Survey: Response Scale: 1 – Strongly Agree, 2 – Agree, 3 – Neutral, 4 – Disagree, 5 – Strongly Disagree.

Survey Question	Pre-Program	Post-Program	Change
1. I am confident I have the ability to learn the material taught in Engineering.	1.58	1.72	0.14
2. I am confident I can do well in Engineering.	1.73	1.64	-0.09
3. I think I will do as well or better than other students in Engineering.	1.96	1.96	0.00
4. I don't think I will be successful in Engineering.	4.28	3.92	-0.36
5. I am confident that I can understand the topics taught in Engineering.	1.73	1.84	0.11
6. I believe that if I exert enough effort, I will be successful in Engineering.	1.46	1.52	0.06
7. I feel like I don't know a lot about Engineering compared to other students.	2.64	3.75	1.11*
8. Compared with other students, I think I have good study skills.	2.23	2.16	-0.07
9. Compared with other students, I don't feel like I'm a good student.	4.36	4.21	-0.15
10. I am confident I can do well on the lecture exams in Engineering.	2.00	2.20	0.20
11. I am confident I can do well in the labs in Engineering.	1.77	1.68	-0.09
12. I am confident I can do well in the projects in Engineering.	1.77	1.60	-0.17
13. I think I will receive a C or better in Engineering courses.	1.62	1.64	0.02
14. I don't think I will get a good grade in Engineering courses.	4.40	4.08	-0.32
15. I am confident that I could explain something learned in this program to another person.	1.85	1.64	-0.21

* The difference is statistically significant ($p < 0.001$).

4. SEI Long-Term Impact: Follow-up Survey for 2009-2012 SEI Graduates

In fall 2013, a follow up survey was administered to graduates of the Summer Engineering Institute. Only students who participated in the 2009, 2010, 2011 and 2012 are included in the survey since 2013 attendees have just completed the institute the previous summer. The purpose of the survey is to determine students current educational status (whether or not they are still attending school), the major that they are currently pursuing or are intending to pursue, and whether or not attending the SEI has made any impact in their educational and career goals. The survey notification was sent by email and completed online.

A summary of the survey results is given below:

- Out of the101 SEI graduates targeted by the survey (25 for 2009, and 26 each for 2010, 2011 and 2012), 55 students responded. This corresponds to a response rate of 54%. Unfortunately, several of the email addresses used are no longer current, and the survey invitation sent by email bounced back.
- All 55 of the survey respondents are still in school.
- Out of the 55 respondents, 45 (or 82.5%) are engineering majors, 3 are STEM (non-engineering majors), and 7 non-STEM.

The percentage of survey respondents who are majoring in engineering (82.5%) compares favorably with the percentage of students who declared one of the engineering fields immediately following the SEI. From Table 3-B (Section 3.3 of this paper), 79 out of the 103 2009-2012 SEI graduates (or 76.7%) indicated an engineering major in the post-program survey.

Table 10. SEI Follow-up Survey: Student Attitudes Towards SEI. Response Scale: 5 – Strongly Agree, 4 – Agree, 3 – Neutral, 2 – Disagree, 1 – Strongly Disagree.

Follow-up Survey Prompt	**Engineers (N=45)**	**Non-Engineers (N=10)**	**All (N=55)**
I enjoyed participating in the Summer Engineering Institute.	4.78	4.80	4.78
My participation in SEI has a significant impact on my choice of career.	4.47	4.00	4.38

The fall 2013 follow-up survey also attempts to determine student attitudes towards SEI and whether or not participation in the program has an impact on the career path they have chosen. Student responses are summarized in Table 10. When asked how much they agree with the statement "I enjoyed participating in the Summer Engineering Institute," the average response is 4.78. The average response for engineering majors (4.78) is slightly lower than those who are non-engineering majors or undecided (4.80). With respect to the prompt "My participation in SEI has a significant impact on my choice of career," the average response is 4.38. Understandably, there is a significant difference in the average response for the engineers (4.47, which is between "Agree" and "Strongly Disagree") and the average response for non-engineers

(4.00, “Agree”). As a whole, the SEI is viewed very positively by the students, and has had a significant influence in students' choice of majors, especially those who decided to pursue a major in engineering.

5. Summary and Conclusions

The collaborative work done by two completely different types of institution—Cañada College, which a community college, and San Francisco State University, which is a large comprehensive urban university—has resulted in the success of the Summer Engineering Institute as a unique program that provides high school students an opportunity to explore the engineering profession and the various pathways to an engineering career. Since it was first implemented in 2009, the Summer Engineering Institute has been successful in achieving most of its goals. The levels of program participation among female students, students from traditionally underrepresented groups, and students who are the first in their families to go to college have been high. The program has been successful in increasing the interest of participants in pursuing careers in engineering as indicated by pre- and post-program surveys. By providing the participants the opportunity to explore the major fields of engineering and increase their knowledge of specific engineering topics, as well as understand the many different pathways to an engineering career, the program has been successful in helping students make a better decision on whether or not pursue engineering as a career, and which particular field of engineering is most suited for them. Among students who solidified their choice of an engineering career and decided to major in one of the engineering fields, the program has provided context to their study of engineering—a strategy that has been proven to increase student motivation and persistence, especially as they struggle through the first two years of their engineering studies.

The program has also been successful in increasing student knowledge of skills needed to succeed in college, as well as the resources and support services available on campus to help them achieve their educational goals. Students' opinions of the activities, workshops and projects done during the institute have been very positive, and have been improving over the last four years. The changes in the curriculum that have been implemented from one year to the next have been viewed very positively by SEI students, faculty and staff. The quality of student work, especially on the culminating projects, have also been steadily improving.

With respect to the program goal of enhancing student self-efficacy in studying engineering, statistically significant improvement of post-program responses was observed in only one of the 15 items surveyed. The participant initial levels of self-efficacy were high, making it less likely for any further statistically significant increases to occur. As a whole, SEI has been successful in maintaining, and perhaps enhancing student self-efficacy in engineering. Although the SEI students clearly have high self-efficacy, it is important provide support and positive reinforcements and experiences to these students as self-efficacy is malleable and can change over time.

The fall 2013 follow-up survey given to the graduates of the first three years (2009-2012) 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 of them are pursuing an engineering major. More than a year after attending the institute, students have an even high opinion of the positive experience they had during the program. SEI graduates who are attribute their participation in the program to having a significant influence in their choice of major.

Cañada College and San Francisco State University plan to continue offering the program for the next four years through funding from the US Department of Education Hispanic Serving Institution Science, Technology, Engineering, and Mathematics (HSI STEM) grant. Program activities will continue to be improved based on feedback from students, faculty, and SEI staff, as well as recent changes in the engineering curriculum. Program personnel will work even more closely with local high schools to identify and recruit students from underrepresented groups and underserved communities who could benefit the most from participating in the program.

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Appendix 1

Summer Engineering Institute Typical Schedule: Week 1

Time	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
7:30AM		Breakfast	Breakfast	Breakfast	Breakfast	Breakfast	
8:30AM		Campus Tour	Project Advisors Project Selection	Civil Engineering	Engineering Curriculum	Mechanical Engineering	
9:30AM		Electrical Engineering					Breakfast
10:30AM							Field Trip 10 AM to 3 PM (bag lunches) Exploratorium
12:00 PM		Lunch	Lunch	Lunch	Lunch	Lunch	
1:30PM		Guaranteed 4.0 Workshop	Computer Engineering	Field Trip : PG&E	International Wheelchair Lab Tour	Guest Speaker	
2:30PM	Registration / Room Check-In						
3:00PM					Communications	Solar Project	Personal Time /Laundry
4:00PM	Welcome Ceremony						
4:30PM		Team Building	Hands-on Workshop (CE)				
6:00PM	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner
7:30PM	Ice Breaker	Homework Time	Project Time	Project Time	Project Time	Project Time	Activity / Movie Night (SC 256)
9:00PM	Personal Time	Personal Time	Personal Time	Personal Time	Personal Time	Personal Time	
10:00PM	In Rooms	In Rooms	In Rooms	In Rooms	In Rooms	In Rooms	
10:30 M	Lights Out	Lights Out	Lights Out	Lights Out	Lights Out	Lights Out	In Rooms

Appendix 1 (Continued)

Summer Engineering Institute Typical Schedule: Week 2

Time	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
7:30AM		Breakfast	Breakfast	Breakfast	Breakfast	Breakfast
8:30AM	Breakfast	Math	Computer Applications: CAD	Robotics Challenge	Project Time	Presentation (SCI-101)
9:30AM	Personal Time					
11:00AM	BBQ & Fun Games (Softball Field)					
12:00PM		Lunch	Lunch	Lunch	Lunch	Awards Buffet Luncheon
1:30PM		Student Panel	Guest Speaker (Financial Aid)	Field Trip Bay Bridge	Mock Presentations Post-Program Survey	
2:00PM						Checkout time
3:00PM	Project Time	Planetarium	Workshop: Robotics			
4:00PM		Project Progress Report - Meeting with Project Advisers				
5:00PM					Personal Time	
6:00PM	Dinner	Dinner	Dinner	Dinner	Dinner	
7:30PM	Personal Time	Project Time	Project Time	Project Time	Talent Show	
9:00PM		Personal Time	Personal Time	Personal Time		
10:00PM	In Rooms	In Rooms	In Rooms	In Rooms		
10:30PM	Lights Out	Lights Out	Lights Out	Lights Out	In Rooms	